DRVNA INDUSTRIJA

ZNANSTVENI ČASOPIS ZA PITANJA DRVNE TEHNOLOGIJE • ZAGREB • VOLUMEN 66 • BROJ 3
SCIENTIFIC JOURNAL OF WOOD TECHNOLOGY • ZAGREB • VOLUME 66 • NUMBER 3

Microberlinia brazzavillensis a. Chev.,

3/15

UDK 630*8+674 CODEN: DRINAT ISSN 0012-6772

UDK 630*8+674 Coden: Drinat ISSN 0012-6772

DRVNA INDUSTRIJA

ZNANSTVENI ČASOPIS ZA PITANJA DRVNE TEHNOLOGIJE
SCIENTIFIC JOURNAL OF WOOD TECHNOLOGY

IZDAVAČ I UREDNIŠTVO
Publisher and Editor's Office
Šumarski fakultet Sveučilišta u Zagrebu
Faculty of Forestry, Zagreb University
10000 Zagreb, Svetošimunska 25
Hrvatska – Croatia
*Tel. (*385 1) 235 25 09*

SUIZDAVAČI
Co-Publishers
Exportdrvo d.d., Zagreb
Hrvatsko šumarsko društvo, Zagreb
Hrvatske šume d.o.o., Zagreb

OSNIVAČ
Founder
Institut za drvnoindustrijska istraživanja, Zagreb

DRVNA INDUSTRIJA je časopis koji objavljuje znanstvene i stručne radove te ostale priloge iz cjelokupnog područja iskorištavanja šuma, istraživanja svojstava i primjene drva, mehaničke i kemijske prerade drva, svih proizvodnih grana te trgovine drvom i drvnim proizvodima.

Časopis izlazi četiri puta u godini.

DRVNA INDUSTRIJA contains research contributions and reviews covering the entire field of forest exploitation, wood properties and application, mechanical and chemical conversion and modification of wood, and all aspects of manufacturing and trade of wood and wood products.

The journal is published quarterly.

OVAJ BROJ ČASOPISA POTPOMAŽE:

Sadržaj
Contents

NAKLADA (Circulation): *700 komada* · **ČASOPIS JE REFERIRAN U (Indexed in):** *CA search, CAB Abstracts, Compendex, DOAJ, Crossref, EBSCO, Forestry abstracts, Forest products abstracts, Geobase, Paperchem, SCI-Expanded, SCOPUS* · **PRILOGE** *treba slati na adresu Uredništva. Znanstveni i stručni članci se recenziraju. Rukopisi se ne vraćaju.* · **MANUSCRIPTS** *are to be submitted to the editor's office. Scientific and professional papers are reviewed. Manuscripts will not be returned.* · **KONTAKTI s uredništvom (Contacts with the Editor) e-mail:** *editordi@sumfak.hr* · **PRETPLATA (Subscription):** *godišnja pretplata (annual subscription) za sve pretplatnike 55 EUR. Pretplata u Hrvatskoj za sve pretplatnike iznosi 300 kn, a za đake, studente i umirovljenike 100 kn, plativo na žiro račun 2360000 – 1101340148 s naznakom "Drvna industrija"* · **ČASOPIS SUFINANCIRA** *Ministarstvo znanosti, obrazovanja i sporta Republike Hrvatske.* · **TISAK (Printed by)** *– DENONA d.o.o., Getaldićeva 1, Zagreb, tel. 01/2361777, fax. 01/2332753, E-mail: denona@denona.hr; URL: www.denona.hr* · **DESIGN** Aljoša Brajdić · **ČASOPIS JE DOSTUPAN NA INTERNETU:** *http://drvnaindustrija.sumfak.hr* · **NASLOVNICA** *Presjek drva* Microberlinia brazzavillensis *a. Chev., ksiloteka Zavoda za znanost o drvu, Šumarski fakultet Sveučilišta u Zagrebu*

DRVNA INDUSTRIJA · Vol. 66, 3 · str. 177- 262· jesen 2015. · Zagreb
REDAKCIJA DOVRŠENA 2.09.2015.

Mehmet Öz[1], İlhan Deniz[2], Onur Tolga Okan[2], M. Said Fidan[3]

Chemical Composition of Oleoresin and Larvae Gallery Resin of *Pinus Brutia* Attacked by *Dioryctria Sylvestrella* Ratz.

Kemijski sastav oleorezina i smole galerije ličinki sa stabla bora (*Pinus brutia*) napadnutoga insektima *Dioryctria sylvestrella* Ratz.

Original scientific paper • Izvorni znanstveni rad
Received – prispjelo: 27. 2. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*813.26; 630*813.27; 674.032.475.4*
doi:10.5552/drind.2015.1408

ABSTRACT • *Dioryctria sylvestrella Ratz. poses a remarkable hazard for the Pinus brutia Ten. in Turkey. In the current study, the larvae gallery resin of five trees and essential oils of resin, which was obtained with the Acid-Paste Method, were analyzed using the Gas Chromatography and Mass Spectrometry (GC-MS) Method. Thirty nine compounds were found in larvae gallery resin, which were produced by Dioryctria sylvestrella Ratz, while thirty six compounds were extracted from oleoresin obtained by the Acid-Paste Method. The most common compounds of larvae gallery resin were α-pinene at a rate of 20.2 %, β-caryophyllen at a rate of 10.8 %, γ-terpinene at a rate of 10.1 % and β-pinene at a rate of 9.4 percent. The most common compounds of oleoresin were α-pinene at a rate of 19.7 %, β-pinene at a rate of 13.3 %, γ-terpinene at a rate of 10.2 % and β-caryophyllen at a rate of 7.8 percent. Also, the quantities of some compounds within larvae gallery resin such as β-pinene, limonene, and sylvestrene decreased compared to those of oleoresin, while the quantities of some compounds in oleoresin including α-longipinene, α-terpineol, and longifolene increased compared to that of larvae gallery resin. However, no qualitative difference was found.*

Key words: *Acid-Paste Method, Dioryctria sylvestrella Ratz, Larvae gallery resin, Oleoresin, Pinus brutia*

SAŽETAK • *Insekti Dioryctria sylvestrella Ratz. izuzetno su opasni za drvo bora (Pinus brutia Ten.) u Turskoj. U provedenom su istraživanju, primjenom metode plinske kromatografije i masene spektrometrije (GC-MS), analizirane smola galerije ličinki s pet stabala i eterična ulja smole (oleorezin) dobivene metodom acid-paste. U smoli*

[1] Author is lecturer at Gumushane University, Vocational School of Higher Education, Department of Forestry, Gumushane, Turkey. [2]Authors are professor and research assistant at Karadenız Technical University, Faculty of Forestry, Department of Forest Industry Engineering, Trabzon, Turkey. [3]Author is assistant professor at Gumushane University, Science and Technology Institute, Forestry and Environmental Sciences, Gumushane, Turkey.

[1] Autor je nastavnik Sveučilišta u Gumushaneu, Strukovna škola visokog obrazovanja, Šumarski odjel, Gumushane, Turska. [2]Autori su profesor i znanstveni asistent Tehničkog sveučilišta u Karadenizu, Šumarski fakultet, Odsjek za inženjerstvo šumskih proizvoda, Trabzon, Turska. [3]Autor je docent Sveučilišta u Gumushaneu, Institut znanosti i tehnologije, Šumarske i prirodne znanosti, Gumushane, Turska.

galerije ličinki, nastaloj zbog napada stabala insektima Dioryctria sylvestrella Ratz., nalazi se 39 spojeva, a 36 njih ekstrahirano je iz eteričnih ulja smole (oleorezina) dobivenih postupkom acid-paste. Najčešći spojevi u smoli jesu α-pinen kojega ima 20,2 %, β-kariofilen, s udjelom od 10,8 %, γ-terpinen, s koncentracijom od 10,1 % i β-pinen, s koncentracijom od 9,4 %. Najčešći spojevi u oleorezinu jesu α-pinen, kojega je 19,7 %, β-pinen, s koncentracijom 13,3 %, γ-terpinen, s koncentracijom 10,2 % i β-kariofilen, s koncentracijom 7,8 %. Također, količina pojedinih spojeva u smoli poput β-pinena, limonena i silvestrena manja je od količine u oleorezinu, a količine pojedinih spojeva u oleorezinu, uključujući α-longipinene, α-terpeniol i longifolene, povećane su u usporedbi s količinama u smoli. Međutim, nije pronađena kvalitativna razlika.

Ključne riječi: *metoda acid-paste, Dioryctria sylvestrella Ratz., smola galerije ličinki, oleorezin, Pinus brutia*

1 INTRODUCTION
1. UVOD

Recently, natural herbal products have been used as raw materials in hundreds of industrial products. The natural resin is the inclusive term used to denote the products obtained from the oleoresin of pine trees. Oleoresin is obtained by the tapping of living pine trees. Collection of the oleoresin is a labour-intensive operation (Coppen and Hone, 1995).The oleoresin has a significant share in global trade of raw material. Turkey has sustainable resources throughout the country such as numerous pine trees, which can be used for the manufacturing of natural resin. The *Pinus* family is represented by five species in Turkey. These are *Pinus nigra* (Black pine), *Pinus brutia* (Turkish pine), *Pinus sylvestris* (Scotch pine), *Pinus halepensis* (Aleppo pine) and *Pinus pinea* (Stone pine) (Sezik *et al*., 2010). Among them, Turkish pine (*Pinus brutia)* is a rapidly growing species spreading over the Aegean, Mediterranean and Marmara regions, although they are infrequent along the coastal line of the West Black Sea region with an area of three million hectares, covering 14.5 % of Turkish forest area (Fig. 1) (Şensöz, 2003; Kanat *et al*., 2004; Tümen *et al*., 2010).

In addition to the critical role in the eco-system (Bonello *et al*., 2006), *Pinus brutia* has a significant economic role. The wood, bark and cones of *Pinus brutia*, in addition to resin, are raw materials with economic value (Dığrak *et al*., 1999). However, amongst all raw materials, oleoresin is a non-wood forest product, which has not lost importance or value since ancient times. Recently, oleoresin has been used as the raw material in adhesive, paper, printing ink, detergent, disinfectant, perfume and throughout the paint industry (Wang *et al*., 2006). Various methods have been developed to extract natural oleoresin. These are open wound methods and close wound method. The open wound methods are Line Method, Big Wound Method and Acid-Paste Method, while the close wound method is Carve Hole Method (Deniz, 2002). A well-recognised method is the Acid-Paste Method. The Acid-Ppaste Method is less wasteful and less hazardous for use than other methods. The paste has the advantage of requiring slightly less frequent applications. The greater penetration of the paste requires the removal of a bigger strip of bark but also fewer visits to the tree (Coppen and Hone, 1995). Also, the Acid-Paste Method causes minimal damage to the tree, wood and resin components (Batur *et al*., 2008).

The compounds of oleoresin consist of turpentine (monoterpenes (C10), sesquiterpenes (C15)), less volatile terpenoids (diterpen resin acids (C20)) and derivatives (Trapp and Croteau, 2001; Mumm *et al*., 2004). The chemical composition of oleoresin is dynamic and can change with the type of environmental stress to

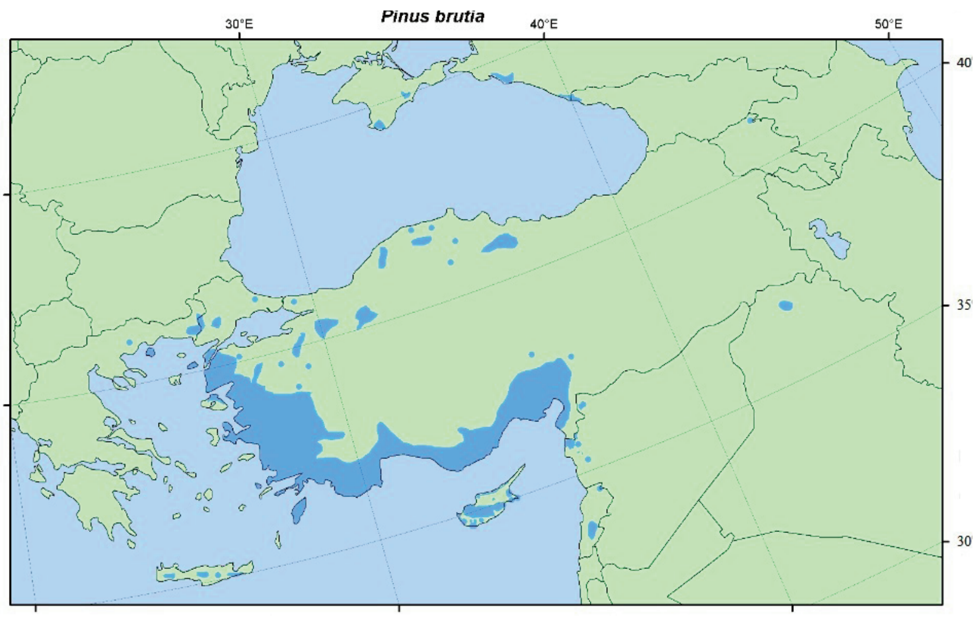


Figure 1 Natural distribution of *Pinus brutia*
Slika 1. Prirodna rasprostranjenost vrste *Pinus brutia*

Figure 2 Discharge of larvae gallery resin after *Pinus nigra* was wounded by *Dioryctria sylvestrella*
Slika 2. Uklanjanje smole galerije ličinki s drva bora (*Pinus nigra*) napadnutoga insektima *Dioryctria sylvestrella*

which the tree is exposed (Zulak and Bohlmann, 2010). Monoterpenes and sesquiterpenes are a type of biochemical label of tree genetics. In addition, terpenes have a significant impact on the behaviour of some types of insects, such as *Diocryctria* (Kleinhentz *et al*., 1999). *Dioryctria sylvestrella* is one of most prominent insects that cause significant damage to coniferous tress in the forest eco-system of Turkey (Anonymos-1, 2013).

In contrast to other species of *Dioryctria*, *Dioryctria sylvestrella* does not cause conical or channel-like damage to the tree. It primarily attacks the main stem and sometimes the branches. Through the bark, the hatched larvae enter into the phloem, where they spend the winter. Larvae peel tree barks, resulting in the discharge of resin (Kleinhentz *et al*., 1999) (Fig. 2). Many studies have reported that many trees under attack from insects change the resin components qualitatively or quantitatively because they affect the behaviour of a variety of insects and may act as attractants or defenses (Paine *et al*., 1997; De Moraes *et al*., 1998; Kleinhentz *et al*., 1999; Mumm *et al*., 2003). A similar case is valid for trees attacked by *Dioryctria sylvestrella* Ratz.

Several limited studies were conducted to determine the effect of *Dioryctria sylvestrella* on the oleoresin chemical composition. Jactel *et al*. (1996) found that Maritime pine attacked by *Dioryctria sylvestrella* contained a significantly higher percentage of limonene, longipinene and copaene, and a discriminant analysis, using the relative percentage of six terpenes, significantly separated infested and uninfested trees. Kleinhentz *et al.* (1999) investigated the terpene composition of the resin between attacked and unattacked maritime pine by *Dioryctria sylvestrella*. They observed no significant quantitative or qualitative difference between *Dioryctria sylvestrella* trees that were attacked and unattacked. However, some differences in terpene proportions (semiquantiative) were significant. Sadof and Grant (1997) studied monoterpene composition of *Pinus sylvestris* varieties wounded by *Dioryctria zimmermani.* They observed that the presence of wounds had no significant effect on the proportion of monoterpenes in the four varieties. In contrast, monoterpene composition varied significantly among varieties. The above studies deal with chemical composition of oleoresin in trees attacked by *Dioryctria sylvestrella*. These studies are generally about chemical composition of essential oil *Pinus sylvestris* and *Pinus pinaster* wounded by *Dioryctria sylvestrella*. However, there is no information about chemical composition of essential oil *Pinus brutia* oleoresin attacked by *Dioryctria sylvestrella.* Therefore, the main aim of this study is to compare chemical composition of essential oil obtained from oleoresin of *Pinus brutia* wounded by *Dioryctria sylvestrella* and acid-paste tapping oleoresin.

2 MATERIALS AND METHODS
2. MATERIJAL I METODE

2.1 Study field
2.1. Područje istraživanja

Samples were taken from Fındıklı Village (37º 30`9 N and 34º 55` 35 E) of Pozantı district, Adana. Five infested *Pinus brutia* trees were randomly selected. The sample trees were aged 12, 20, 25, 35 and 38 years, and they were 8, 13, 18, 15 and 18 meters in height and 18, 20, 22, 30 and 35 cm in diameter. The Mediterranean climate is dominant in the region and the mean air temperature is 28.2 °C.

2.2 Preparing and collecting samples
2.2. Priprema i skupljanje uzoraka

Oleoresin and larvae gallery resin samples were taken from the same tree. Oleoresin samples were collected 1 m above ground level using Acid-Paste Method. The acid-paste was supplied by DYO INC. A sampling method was used to collect sufficient oleoresin. A horizontal strip of bark, 8 cm in width and 3.5-4 cm in height, was removed using wounding apparatus from the stem of the *Pinus brutia.* Then, the gutter was placed just below the wound to cause the oleoresin and the chemical stimulant to flow (Fig. 3). The acid-paste used as chemical stimulant was applied from 50 cm^3 plastic syringes. Acid-paste consisted of 65 % solution of sulphuric acid and coal, dust, barley and rice bran, dyotamide soil. Following this application, resins were

Figure 3 System of oleoresin tapping using the Acid-Paste Method
Slika 3. Sustav prikupljanja oleorezina *acid-paste* metodom

collected from the oleoresin receiver three weeks later, in June. Resins were stored at 0 °C until analysis.

Larvae gallery resins of *Pinus brutia* wounded by *Dioryctria sylvestrella* Ratz were collected from bark cracks at 15-20 cm above ground in May. Fresh samples of these larvae gallery resin were selected.

2.3 Extraction of essential oils and analysis
2.3. Ekstrakcija eteričnih ulja i analiza

Essential oils were extracted by hydro distillation of fresh larvae gallery resin and oleoresin using a Clevenger-type apparatus for 4 h. Resins were obtained from larvae gallery at the weight of 21.7, 21.4, 21.8, 21.6 and 21.5 g, while oleoresins were collected using the Acid-Paste Method at the weight of 5.6, 6.5, 5.8, 20.7 and 7.5 g, since poor raw material was released. All samples were separately transferred to a volumetric flask. Samples were ground into small pieces and distilled water (300 ml) was added to fully immerse the samples into the volumetric flask. Clevenger type apparatus was connected to a cooling bath, which was adjusted to -18 °C for 4 h. The obtained oils were dissolved in n-hexane 0.5 ml (HPLC Grade) and dried over anhydrous sodium sulfate. The dissolved samples were stored in amber coloured bottles, which were tightly closed with paraffin applied caps, at 4 °C until analysis. The density was determined using a numeric densimeter. The following formula was used to calculate % turpentine and % rosin (1).

$$\%A = \frac{E}{W} x100 \text{ and } \%C = 100 - A \qquad (1)$$

Where A is the turpentine content (%), E is the essential oil content (g), W is the sample weight (g), C is the rosin content (%).

The capillary GC-FID analysis was performed using Agilent-5973 Network System, equipped with a FID (supplied with air and hydrogen of high purity) and a split inlet. The chromatographic column for analysis was an HP-5 capillary column (30 m x 0.32 mm i.d., film thickness 0.25 μm). Helium was used as the carrier gas at a flow rate of 1 mL/min. The injection was performed in splitless mode at 230 ºC. Essential oil solution (1 μL) in hexane (HPLC Grade) was injected and analyzed with the column held initially at 60 ºC for 2 min and then increased to 260 ºC with a 3 ºC/min heating ramp. The sample was analyzed twice and the percentage constituents of oils were computed from the GC peak areas without using correction factors. GC-MS analysis was performed using Agilent-5973 Network System. A mass spectrometer with a ion trap detector in full scan under electron impact ionization (70 eV) was used. The chromatographic column for the analysis was an HP-5 capillary column (30 m x 0.32 mm i.d., film thickness 0.25 μm). Helium was used as carrier gas, at a flow rate of 1 mL/min. The injection was performed in splitless mode at 230 ºC. Essential oil solution (1 μL) in hexane (HPLC Grade) was injected and analyzed with the column held initially at 60 ºC for 2 min, and then increased to 260 ºC with a 3 ºC/min heating ramp. Retention indices of all the components were determined by the Kovats method using n-alkanes (C_6-C_{18}) as standards. The identification of the compounds was based on mass spectra libraries (compared with Wiley and NIST).

2.4 Statistical analysis
2.4. Statistička analiza

Statistical Package for the Social Sciences (SPSS) 11.5 software pack was used for all statistical analyses. Independent samples *t* test and correlation analysis were used. Independent samples *t* test was separately performed for each variable.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Density of essential oil collected from larvae gallery resin and oleoresin at room temperature was 0.86 g/cm^3. The quantity of turpentine and rosin in the raw material, obtained from larvae gallery resin and oleoresin, is given in Table 1. The quantity of resin, obtained from oleoresin using the Acid Paste Method, was lower than that of larvae gallery resin. According to the table, for five different trees, considering the quantity of essential oil (turpentine), the mean quantity was 12.82 % in larvae gallery resin and 31.64 % in oleoresin. Considering the quantity of rosin, the mean quantity was 87.18 % in larvae gallery resin and 68.36 % in oleoresin. There was a difference between the two resin groups in terms of quantity of turpentine and ros-

Table 1 Mean amounts of turpentine and rosin in *Pinus brutia* Ten. oleoresin and larva gallery resins
Tablica 1. Prosječne količine terpentina i kolofonija u oleorezinu i smoli galerije ličinki od drva bora (*Pinus brutia*)

Tree No *Broj stabla*	**Age** *Starost*	**Diameter** *Promjer* cm	**Height** *Visina* m	**Collected Resin** *Prikupljena smola* g		**Turpentine** *Terpentin* %		**Rosin** *Kolofonij* %	
				LGR	OR	LGR	OR	LGR	OR
1	35	30	18	21.7	5.6	11.9	33.0	88.1	67.0
2	12	18	8	21.4	6.5	8.9	46.3	91.1	53.7
3	38	35	18	21.8	5.8	16.2	17.2	83.8	82.8
4	25	22	13	21.6	20.2	11.1	17.5	88.9	82.5
5	20	15	20	21.5	7.4	16.0	44.2	84.0	55.8
				Average		12.82	31.64	87.18	68.36

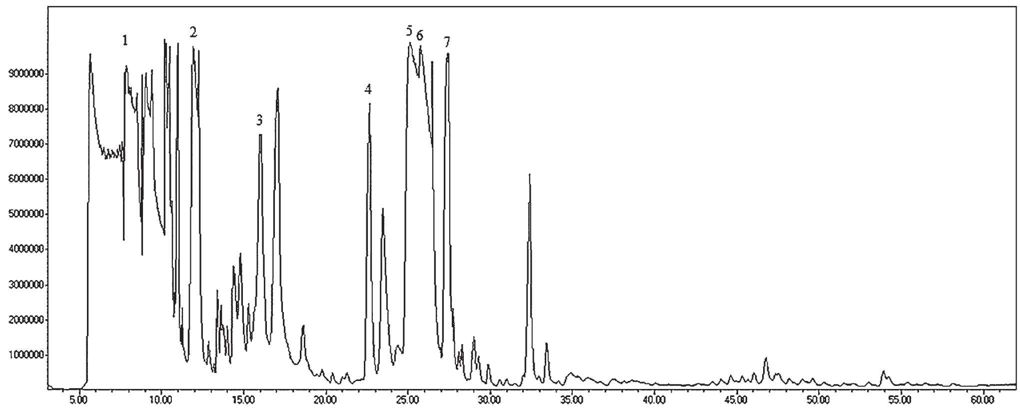
LGR – Larvae gallery resin / *smola galerije ličinki*, OR – Oleoresin / *oleorezin*

in. When larvae gallery resin and oleoresin were analyzed with independent two samples *t* test, a significant difference was found between the quantity of raw material and quantities of turpentine and rosin ($p<0.05$). However, there was no significant correlation between tree dimensions (age, diameter, height) and quantity of turpentine and rosin ($p>0.05$).

Components of oleoresin, obtained from five different trees of *Pinus brutia,* and components of larvae gallery resin of *D.sylvestrella Ratz* are given in Table 2. The representative chromatograms of oleoresin and larvea gallery resin of tree No. 2 are given in Figure 4 and 5. Thirty six components were identified in oleoresin, while 39 components were identified in larvae gallery resin. For both, oleoresin and larvae gallery resin, α-pinene, β-pinene and γ-terpinene were found in the highest quantities among all identified monoterpene components. Amongst all the components of monoterpenoids, which were identified in oleoresin, isopinocampheol, terpinene-4-ol and α-terpineol were in the highest quantities. However, for monoterpenoids identified in larvae gallery resin, the highest quantities were recorded for thymol methyl ether, p-menth-1-en-8-ol and terpinene-4-ol in decreasing order. Isopinocamphone, terpinene-4-ol and α-terpineol were in the highest quantities and they accounted for 48 % of all components of monoterpenoids, which were identified in oleoresin. However, the highest quantities were recorded for thymol methyl ether, p-menth-1-en-8-ol and terpinene-4-ol and they accounted for 51 % of monoterpenoids identified in larvae gallery resin. Among the sequiterpenes, longifolene, β -caryophyllene and α–humulene provided the highest quantities in oleoresin and they accounted for 27 % of all sesquiterpenes for larvae gallery resin. The highest quantities were found for β -caryophyllene, α-himachalene and longicyclen, respectively, and they accounted for 24 % of all sesquiterpenes.

When Table 2 is taken into consideration, the following components were found in oleoresin, while they could not be identified in larvae gallery resin: *p*-cymene and Δ^2-carene (monoterpenes), nopinon, isopinocamphone, carvacrol methyl ether and cuminaldehyde (monoterpenoids) and α-amorphen (sesquiterpenes). In contrast, the following components were found in larvae gallery resin, but they could not be identified in oleoresin: myrcene (monoterpenes), thujone-2-on, cis-pinocarveol, p-menth-1-en-8-ol, thymol methyl ether and perillal (monoterpenoids), γ-muurolene (sesquiterpenes) and spathulenol (sesquiterpenoids). Also, according to literature, cortical monoterpene compositions of susceptible varieties tend to be higher in Δ^3-carene and terpinolene (Tobolski and Hanover, 1971; Ruby and Wright, 1976). However, our data does not exactly support the hypotheses associating susceptibility of pines attacked by *D. sylvestrella* Ratz with high levels of Δ^3-carene and terpinolene in pine oleoresin.

When Figure 6 is examined, quantities of the following components are remarkably lower in larvae gallery resin than in the oleoresin: β-pinene, limonen, sylvestrene, 1.3.8-p- menthatiren, α-terpineol, α-longi-



(1) β-pinene; (2) 1.3.8-p- menthatiren; (3) α-terpineol; (4) α-longipinene; (5) longifolene; (6) α-himachalene; (7) α-humulene

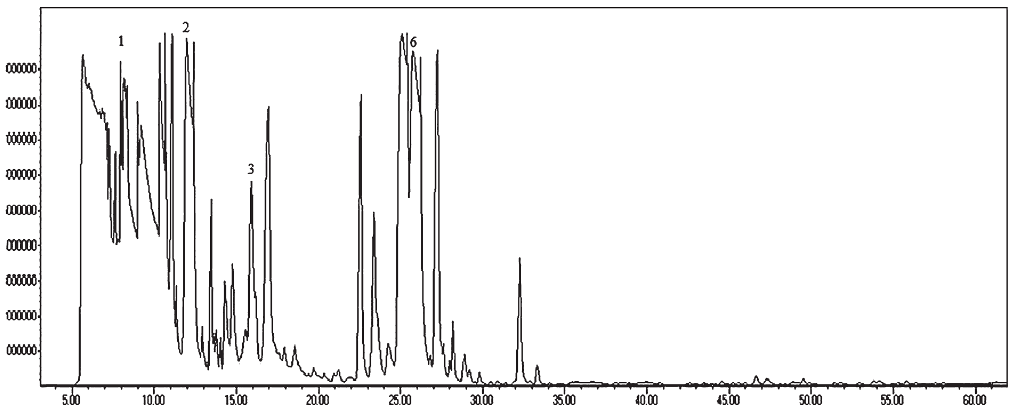
Figure 4 GC-MS chromatogram of oleoresin in *Pinus brutia* for tree No. 2
Slika 4. GC-MS kromatogram oleorezina sa stabla *Pinus brutia* broj 2

Table 2 Identified components in the essential oil of *P. brutia* oleoresin and larvae gallery resin
Tablica 2. Identificirane sastavnice eteričnih ulja oleorezina i smole galerije ličinki dobivenih od bora (*Pinus brutia*)

Compound *Sastavnica*		**RI**	**Tree No** / *Broj stabla*					**AVG.** *Prosječno*
			1	2	3	4	5	
			%					%
α-Pinene	LGR	940	14.7	31.1	25.8	12.1	17.3	20.2
	OR		15.4	18.4	11.3	27.2	26.0	19.7
Camphene	LGR	956	5.9	3.0	3.8	-	-	4.2
	OR		10.1	-	3.6	-	1.3	5.0
β-Pinene	LGR	980	2.0	16.2	17.0	2.7	9.3	9.4
	OR		7.9	14.7	11.3	21.1	11.7	13.3
Myrcene	LGR	995	-	-	2.2	-	-	2.2
	OR		-	-	-	-	-	-
Δ^2-Carene	LGR	1005	-	-	-	-	-	-
	OR		-	-	8.4	5.3	-	6.9
Limonene	LGR	1025	9.1	-	0.8	-	1.7	3.9
	OR		6.2	-	6.2	-	-	6.2
Sylvestrene	LGR	1026	-	-	-	4.0	4.0	4.0
	OR		-	-	-	-	7.4	7.4
Δ^3-Carene	LGR	1028	-	5.5	0.7	-	-	3.1
	OR		-	4.7	-	2.0	-	3.7
2-β-Pinene	LGR	1039	0.4	-	-	-	-	0.4
	OR		-	-	-	-	-	-
γ-Terpinene	LGR	1053	12.7	2.2	20.2	7.0	8.6	10.1
	OR		8.9	7.7	3.8	19.6	10.9	10.2
Terpinolene	LGR	1090	5.1	7.2	4.2	8.4	5.9	6.2
	OR		3.9	6.5	-	8.2	-	6.2
p-Cymene	LGR	1096	-	-	-	-	-	
	OR		-	-	1.6	-	-	1.6
1,3,8-*p*-Menthatirene	LGR	1111	0.1	0.2	-	0.2	0.4	0.2
	OR		-	0.3	0.2	-	-	0.3
α-Campholenal	LGR	1122	0.5	0.9	0.2	1.1	1.1	0.8
	OR		0.8	0.4	0.7	-	0.3	0.6
4,8-epoxy-p-menth-1-ene	LGR	1138	0.1	-	-	-	-	0.1
	OR		-	-	-	-	-	-
trans-Pinocarveol	LGR	1136	0.7	0.8	0.2	1.1	-	0.7
	OR		1.2	1.1	0.5	-	0.6	0.9
Nopinon	LGR	1144	-	-	-	-	-	-
	OR		-	-	-	-	0.2	0.2
Isopinocampheol	LGR	1176	-	-	-	-	-	-
	OR		-	4.6	-	-	-	4.6
Terpinen-4-ol	LGR	1179	1.6	0.4	0.8	4.3	3.7	2.2
	OR		-	-	3.9	0.3	1.0	1.7
cis-Pinocarveol	LGR	1180	-	-	-	-	1.9	1.9
	OR		-	-	-	-	-	-
Thujone-2-one	LGR	1238	0.2	-	-	-	-	0.2
	OR		-	-	-	-	-	-
α-Terpineol	LGR	1189	2.6	2.4	0.9	-	0.8	1.7
	OR		4.3	5.0	3.1	0.4	2.2	3.0
Myrtenal	LGR	1198	-	2.0	-	-	-	2.0
	OR		0.8	-	-	-	0.4	0.6
p-menth-1-en-8-ol	LGR	1211	-	-	-	-	5.0	5.0
	OR		-	-	-	-	-	-
Thymol methyl ether	LGR	1230	-	-	-	5.3	-	5.3
	OR		-	-	-	-	-	-
Cuminaldehyde	LGR	1240	-	-	-	-	-	-
	OR		-	-	-	-	0.4	0.4
Carvacrol methyl ether	LGR	1245						
	OR		-	-	0.4	-	-	0.4
Perillal	LGR	1270	-	-	-	-	0.7	0.7
	OR		-	-	-	-	-	-

Compound *Sastavnica*		**RI**	**Tree No** / *Broj stabla*					**AVG.** *Prosječno*
			1	2	3	4	5	
			%					%
α-Longipinene	LGR	1356	-	-	-	0.4	-	0.4
	OR		2.9	2.9	3.1	0.6	2.4	2.4
Longicyclen	LGR	1370	1.6	2.1	0.8	3.5	4.4	2.5
	OR		1.7	2.6	1.8	-	-	2.0
β-Cubeben	LGR	1390	1.0	2.0	0.6	3.6	2.6	2.0
	OR		0.3	-	-	-	0.5	0.4
Sativen	LGR	1395	0.3	-	-	-	-	0.3
	OR		-	-	0.4	-	-	0.4
Longifolene	LGR	1412	-	-	-	-	0.7	0.7
	OR		10.8	17.0	10.2	5.5	6.0	9.9
β -Caryophyllene	LGR	1421	7.0	8.2	5.6	24.4	8.5	10.8
	OR		8.6	1.9	9.9	7.6	10.9	7.8
α-Himachalene	LGR	1451	8.2	9.0	9.3	2.6	7.6	7.3
	OR		-	0.3	-	-	0.6	0.5
α-Humulene	LGR	1456	0.1	-	-	-	0.7	0.4
	OR		2.8	4.6	3.6	1.7	3.9	3.3
γ-Muurolene	LGR	1485	2.1	2.3	1.6	6.8	3.4	3.2
	OR		-	-	-	-	-	-
γ- Himachalene	LGR	1488	-	0.4	-	0.9	-	0.7
	OR		0.7	0.6	0.6	-	0.8	0.7
α-Amorphen	LGR	1488	-	-	-	-	-	-
	OR		-	0.2	-	-	-	0.2
α- Murolen	LGR	1503	-	-	-	0.3	-	0.3
	OR		0.2	0.4	-	-	0.2	0.3
β-Himachalene	LGR	1505	0.2	0.2	-	0.6	-	0.3
	OR		-	-	0.2	-	-	0.2
β-Bisabolene	LGR	1508	-	-	-	-	0.8	0.8
	OR		-	0.2	-	-	-	0.2
Δ-Amrophen	LGR	1515	-	-	-	0.4	0.2	0.3
	OR		-	0.1	-	-	-	0.1
Spathulenol	LGR	1573	0.5	-	-	-	3.4	2.0
	OR		-	-	-	-	-	-
Humulene epoxide-II	LGR	1580	-	-	-	-	0.3	0.3
	OR		-	-	0.3	-	-	0.3
Caryophyllen oxide	LGR	1585	1.1	1.1	0.6	4.6	1.9	1.9
	OR		2.0	1.8	1.8	0.2	1.6	1.5
Total	LGR		77.8	97.2	95.3	94.3	94,9	91.15
	OR		89.5	95.9	86.9	99.7	89.3	92.26

RI – Retention Index / *indeks retencije*; LGR – Larvae Gallery Resin / *smola galerije ličinki*; OR – Oleoresin / *oleorezin*



(1) β-pinene; (2) 1.3.8-p- menthatiren; (3) α-terpineol; (6) α-himachalene.

Figure 5 GC-MS chromatogram of larvae gallery resin in *Pinus brutia* for tree No. 2
Slika 5. GC-MS kromatogram smole galerije ličinki sa stabla *Pinus brutia* broj 2

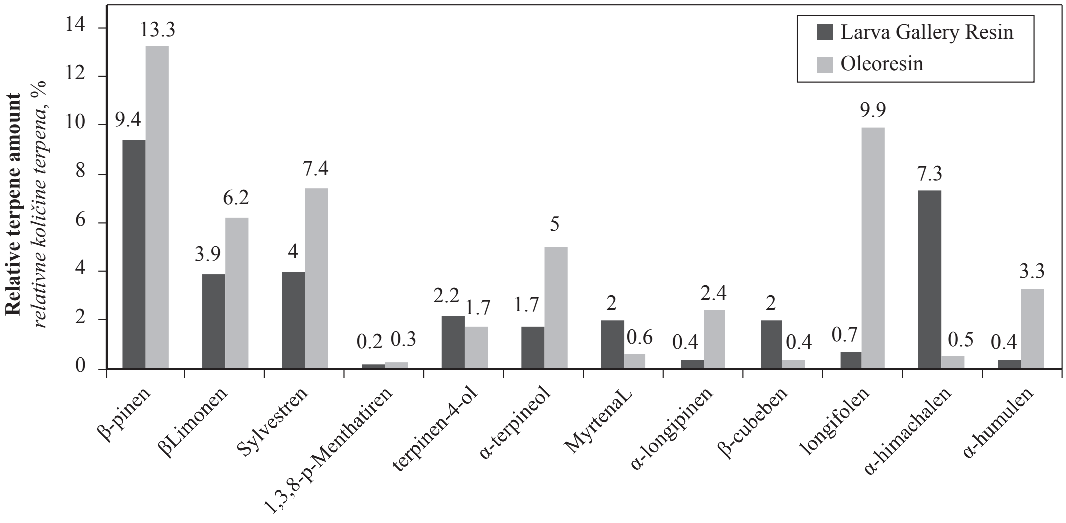


Figure 6 Comparison between chemical compositions (relative terpene amount - %) of larvae gallery resin and *Pinus brutia* oleoresin
Slika 6. Usporedba kemijskog sastava smole (relativne količine terpena - %) galerije ličinki i oleorezina od stabla bora *Pinus brutia*

pinene, longifolene and α-humulene. Terpinen-4-ol, β-cubebene, myrtenal, and α-himachalene were found in higher quantities in larvae gallery resin than in the oleoresin. Based on statistical analysis with *t* test only, significant differencea were found between sylvestrene, myrtenal, α-longipinene, longifolene, α-himachalene and α-humulene ($p<0.05$).

Table 3 shows quantities of terpenes for larvae gallery resin and oleoresin. According to the table, the quantity of monoterpenes identified in oleoresin was generally higher in comparison with the larvae gallery resin except for tree No. 2 and 3. Quantities of all other monoterpenoids, sesquiterpenes and sesquiterpenoids were generally lower in larvae gallery resins except for tree No. 4 and 5. However, when statistical analysis was made with the T test, no significant differences were found between monoterpenes and monoterpeneoids. No significant differences were either found between sesquiterpenes and sesquiterpenoids ($p>0.05$).

The following compounds are found in turpentine of *Dioryctria sylvestrella* Ratz's larvae gallery resin, while they are not found in turpentine of oleoresin: 2-β-pinene (0.4 %), myrcen (2.2 %), 4,8-epoxy-p-menth-1-en (0.1 %), thujone-2-on (0.2 %), cis-pinocarveol (1.9 %), p-menth-1-en-8-ol (5.0%), thymol methyl ether (5.3%), perillal (0.7 %), spathulenol (2.0 %) and γ-muurolene (3.2 percent). In comparison with larvae gallery resins of *Dioryctria sylvestrella Ratz*, the following compounds are found only in oleoresin: *p*-cymene (1.6%), Δ^2-carene (6.9 %), nopinon (0.2 %), isopinocamphone (4.6 %), carvacrol methyl ether (0.4 %), cuminal (0.4 %) and α-amorphen (0.2 %).

In the present study, the quantity of oleoresin was far lower than the quantity of larvae gallery resin. However, the quantity of turpentine obtained from oleoresin is considerably higher than larvae gallery resin. It is reported in previous studies that the underlying reason originates from the difference between the release times of resin samples (Deniz *et al*., 2006). The difference between quantities of turpentine obtained from *Pinus bruita* using the Acid-Paste Method can be secondary to the difference between the genetic features of trees (Gül, 1999). Another prominent finding is that there is no correlation between the dimensions of tree (diameter, age, height) and quantity of turpentine and rosin in oleoresin. This finding is consistent with results of previous studies (Kleinhentz *et al*., 1999).

Quantities of essential oil components, which were identified in the oleoresin of *Pinus brutia*, are largely in concordance with the literature; there are, however, some qualitative differences (Acar, 1988; Gül, 1999; Gören *et al*., 2010). Previous studies report that genetic features and ecological conditions may quantitatively and qualitatively change the resin com-

Table 3 The main terpene-class quantities in *P. brutia* Ten. oleoresin and larvae gallery resin
Tablica 3. Količine glavnih terpena u oleorezinu i smoli galerije ličinki od stabla bora *Pinus brutia*

Tree No. *Broj stab*la	**Monoterpenes** *Monoterpeni* %		**Monoterpenoids** *Monoterpenoidi* %		**Sesquiterpenes** *Seskviterpeni* %		**Sesquiterpenoids** *Seskviterpenoidi* %	
	LGR	OR	LGR	OR	LGR	OR	LGR	OR
1	50.0	52.4	5.6	7.1	20.5	28.0	1.6	2.0
2	65.4	52.3	6.5	11.1	24.2	30.8	1.1	1.8
3	74.7	46.4	2.1	8.6	17.9	29.8	0.6	2.1
4	34.4	83.4	11.8	0.7	43.5	15.4	4.6	1.0
5	47.2	57.3	13.6	5.1	28.9	25.3	5.6	1.6
Avg.	54.34	58.36	7.92	6.52	27.0	25.86	2.7	1.7

ponents of trees (Gül, 1999; Dob *et al*., 2005; Gören *et al.*, 2010). For instance, in Izmir, Acar (1988) reported that α-pinene, β-pinene Δ^3-carene and camphene in *Pinus brutia* oleoresin was 78 %, 13 %, 4 %, 0.9 %, respectively. However, Gül *et al.* (1999) documented that α-pinene, β-pinene Δ^3-carene and camphene in *Pinus brutia* oleoresin, located in the same region as Acar's findings, were 50 %, 29 %, 14 %, 1.2 %, respectively. In the analysis of oleoresin of *Pinus brutia* found in Greece, the reported rates were 13.7 %, 5.1 %, 0.5 % and 0.4 %, respectively, for α-pinene, β-pinene, α-myrcene and limonene. However, Δ^3-carene could not be found (Papajannopoulos *et al*., 2001).

Previous studies also reported some qualitative and quantitative changes in the chemical composition of resins of trees, where *Dioryctria sylvestrella* Ratz is hosted (Kleinhentz *et al*., 1999; Mumm *et al*., 2003; Mumm *et al*., 2004). In the present study, α-pinene is found in the highest amounts in *Pinus bruita* oleoresin and larvae gallery resin. This finding is consistent with the results of a previous study conducted on *Pinus sylvestris* (Kleinhentz *et al*., 1999). In larvae gallery resin, another monoterpenes compound, Δ^3-carene, was found in low quantities. No change was observed in the quantity of terpinolen. In previous studies, it was reported that in samples of *Dioryctria zimmermani,* the quantity of Δ^3-carene and terpinolene components was high (Tobolski and Hanover, 1971; Wright *et al.*, 1975; Ruby and Wright, 1976). However, in a similar study conducted by different researchers, low quantities of Δ^3-carene and terpinolene were reported in the resin components (Sadof and Grant, 1997). In another study, monoterpenes components of resins of *Pinus pinaster*, which was attacked by *D.sylvestrella*, were examined and it was found that the quantity of terpinolene was undoubtedly high, but the component of Δ^3-carene could not be identified in larvae and oleoresin (Kleinhentz *et al*., 1999).

Amongst the components of larvae gallery resin, myrcene was exclusively identified. It was also apparent that the quantity of β-caryophyllene components was high, while the quantities of limonen, longifolene and camphene were low. A study was conducted on the examination of resin components following an attack of *D. sylvestrella* on *Pinus pinaster*, and it was found that excluding the change in the quantity of limonene, the changes in quantities of other resin components were consistent with that of our study (Kleinhentz *et al*., 1999). However, in another study examining resin components of *Pinus sylvestris* attacked by *Diprion pini*, the changes in quantity of limonene were consistent with values obtained in the present study (Mumm *et al*., 2003). It was reported that due to toxic effects, limonene is found in high quantities in trees belonging to the *Abies, Picea* and *Pinus* species and attacked by various insects (Norlander, 1990; Sadof and Grant, 1997). However, limonene can be easily transformed into other compounds, such as α-terpineol and cis-carveol, via biotransformation under the effect of various microorganisms (Henriksson *et al*., 2004; Noma and Asakawa, 2010). In the present study, the quantity of limonene was low in the larvae gallery resin of *Pinus brutia* in comparison with oleoresin.

In the present study, myrtenal, a monoterpenoid component, was found in low quantities in oleoresin; the quantity was high in larvae gallery resin. Mumm *et al*. (2004) reported similar results in a study which was conducted on *Pinus nigra* attacked by *Diprion pini*. β-caryophyllen, a sesquiterpenes, was also found at high rates in larvae gallery resin. Various studies have reported that following ovulation (egg laying) of various insects, the quantity of β-farnesene dramatically increases oleoresin (Mumm and Hilker, 2006; Köpke, 2010). The higher quantity of β-farnesene in trees, which were exposed to ovulation, is considered as a defence mechanism that attracts egg parasites to the tree. However, β-farnesene alone is not sufficient to attract egg parasites. Two other important components, which are required to attract egg parasites, are β-caryophyllene and α-humulene (Beyaert *et al*., 2010). In addition, studies report that β-farnesene is synthesized primarily for producing β-caryophyllen (Köpke, 2010).

In comparison with quantities recorded in oleoresin, the quantity of monoterpenoids (oxidized monoterpenes), sesquiterpenes and sesquiterpenoid components is higher in larvae gallery resin, while the quantity of monoterpenes is decreased. As studies suggest, the interactions between bark beetles, their associated fungi and the host tree phloem produce oxygenated monoterpenes. In addition, previous studies reported that sesquiterpenes are found at higher rates in trees which are attacked by insects (Mumm *et al*., 2003; Köpke, 2010).

4 CONCLUSIONS
4. ZAKLJUČAK

In the current study, no significant qualitative difference was found between the larvae gallery resin and oleoresin of *Dioryctria sylvestrella* Ratz. in terms of terpene components. The changes identified in both larvae gallery resins and oleoresins are largely consistent with the literature. In addition, ecological conditions and tree genetics may change the chemical composition of oleoresin.

5 REFERENCES
5. LITERATURA

1. Acar, M. İ., 1988: Chemical composition of Redpine (*Pinus brutia*). Ankara, Turkey: Forest Research Institute Press, 3 (1): 35-47.
2. Batur, M.; Kiracıoglu, Ö.; Akkaya, M., 2008: The Effects of Acid-Paste Method on Volume Increment and Product Distribution in Resin Production. Ministry of Environment and Forestry, Ege Forestry Research Instıtute, Technical bulletin: 37, İzmir, Turkiye, pp.1-36.
3. Beyaert, I.; Wäschke, N.; Scholz, A.; Varama, M.; Reinecke, A.; Hilker, M., 2010: Relevance of resource-indicating key volatiles and habitat odour for insect orientation. Animal Behav., 79: 1077-1086. http://dx.doi.org/10.1016/j.anbehav.2010.02.001.
4. Bonello, P.; Gordon, T. R.; Herms D. A.; Wood D. L.; Erbilgin, N., 2006: Natural and ecological implications of pathogen-induced systemic resistance in conifers: A

novel hyppthesis. Physiol and Molec Plant Path, 68: 95-104. http://dx.doi.org/10.1016/j.pmpp.2006.12.002
5. Coppen, J. J. W.; Hone, G. A., 1995: Gum naval stores: turpentine and rosin from pine resin. Rome, Food and Agriculture Organization of United Nations (FAO) Press, pp.17-23.
6. De Moraes, C. M.; Lewis, W. J.; Parè, P. W.; Alborn, H. T.; Tumlinson, J. H., 1998: Herbivore infested plants selectively attract parasitoids. Nature, 393: 570-573. http://dx.doi.org/10.1038/31219
7. Deniz, İ, 2002: The biosynthesis of the resin and the gumrosin production. Kastamonu Educat J, 10: 375-386.
8. Deniz, İ.; Eroğlu, M.; Yaşar, A.; Öz, M.; Şahin, H. İ., 2006: Reçine kelebeği (Dioryctria sylvestrella) tahribatıyla oluşan kızılçam reçinesinin uçucu bileşenleri. Proceeding of I. International Non-Wood Forest Product, 1-4 November 2006; Trabzon, Turkey, pp. 147-148.
9. Dığrak, M.; Ilçim A.; Alma, M. H., 1999: Antimicrobial activities of several parts of Pinus brutia, Juniperus oxycedrus, Abies cilicia, *Cedrus libani* and *Pinus nigra*. Phytother Res, 13: 584-587. http://dx.doi.org/10.1002/(SICI)1099-1573(199911)13:7<584::AID-PTR508>3.0.CO;2-S
10. Dob, T.; Berramdane, T.; Chelgoum, C., 2005: Chemical composition of essential oil of Pinus halepensis Miller growing in Algeria. C. R. Chimie, 8: 1939-1945. http://dx.doi.org/10.1016/j.crci.2005.05.007
11. Gören, A. C.; Bilsel, G.; Öztürk, A. H.; Topçu, G., 2010: Chemical composition of natural colophony from pinus brutia and comparisons with synthetic colophony. Nat Prod Commun, 5: 1729-1732.
12. Gül, S., 1999: Studies on the composions of gum and sulphate turpenties produced in Turkey and the production of some new commercial products. Ege Forestry Research Institute, Izmir-Turkey.
13. Henriksson, M. L.; Isaksson, D.; Vanèk, T.; Valterová, I.; Högberg, H. E.; Sjödin, K., 2004: Transformation of terpenes using a Picea abies suspension culture. J. of Biotechnol., 107: 173-184. http://dx.doi.org /10.1016/j.jbiotec.2003.10.009.
14. Jactel, H.; Kleinhentz, M.; Bezard, A. M; Poll, M. F.; Menassıeu, P; Burban, C., 1996: Terpene variations in maritime pine constitutive oleoresin related to host tree selection by *Dioryctria sylvestrella* RATZ. (Lepidoptera: Pyralidae). J. Chem. Ecol., 22 (5): 1037-1050. http://dx.doi.org/10.1007/BF02029953
15. Kanat, M.; Sivrikaya, F., 2004: The effects of chemical control against pine processionary moth, *Thaumetopoea pityocampa* (Schiff.) on diameter increment in *Pinus brutia* (Ten.) trees in Kahramanmaraş region. KSU J. Sci. and Eng., 7 (2): 60-64.
16. Kleinhentz, M.; Jactel, H.; Mensassieu, P., 1999: Terpene attractant candidates of *Dioryctria sylvestrella* in maritime pine (*Pinus pinaster*) oleoresin, needles, liber and headspace samples. J. Chem. Ecohol., 25 (12): 2741-2756. http://dx.doi.org/10.1023/A:1020803608406
17. Köpke, D., 2010: Molecular Characterization of Pine Response to Insect Egg Deposition. PhD, Pharmazie der Freien Universität, Berlin, Germany.
18. Mumm, R.; Schrank, K.; Wegener, R.; Schulz, S.; Hilker, M., 2003: Chemical analysis of volatiles emitted by *Pinus sylvestris* after induction by insect oviposition. J. Chem. Ecol., 29 (5): 1235-1252. http://dx.doi.org/10.1023/A:1023841909199
19. Mumm, R.; Tiemann, T.; Schulz, S.; Hilker, M., 2004: Analysis of volatiles from black pine (*Pinus nigra*): significance of wounding and egg deposition by a herbivorous sawfly. Phytochem, 65: 3221-3230. http://dx.doi.org/10.1016/j.phytochem.2004.10.010
20. Mumm, R.; Hilker, M., 2006: Direct and indirect chemical defence of pine against folivorous insects. Trends in Plant Scien, 11 (7): 351-358. http://dx.doi.org/10.1016/j.tplants.2006.05.007
21. Noma, Y.; Yoshinori, A., 2010: Biotransformation of monoterpenoids by microorganisms, insects and mammals. Başer, K. H. C. and Buchbauer, G. Jr. (Ed.): Essential Oil. Newyork, USA: CRC Press, pp. 585-726.
22. Norlander, G., 1990: Limonene inhibits attraction to α-pinenee in the pine weevils *Hylobies abietis* and *H. pinastri*. J. Chem. Ecol., 16 (4): 1307-1320. http://dx.doi.org/10.1007/BF01021028
23. Paine, T. D.; Radda, K. F.; Harrington, T. C., 1997: Interaction among scolytid bark beetles, their associated fungi and live host conifers. Annu. Rev. Entomol., 42: 179-206. http://dx.doi.org/10.1146/annurev.ento.42.1.179
24. Papajannopoulos, A. D.; Song, Z. Q.; Liang, Z. Q.; Spanos, J. A., 2001: GC-MS analysis of oleoresin of three Greek pine species. Holz als Roh- Werkstoff, 59: 443-446. http://dx.doi.org/10.1007/s00107-001-0249-x
25. Ruby, J. L.; Wright, J. W., 1976: A revised classification of geographic varieties in Scotch pine. Silvae Genet., 25: 169-175.
26. Şensöz, S.; 2003. Slow pyrolysis of wood barks from *Pinus brutia* Ten. and product compositions. Bioresourc. Tecnohol., 89: 307-311. http://dx.doi.org/10.1016/S0960-8524(03)00059-2.
27. Sezik, E.; Üstün, O.; Demirci, B.; Başer, K. H. C., 2010: Composition of the essential oils of *Pinus nigra* Arnold from Turkey. Turk. J. Chem., 34: 313-325. http://dx.doi.org/10.3906/kim-0903-39
28. Tobolski, J. J.; Hanover, J. W., 1971: Genetic variation of the monoterpenes of Scotch pine. For. Sci., 17: 293-299.
29. Trapp, S.; Croteau, R., 2001: Defensive resin biosynthesis in conifers. Annu Rev Plant Physiol Plant Mol Biol, 52: 589-724. http://dx.doi.org/10.1146/annurev.arplant.52.1.689
30. Tümen, İ.; Reunanen, M., 2010: A comparative study on turpentine oils of oleoresins of *Pinus sylvestris* L. from three districts of Denizli. Rec. Nat. Prod., 4: 224-229.
31. Wang, Z.; Calderon, M. M.; Carandang, M. G., 2006: Effects of resin tapping on optimal rotation age of pine plantation. J Forest Eco, 11: 245-260. http://dx.doi.org/10.1016/j.jfe.2005.10.001
32. Wright, J. W.; Wilson, L. F.; Bright, J. N., 1975: Genetic variation in resistance of Scotch pine to Zimmerman pine moth. Great Lakes Entomol., 8: 231-236.
33. Zulak, G. K.; Bolhmann, J., 2010: Terpenoid biosynthesis and specialized vascular cells of conifer defense. J. Integr. Plant Biol., 52 (1): 86-97. http://dx.doi.org/10.1111/j.1744-909.2010.00910.x
34. *** 2013: Ormanların korunması. In: Ormancılık ve Su Şurası, 21-23 March 2013, Ankara, pp. 1-27.

Corresponding address:

Lecturer MEHMET OZ

Department of Forestry
Vocational School of Higher Education
Gumushane University
29000 Gumushane, TURKEY
e-mail: mehmetoz@gumushane.edu.tr

Jan Baar, Jitka Ondroušková, Peter Rademacher[1]

Change of Wood Moisture Content During Artificial Light Irradiation and its Influence on Colour Measurement

Promjena sadržaja vode u drvu tijekom izlaganja umjetnoj svjetlosti i njezin utjecaj na mjerenje boje

Original scientific paper • Izvorni znanstveni rad
Received – prispjelo: 1. 9. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*812.22; 630*812.111*
doi:10.5552/drind.2015.1430

ABSTRACT • *This paper discusses the differences between colour parameters of dried and conditioned wood surfaces irradiated by light. Samples of two wood species – Hevea (Hevea brasiliensis Müll. Arg.) and Jatoba (Hymenaea courbaril L.) – were exposed to artificial sunlight. During this process, sample moisture content decreased by 6 %. The colour parameters were measured immediately after irradiation and after conditioning on former moisture content level. Statistically significant differences were found between colour parameter values. Nevertheless these differences were too low for practical importance.*

Key words: *colour, conditioning, moisture content, light irradiation*

SAŽETAK • *U radu se analiziraju razlike parametara boje površine suhoga i kondicioniranog drva nakon izlaganja umjetnoj svjetlosti. Uzorci dviju vrsta drva – Hevea brasiliensis Mull Arg. i Hymenaea courbaril L. – bili su izloženi umjetnoj Sunčevoj svjetlosti. Tijekom tog procesa sadržaj vode u uzorcima smanjen je za 6 %. Parametri boje izmjereni su odmah nakon izlaganja svjetlosti i nakon kondicioniranja uzoraka na početni sadržaj vode. Utvrđene su statistički značajne razlike između vrijednosti parametara boja. Ipak te su razlike premalene da bi imale praktičnu važnost.*

Ključne riječi: *boja, kondicioniranje, sadržaj vode, izlaganje svjetlosti*

[1] Authors are assistant, master´s student and research assistant at Faculty of Forestry and Wood Technology, Mendel University in Brno, Czech Republic.
[1] Autori su asistent, student i znanstveni asistent Fakulteta šumarstva i drvne tehnologije, Mendelovo sveučilište u Brnu, Brno, Republika Češka.

1 INTRODUCTION
1. UVOD

Wood in outdoor use is exposed to weathering. The appearance and surface properties of wood are mainly changed by sunlight, especially its UV part, which induces photochemical reactions in wood (Hon, 2001; Müller *et al*., 2003). It is difficult to repeat the natural weathering conditions, therefore the wood photodegradation is often induced in artificial conditions by xenon lamp as the most frequently used light source (Tolvaj and Varga, 2012).

Due to the light, the colour of most wood species changes to yellow up to brown because of lignin and extractive photo-oxidation (Feist and Hon, 1984). Wood rich in extractives can fade before browning shows distinctly (Feist, 1983). The reddish brown heartwood of Jatoba is characterized by distinct darkening if it is exposed to sunlight (Jankowska *et al*., 2011; Baar and Gryc, 2012). The minor effect of UV light on chromatic parameters with slight reddening was showed for Jatoba (Pastore *et al*. 2004; Costa *et al*. 2010). Decrease in value of lightness and increase in the chromaticity parameters *a* and *b* was observed in light coloured Hevea by Srinivas and Pandey (2012).

The photodegradation of wood surface is closely connected to surface heating and subsequent thermal degradation. The temperature of wood surface exposed to sunlight depends on its darkness; sun-irradiated wood can reach 60 °C, or even 90 °C if it is dark enough (Tolvaj *et al*., 2011). During wood photodegradation experiments under artificial conditions, higher temperatures ranging between 40 and 60 °C are often used in the testing chamber for a period of up to 500 hours (Chang *et al*., 2010; Tolvaj and Mitsui, 2005; Blanchard and Blanchet, 2011; Pastore *et al*., 2004). This temperature is high enough for wood drying, especially where it is applied in the long term. According to Brunner and Hildebrand (1987), the normal drying temperature used in industry for wood drying ranged from 40 to 90 ºC. Simpson (1999) stated that a typical hardwood drying schedule in United States of America might begin at 49 °C and 80 % relative humidity when the lumber is green.

The moisture content of wood is changed during the irradiation if the relative air humidity is not controlled. Hon and Minemura (2001) stated that colour is darker in unseasoned wood than in seasoned one, because of free water which replaces the air inside the cell. The index of refraction of water is higher than that of air, which results in an increase of scattering events before the light leaves the surface. Part of the diffuse light is captured within the wet layer of the surface, so less light is reflected from a wet surface (Meichsner *et al*., 2011). On the other side, there is limited information as to whether the change of moisture content below fibre saturation point influences colour parameters as well. Neméth *et al*. (2013) showed for black locust and poplar wood that colour co-ordinates were not influenced by moisture content below fibre saturation point if the temperature was kept low.

We assumed that the moisture content of samples is decreased during irradiation process because of higher temperature and that its change can influence the measurement of colour parameters of irradiated surface.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The wood species used were Hevea (*Hevea brasiliensis* Müll. Arg.) and Jatoba (*Hymenaea courbaril* L.) heartwood from commercial sources. Twenty-five samples of each species, measuring 15 × 4 × 50 mm (L × R × T) with sanded tangential surface, were exposed to artificial sunlight of a xenon lamp (1800W xenon arc lamp – full-spectrum, irradiance 0.55 W/m^2 – 340 nm) for up to 192 hours at 60 °C without controlling relative air humidity. The sample dimension in longitudinal direction was adapted to the measuring aperture of spectrophotometer and was as short as possible because of easier moisture content equalization and more homogeneous moisture content distribution after irradiation.

Samples were removed from the chamber at regular intervals and put into the drying chamber with the temperature preset at 60 °C during sample weighing and colour measurement. The colour changes were first analyzed immediately after exposure at two marked spots on each sample. Discolouration of wood surface due to UV irradiation was measured by mobile spectrophotometer Spectro-guide 45/0 (45/0 measuring geometry, 10º standard observer, D65 standard illuminant, aperture 11 mm, CIEL**a***b** colour system) in the following intervals: 1, 2, 4, 6, 12, 24, 48, 96, 192 hours. Colour parameters *L*, *a*, *b* were measured at two marked spots on each specimen and the average value was calculated. These values were used to calculate the overall colour change *E* according to the following equation:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

where ΔL^*, Δa^*, Δb^* represent the differences between the colour parameter values of original and irradiated surfaces.

After colour measurement, the samples were stored in a dark room for conditioning till the moisture content was stable and colour was measured again at the same spots. Samples weight was measured before exposure, after taking them out from the xenon test chamber and then again following conditioning. The samples were dried in the drying chamber at 103 °C at the end of the experiment to get the oven-dry sample weight. Moisture content was calculated using the following equation:

$$MC = (m_w - m_0) / m_0$$

where m_0 is the mass of the oven-dry specimen and m_w is the mass of the specimen at the given moisture content.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The average moisture content of samples before irradiation was 7.4 % in conditioned state for both spe-

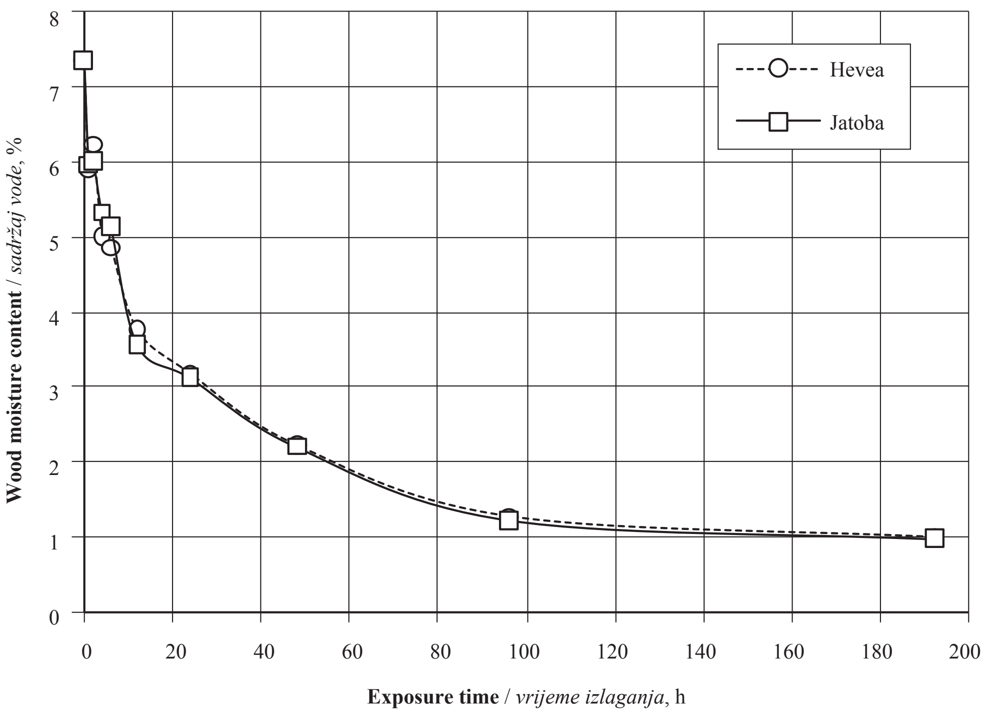


Figure 1 Moisture content change due to light-irradiation
Slika 1. Promjena sadržaja vode zbog izlaganja svjetlosti

cies. During the process of light-irradiation, when the temperature was kept at 60 ºC, the moisture content of samples decreased depending on the duration of the irradiation cycle. The change of moisture content is shown in Figure 1. After the longest uninterrupted interval of irradiation (96 hours), the moisture content of samples was lower than 1 %. The changes in relative humidity and temperature of the surrounding air established conditions suitable for wood drying. Changes in wood moisture content are usually gradual, and short-term fluctuations tend to influence only the wood surface. The sample dimension, especially in longitudinal direction, was as short as possible to intensify drying in the whole volume and to get homogenous distribution. Usually, the tested samples are more large-sized and the moisture changes are mostly limited to the surface, however the colour is measured just there.

The colour parameters L^*, a^* and b^* of samples were measured in intervals immediately of the chamber when the surface was still dried. After each interval, samples were conditioned to the moisture content around 7.5 %. Table 1 shows the colour parameters and colour change ΔE for samples before and after conditioning after the last period of irradiation (96 hours). The discoloration development of both species corresponded to colour changes stated in literature (Pastore *et al*., 2004; Costa *et al*., 2010; Srinivas and Panday, 2012). All three parameters had slightly higher values after conditioning. The difference of these colour parameters was about 1, so it is not detectable by human eye. The chromatic parameters a^* and b^* were more intensive with higher moisture content. On the other hand, the surface colour of dried wood was darker than wood with higher moisture content. It differs from the situation when free water is present in wood, as the surface looks darker with higher wood moisture content. The refractive index of the fibres is completely altered when water molecules get trapped in the cell wall, which changes the amount of light internally reflected back to the observer's eye, hence the shade of the colour is perceived differently. Németh *et al*. (2013) analyzed colour change during drying under different temperature conditions in Black locust and Poplar. In both cases more distinct discolouration was caused by higher temperature (60 and 80 ºC). The colour parameters were almost stable when the wood was only ex-

Table 1 Colour parameter values measured before and after sample conditioning (192 hours)
Tablica 1. Vrijednosti parametara boje mjerene prije i nakon kondicioniranja uzoraka (192 sata)

Wood species *Vrsta drva*	**Treatment** *Obrada*	L^*	a^*	b^*	ΔE^*
Hevea	Non-irradiated / *bez izlaganja*	72.74	4.58	21.11	-
	Irradiated / *izlagano svjetlosti*	74.76	3.15	28.75	8.53
	Conditioned / *kondicionirano*	75.23	3.91	30.09	9.77
Jatoba	Non-irradiated / *bez izlaganja*	49.26	11.26	23.06	-
	Irradiated / *izlagano svjetlosti*	47.35	11.31	20.53	5.86
	Conditioned / *kondicionirano*	48.09	12.68	21.8	5.58

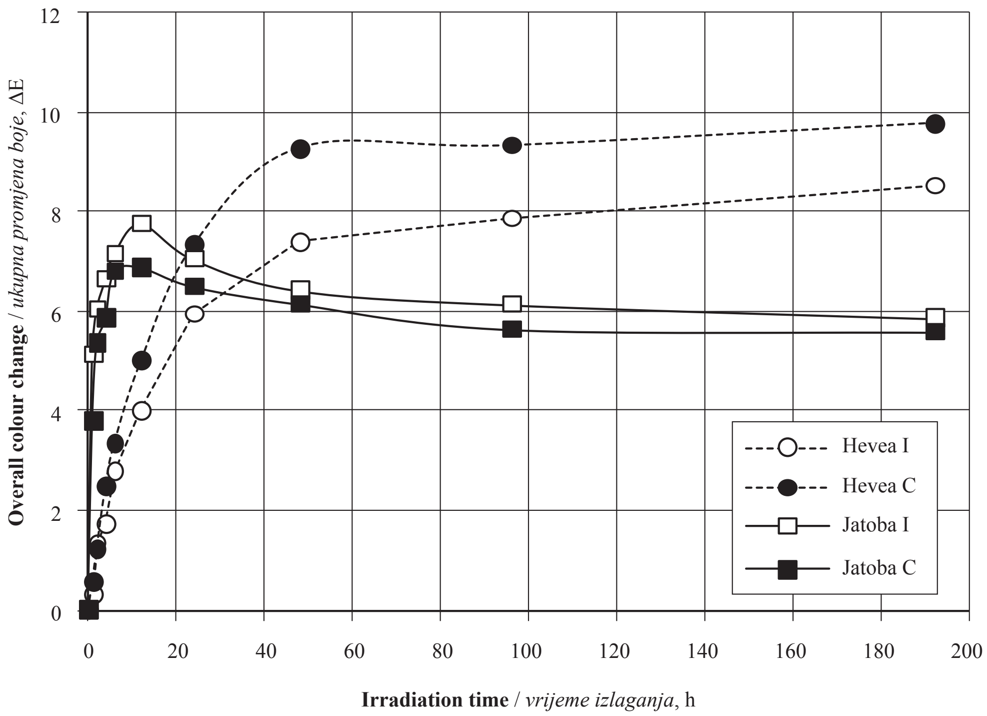


Figure 2 Differences in overall colour change Δ*E* after irradiation and conditioning (I – irradiation, C – conditioning)
Slika 2. Razlike ukupnih promjena boje nakon izlaganja svjetlosti i kondicioniranja (I – drvo izlagano svjetlosti, C – kondicionirano drvo)

posed to the temperature of 20 ºC and the wood moisture content was below 20 %.

The highest differences between dry and conditioned surface were found for overall colour change Δ*E*. Figure 2 shows its value progress during irradiation. The changed wood moisture content influenced more the colour of light-coloured Hevea than dark brown Jatoba. The colour of wood is probably influenced by moisture content below fibre saturation point as well. The expected difference in moisture content (up to 6.5 %) during irradiation is too low to see distinct colour change and, therefore, in this case the sample conditioning is not necessary.

The paired *t*-test was used for finding statistical differences between values measured before and after sample conditioning. The *p* values for individual colour parameters and intervals, taking Hevea as an example, are stated in Table 2. The values after conditioning differed significantly from values measured before conditioning for all intervals, even for the shortest irradiation interval (1 hour), when the moisture content decreased only by 1 %. The surface is dried more intensively and it reaches similar moisture content independently of the duration of exposure, whereas longer period is necessary for the decrease in moisture content of the inner part. However, from a practical point of view, these differences are negligible, because they are too low to be seen by the human eye. Also, the colour variation in the same wood piece can lead to higher differences if it is not measured exactly at the same spot.

4 CONCLUSION
4. ZAKLJUČAK

The moisture content of samples decreases during the process of artificial light irradiation if the temperature is higher (40-60 ºC) and moisture content in the chamber is not controlled. Therefore, the samples should be conditioned before colour measuring to provide identical conditions. Statistically significant differences were found between values of colour parameters measured before and after conditioning. From a practical point of view, these differences are negligible. They are too low to be seen by the human eye and usually not measured at exactly the same spot, which prob-

Table 2 The *p* value of paired *t*-test for colour parameters measured before and after conditioning (at 95 % confidence level) for Hevea ([n.s.] statistically non-significant)
Tablica 2. Vrijednosti vjerojatnosti *p* za *t*-test između parova izmjerenih parametara boje prije i nakon kondicioniranja za drvo *hevea* ([n.s.] statistički nije značajno)

Colour parameter *Parametar boje*	**Time of irradiation, h** / *Vrijeme izlaganja svjetlosti, h*								
	1	2	4	6	12	24	48	96	192
Δ*E*	0.004	0.09[n.s.]	0.000	0.000	0.000	0.000	0.000	0.000	0.000
*L**	0.000	0.07[n.s.]	0.000	0.000	0.000	0.000	0.000	0.000	0.000
*a**	0.000	0.000	0.035	0.011	0.002	0.91[n.s.]	0.000	0.37[n.s.]	0.000
*b**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ably leads to higher differences in wood colour because of its heterogeneity.

5 REFERENCES
5. LITERATURA

1. Baar, J.; Gryc, V., 2012: The analysis of tropical wood discoloration caused by simulated sunlight. European Journal of Wood and Wood Products, 70: 263-269. http://dx.doi.org/10.1007/s00107-011-0551-1
2. Blanchard, V.; Blanchet, P., 2011: Colour stability for wood products during use: Effects of inorganic nanoparticles. BioResources, 6: 1219-1229.
3. Brunner, R.; Hildebrand, K., 1987: Die Schnittholztrocknung. Buchdruckwerkstätten Hannover GmbH, Hannover, pp. 322.
4. Chang, T. C.; Chang, H. T.; Wu, C. L.; Lin, H. Y.; Chang, S. T., 2010: Stabilizing effect of extractives on the photooxidation of *Acacia confusa* wood. Polymer Degradation and Stability, 95: 1518-1522. http://dx.doi.org/10.1016/j.polymdegradstab.2010.06.012
5. Costa, J. A.; Gonçalez, J. C.; Camargos, J. A. A.; Gomes, I. A. S., 2010: Fotodegradação de duas espécies de madeiras tropicais: Jatobá (*Hymanaea courbaril*) e Tauari (*Couratauri oblongifolia*) submetidas à radiação ultra violeta, Cerne, 17: 133-139. http://dx.doi.org/10.1590/S0104-77602011000100016
6. Hon, D. N. S., 2001: Weathering and photochemistry of wood. In: Hon, D. N. S., Shiraishi, N. (Eds.): Wood and cellulosic chemistry. New York, Marcel Dekker, pp. 513-546.
7. Hon, D. N. S.; Minemura, N., 2001: Color and discoloration. In: Hon, D. N. S., Shiraishi, N. (Eds.): Wood and cellulosic chemistry. New York, Marcel Dekker, pp. 385-442.
8. Jankowska, A.; Kozakiewicz, P.; Szczęsna, M., 2011: The study of color changes of chosen species of wood from South America caused by transparent coatings and light action, Annals of Warsaw University of Life Sciences, 74: 120-124.
9. Meichsner, G.; Hiesgen, R.; Esslinger, A.; Schottka, A., 2011: Richtig anfeuern - farbmetrische Charakterisierung von Holzoberflächen, Farbe und Lack, 117: 24-29.
10. Müller, U.; Rätzsch, M.; Schwanninger, M.; Steiner, M.; Zöbl, H., 2003: Yellowing and IR-changes of spruce wood as result of UV-irradiation. Journal of Photochemistry and Photobiology B: Biology, 69: 97-105. http://dx.doi.org/10.1016/S1011-1344(02)00412-8
11. Németh, R.; Ott, Á.; Takáts, P.; Bak, M., 2013: The effect of moisture content and drying temperature on the colour of two Poplars and Robinia wood. BioResources, 8: 2074-2083. http://dx.doi.org/10.15376/biores.8.2.2074-2083
12. Pastore, T. C. M.; Santos, K. O.; Rubim, J. C., 2004: A spectrocolourimetric study on the effect of ultraviolet irradiation of four tropical hardwoods. Bioresource Technology, 93: 37-42. http://dx.doi.org/10.1016/j.biortech.2003.10.035
13. Simpson, W. T., 1999: Drying and control of moisture content and dimensional changes. Wood handbook: wood as an engineering material. Madison, WI : USDA Forest Service, Forest Products Laboratory, General technical report FPL, GTR-113.
14. Srinivas, K.; Pandey, K. K., 2012: Photodegradation of thermally modified wood. Journal of Photochemistry and Photobiology B: Biology, 117: 140-145. http://dx.doi.org/10.1016/j.jphotobiol.2012.09.013
15. Tolvaj, L.; Mitsui, K., 2005: Light source dependence of the photodegradation of wood. Journal of Wood Science, 51: 468-473. http://dx.doi.org/10.1007/s10086-004-0693-4
16. Tolvaj, L.; Persze, L.; Albert, L., 2011: Thermal degradation of wood during photodegradation. Journal of Photochemistry and Photobiology B: Biology, 105: 90-93. http://dx.doi.org/10.1016/j.jphotobiol.2011.07.005
17. Tolvaj, L.; Varga, D., 2012: Photodegradation of timber of three hardwood species caused by different light sources. Acta Silvatica et Lignaria Hungarica, 8:145-155. http://dx.doi.org/10.2478/v10303-012-0012-5

Acknowledgement – Zahvala

The paper was supported by the European Social Fund and the state budget of the Czech Republic, project "The Establishment of an International Research Team for the Development of New Woodbased Materials" reg. no. CZ.1.07/2.3.00/20.0269. Authors would also like to thank the company MAGNUM Parket a.s. for the supply of materials used in the experiment.

Corresponding address:

Ing. JAN BAAR

Department of Wood Science
Faculty of Forestry and Wood Technology
Mendel University in Brno
Zemědělská 3
Brno, 613 00, CZECH REPUBLIC
e-mail: jan.baar@mendelu.cz

Hubert Paluš[1], Ján Parobek[1], Branko Liker[2]

Trade Performance and Competitiveness of the Slovak Wood Processing Industry within the Visegrad Group Countries

Rezultati trgovine i konkurentnost slovačke drvoprerađivačke industrije unutar zemalja Višegradske skupine

Original scientific paper • Izvorni znanstveni rad
Received – prispjelo: 4. 9. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*74; 630*79*
doi:10.5552/drind.2015.1431

ABSTRACT • *The aim of this paper is to analyse trade performance and competitiveness of the Slovak wood processing industry sectors and their comparison with the Visegrad group countries. The competitiveness is studied for the products of primary wood processing, namely coniferous and non-coniferous sawnwood, wood based panels, wood pulp, paper and paperboard products. A set of trade performance and competitiveness indicators is used to analyse the position and changes in competitiveness of the respective countries in 2003-2012. In particular, Trade Specialisation Index, Export/Import Ratio, Standard Grubel-Lloyd Index, Revealed Comparative Advantage and Vollrath's Revealed Competitive Advantage Indexes were used to identify comparative advantages and trade specialisation for individual forest product categories and a specific country's performance. Within the group of analysed countries, Slovakia has revealed comparative advantage in most of the products, in particular in the trade with coniferous sawnwood, non-coniferous sawnwood, wood based panels and paper and paperboard products. Results of the analysis also pointed out that intra-industry specialisation is increasing with the level of value added to products.*

Key words: *trade performance, competitiveness, wood products, Visegrad group*

SAŽETAK • *Cilj je rada bio analizirati učinkovitost trgovine i konkurentnost slovačke drvoprerađivačke industrije i usporediti ih sa zemljama Višegradske skupine. Konkurentnost je analizirana na proizvodima primarne prerade drva, i to na proizvodima piljenog drva četinjača i ostaloga piljenog drva, pločama na bazi drva, celulozi, papiru i proizvodima od kartona. Skup pokazatelja uspješnosti trgovine i konkurentnosti upotrijebljen je za analizu pozicije i promjene konkurentnosti pojedinih zemalja u razdoblju od 2003. do 2012. godine. Konkretno, indeks specijalizacije trgovine, omjer izvoza i uvoza, standardni Grubel-Lloydov indeks, indeks otkrivene komparativne prednosti i Vollrathov indeks otkrivene konkurentske prednosti upotrijebljeni su za identifikaciju komparativnih*

[1] The authors are associate professor and assistant at Technical University in Zvolen, Faculty of Wood Sciences and Technology, Zvolen, Slovak Republic. [2]The author is Chief Executive Officer in Drvenjača d.d., Fužine, Croatia.
[1] Autori su izvanredni profesor i asistent Tehničkog sveučilišta u Zvolenu, Fakultet za znanost o drvu i drvnu tehnologiju, Zvolen, Slovačka. [2]Autor je izvršni direktor u tvrtki Drvenjača d.d., Fužine, Hrvatska.

prednosti i trgovinsku specijalizaciju za pojedine kategorije šumskih proizvoda i uspješnost određene zemlje. Unutar skupine analiziranih zemalja za Slovačku je utvrđena komparativna prednost za većinu proizvoda, osobito u trgovini piljenog drva četinjača i ostalog piljenog drva, ploča na bazi drva, celuloze, papira i proizvoda od kartona. Rezultati analize također su pokazali da specijalizacija unutar industrije povećava razinu dodane vrijednosti proizvoda.

Ključne riječi: *uspješnost trgovine, konkurentnost, proizvodi od drva, zemlje Višegradske skupine*

1 INTRODUCTION
1. UVOD

1.1 Competitiveness
1.1. Konkurentnost

Timber companies must continually strive to improve or at least maintain their market share (Oblak and Glavonjić, 2014). Globalisation as the process of international integration is affecting all industries, including forest based industry. As there are new products with lower prices available on the market, new strategies and advantages are required to face international competitors. These, among other, include new business models, improvement of productivity, innovations and cooperation in terms of technology, outsourcing and supply chain. The process of globalisation has led to the gradual reduction in trade barriers, and competitiveness has become a key issue in international markets since it can be considered as the major source of export development. The issues of competitiveness have also ascended high on the agenda of national governments and of the EU. In case of environmentally sensitive markets, the competitiveness of forest products can be influenced by factors related to the origin of wood material from sustainable and renewable sources (Kaputa, 2013; Paluš and Kaputa, 2009).

Wolff *et al*. (2007) state that the concept of competitiveness is rather complex as the term is used at different levels of aggregation with different meanings. The concepts of competitiveness can be distinguished at the level of products, business units or firms, as well as at industry and national or regional level. Jansik *et al*. (2014) state that the main difference between the competitiveness of business units and national economies is in the ultimate objective. For a company, it is the success or survival of a company, while for the economy the objective is to raise living standards. In this sense, competitiveness is a comparative concept of the ability and performance of a firm, subsector or country to sell and supply goods or services in a given market. A nation's competitiveness can be described as the degree to which it can, under free and fair market conditions, produce goods and services that meet the test of the international markets, while simultaneously maintaining and expanding the incomes of its people over the longer term. In a broader context, Latruffe (2010) defines competitiveness in two perspectives: (i) as the ability to face competition and to be successful when facing competition, and (ii) as the ability to sell products that meet demand requirements and, at the same time, ensure profits over time that enable the firm to thrive.

Consumers are, nowadays, very demanding and they require as much as possible information about the product to be sure about its quality (Oblak and Glavonjić, 2014). Due to growing global demand for wood and wood products, it is crucial to be competitive on international market in order to make use of the potential gains of increased demand. A country that best utilises its given resources within a particular sector may enjoy a significant comparative advantage in respective international markets. According to Noor *et al*. (2008), the concept of comparative advantage is derived from traditional theory of international trade, while the term competitiveness goes beyond comparative advantage as no country can be competitive in every economic activity. Porter (1990) claims that productivity is the only meaningful concept of competitiveness. According to Kagochi (2007), some of the underlying factors that influence competitiveness include technology, human capital, product quality and differentiation, exchange rate, and other external factors.

Traditional trade theory understands international competitiveness via the comparative advantage of nations: A nation engages in trade and gains a comparative advantage not because it can produce a good or service absolutely cheaper, but because it is relatively more efficient than other nations in producing this good or service (Ricardo, 1911). The theory proved that each nation would benefit from specializing in the product in which it enjoys a comparative advantage, that way raising the total global output of each product and improving the situation of all participating nations (Carvalho *et al.,* 2009). The Heckscher- Ohlin theorem (Ohlin, 1933) assumes that especially the relative endowments of production factors, such as natural resources, labour and capital, determine a nation's comparative advantage. The theorem states that each country exports the commodity which requires for its production relatively intensive use of the factor relatively abundant in that country (Gonuguntla, 2007). The measurement of competitiveness in this sense stresses a country's performance on international markets and refers e.g. to trade flows, net exports, or countries' shares of the world market (Wolff *et al.,* 2007).

There have been several indicators developed to measure the competitive situation of a specific sector or country. According to Gries and Hentschel (1994), these can be classified into (i) result-oriented indicators that reveal the realised competitive situation of a sector or country from the ex-post perspective (indicators such as terms of trade, revealed comparative advantage, constant market shares, etc.), and (ii) determinant-oriented indicators that are based on the assumption of a correlation between the determinants and the competitive situation of a country (indicators such as the legal and institutional framework of a country, its infrastructure, social security system, private and public expenditure for research and development, etc.).

1.2 Literature review
1.2. Pregled literature

Many studies using the result-oriented indicators to evaluate competitiveness of forest based and related agricultural sectors have been elaborated in different countries. Carvalho *et al.* (2009) used the revealed comparative advantage (RCA) and relative position in the market (RPM) indices to evaluate competiveness of Brazilian wood pulp in the international market and observed that Brazil ranked among the top countries for competitiveness in the international market of wood pulp. Gonuguntla (2007) used the RCA index to analyse New Zealand's forestry sector comparative advantage in some forestry products. The study showed that New Zealand's comparative advantage decreased in low value products but increased in high value products within the forestry sector. Prasad (2004) used the revealed comparative advantage (RCA) index and revealed symmetric comparative advantage (RSCA), to measure Fiji's competitiveness in comparison to a set of reference countries. A comprehensive study on the competitiveness in the global forest industry sector with the emphasis on the German forest industry was elaborated by Dieter and Englert (2007). The study considered competitiveness of different wood commodities according to the level of processing using the revealed comparative advantage (RCA) index and the constant market share (CMS) analysis. The highest values of competitiveness indicators were shown by Russia for raw wood, Finland for semi-finished wood products and by Poland for finished wood products. The market share analysis also delivered the result that most of the leading timber exporters in absolute terms show only low export growth rates and vice versa. Mäkelä (2009) studied the competitiveness of the Russian forest industry and the influence of export taxes on competitiveness of individual wood commodities. He realised that the Russian forest sector is competitive primarily in products with a low added value. Noor *et al.* (2008) used the approach of revealed comparative advantage to analyse the strength of Malaysia in exporting the wood and forest products to world market. The results showed that Malaysia has the comparative advantage based on the performance of exporting wood and forest products to Europe. A similar study was elaborated by Zhang *et al.* (2012), who evaluated the competitiveness of Chinese industries, including the competitiveness of wood products. The competitiveness of US household and office furniture industry and its comparison with the major world furniture exporters was studied by Song and Gazo (2013).

1.3 Slovak forestry and wood processing industry
1.3. Slovačko šumarstvo i drvoprerađivačka industrija

In general, forest industry in Slovakia is divided into the forestry and wood processing industry. A long history of the forest industry is based on the rich wood resources and mining history. The total area of forests is almost 2 mil. ha and the growing stock in the Slovak forests was 452 mil. m^3 in 2012. Total felling in 2012 was 8.2 mil. m^3. In spite of the sufficient domestic wood processing capacities (mainly for softwood logs), a significant part of roundwood production was exported (over 2.4 mil. m^3 in 2012). The primary wood processing industry consists of three main sectors represented by sawmilling, wood based panels and pulp and paper sector. The secondary wood processing industry is represented by furniture sector. Due to the low domestic consumption of final products, the whole industry is strongly export-oriented. The primary processing sectors have been traditionally using the domestic wood resources; however the increasing pulp and paper production resulted in a growth in imports of hardwood pulp wood in the latest years. Sawmilling sector is very heterogeneous and mostly oriented to production of low value construction coniferous sawnwood (Paluš and Parobek, 2013). In 2012, the Slovak sawmills produced 1.56 mil. m^3 of sawnwood, out of which 40 % was exported. Wood based panel industry is represented mainly by particle board producers that produced 0.53 mil. m^3 of boards in 2012. At the same time over 64 % of production was exported and nearly 0.23 mil. m^3 of particle board imported to Slovakia. Pulp and paper industry is one of the most powerful sectors in the Slovak economy (Šupín, 2011). In 2012, the production of the main paper categories - printing and writing paper was 0.54 mil. tons, out of which nearly 96 % was exported. The future development of the industry is dependent on the level of utilisation of wood resources, investments into wood processing capacities and innovation activities of the industry (Loučanová, 2004). It is a generally accepted fact that socioeconomic development greatly depends on investment and, therefore, long-term development can only be achieved through investment, because well targeted investment activity is the primary assumption for all aspects of competitiveness (Ojurovic *et al.* 2013).

The objective of this paper is to analyse trade performance and competitiveness of the Slovak wood processing industry sectors and their comparison with the Visegrad group (V4) countries for the products of primary wood processing with the use of a set of trade performance and competitiveness indicators.

2 METHODS
2. METODE

Trade performance and competitiveness of the Slovak (SK) wood processing industry was examined in comparison with other Visegrad group countries (V4), namely Poland (P), Czech Republic (CZ) and Hungary (H). As for the definition of forest products, the FAO classification of forest products (FAO, 2014a) was used to set up the main categories of products according to the type and level of processing and added value (Table 1). Particular products and product groups included in the analyses were coniferous sawnwood, non-coniferous sawnwood, wood based panels, wood pulp, paper and paperboard.

Table 1 Categories of examined wood products
Tablica 1. Kategorije istraživanih drvnih proizvoda

Category *Kategorija*	**Product groups** *Skupina proizvoda*	**Products included** *Proizvodi*
Semi-finished mechanical wood products *polugotovi mehanički drvni proizvodi*	Sawnwood / *piljeno drvo*	Coniferous sawnwood / *piljeno drvo četinjača*
		Non-coniferous sawnwood / *piljeno drvo osim četinjača*
	Wood based panels / *ploče na bazi drva*	Veneer / *furnir* Plywood / *furnirske ploče* Particle board / *iverice* Fibreboard / *vlaknatice*
Semi-finished chemical wood products *polugotovi kemijski drvni proizvodi*	Wood pulp / *drvna pulpa*	Chemical wood pulp / *kemijska drvna pulpa* Semi-chemical wood pulp / *polukemijska drvna pulpa* Mechanical wood pulp / *mehanička drvna pulpa* Dissolving wood pulp / *otopina drvne pulpe*
	Paper and paperboard / *papir i karton*	Newsprint / *roto-papir* Printing and writing paper / *papir za printanje i pisanje* Other paper and paperboard / *ostali papiri i karton*

The study adopts the widely accepted trade and competitiveness indicators *(Trade Specialisation Index, Export/Import Ratio, Standard Grubel-Lloyd Index, Revealed Comparative Advantage, Vollrath's Revealed Competitive Advantage Indexes)* based on forest products trade data in 2003 and 2012 available from the FAO Forest Products Statistics (FAOSTAT, 2014b) and the UN Comtrade Database (UN, 2014).

Trade Specialisation Index

According to Balassa (1966), country's trade advantage in a particular industry could be obtained by calculating the Trade Specialisation Index as a ratio of net trade to the total trade in the commodity category. This index is also referred to as the Net Trade Revealed Comparative Advantage Index (Prasad, 2004). The ratio is calculated as:

$$TSI_j^A = \frac{X_j^A - M_j^A}{X_j^A + M_j^A} \qquad (1)$$

where:
X_j^A- country A's export of product *j*
M_j^A - country A's export of product *j*

This ratio ranges from -1 when there are no exports ($X_j^A = 0$) to +1 when there are no imports ($M_j^A = 0$). The values indicate comparative disadvantage when it is between –1 and 0 and comparative advantage when the value is between 0 and +1. However, if it is equal to 0, it indicates that exports and imports of a particular product are equal. More specifically, this index measures the degree of specialisation of a country in exporting a particular product (Prasad, 2004).

Export/Import Ratio

The ratio is calculated as:

$$EIR_j^A = \frac{X_j^A}{M_j^A} \cdot 100 \qquad (2)$$

The higher the value of the ratio, the more a country has international trade competitiveness in a particular industry. By taking natural logarithm (Ln) to the ratio, the index is thus calculated as:

$$LnEIR_j^A = Ln\left(\frac{X_j^A}{M_j^A}\right) \cdot 100 \qquad (3)$$

A positive value of this index indicates international trade competitiveness of a country for a particular product, and a negative value of the index implies that there is no international trade competitiveness.

Standard Grubel-Lloyd Index

Grubel and Lloyd (1975) carried out an empirical study on the importance of intra-industry trade and how to measure it. The index *(GL)* is the ratio of the absolute value of differences in exports and imports to total trade of a particular industry or commodity group:

$$GL_j^A = 1 - \left(\frac{\left|X_j^A - M_j^A\right|}{X_j^A + M_j^A}\right) \cdot 100 \qquad (4)$$

The Grubel–Lloyd index varies between zero (indicating pure inter-industry trade) and one (indicating pure intra-industry trade) or between 0 and 100 when expressed in percentage terms, respectively. Inter-industry trade is defined as trade between two countries where the goods are from different sectors, while intra-industry trade is when the traded goods are of the same sector.

Revealed Comparative Advantage Index

The revealed comparative advantage index (RCA) was proposed by Balassa (1965) to demonstrate whether a country has comparative advantage in producing a given product, comparing its share to the volume of domestic and international exports. According to Carvalho *et al.* (2009), an index greater than unity indicates that a country has comparative advantage in producing a product, while an index less than unity indicates that the country has revealed comparative disadvantage. The higher the index, the greater the comparative advantage of the country in international trade. The Balassa's RCA index is defined as:

$$RCA_j^A = \frac{X_j^A / X^A}{X_j^W / X^W} \qquad (5)$$

where:
X^A - total exports of country A
X^W - total world exports (exports of a set of referenced countries)

Gonuguntla (2007) argues that although RCA reveals a country's resource based comparative advantage, it is quite likely that a country's comparative advantage is influenced by other variables such as changes in resource endowment, technology and demand. Another problem with the RCA index is that large differences in country sizes can cause problems when applying the RCA across countries and, therefore, Laursen (1998) adjusted the RCA index to make it symmetric (RSCA), such that the adjusted index values are between – 1 and +1. This RSCA index is defined as:

$$RSCA_j^A = (RCA_j^A - 1) / (RCA_j^A + 1) \quad (6)$$

Positive values of RSCA show a competitive advantage, and negative values of RSCA show a competitive disadvantage in exporting product *j*.

Vollrath's Indexes of Revealed Competitive Advantage

Vollrath (1991) investigated alternative indexes under RCA theory. These are relative export advantage (RXA) index, relative import advantage (RMA) index, relative trade advantage (RTA) index, and revealed competitiveness (RC). Vollrath's indexes are presented below:

$$RXA_j^A = \frac{X_j^A / X_n^A}{X_j^R / X_n^R} \quad (7)$$

$$RMA_j^A = \frac{M_j^A / M_n^A}{M_j^R / M_n^R} \quad (8)$$

$$RC_j^A = Ln(RXA_j^A) - Ln(RMA_j^A) \quad (9)$$

where:

X_n^A – exports of all products excluding product *j* by country *A*

X_j^R – exports of product *j* by all countries in the world excluding country *A*

X_n^R – exports of all products excluding product *j* by all countries in the world excluding country *A*

M_n^A - imports of all products excluding product *j* by country *A*

M_j^R – imports of product *j* by all countries in the world excluding country *A*

M_n^R– imports of all products excluding product *j* by all countries in the world excluding country *A*

According to Song and Gazo (2013) if the RXA_j^A has a value greater than one, it reveals that country *A* has a competitive advantage in exports of commodity *j*. When the RXA_j^A has a value less than one, it reveals a competitive disadvantage. If the RMA_j^A has a value lower than one, it means that country *A* has a competitive advantage in imports of commodity *j*. RMA_j^A has a value higher than one when it has a competitive disadvantage. RC_j^A value greater than zero indicates a net competitive advantage, and RC_j^A lower than zero indicates a net competitive disadvantage of country *A*.

Wanat and Lis (2012) underlined that the indexes of revealed comparative advantage and intensity of economy share in intra-industry trade are interrelated. The competitiveness of products from a given market should not be determined only and exclusively by the credit balance of trade in relation to particular products. It is important to determine the intensity of simultaneous export and import within a given branch. If the value of exports and imports is similar, such a situation is referred to as so-called partner competitiveness.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Overall Slovakia's performance of trade with respective wood products and product groups in 2003-2012 is shown in Table 2 and Table 3.

A positive value of the TSI indicates that Slovakia has a comparative advantage in the trade of coniferous and non-coniferous sawnwood as well as paper and paperboard products. On the other hand, comparative disadvantage is in trade with wood based panels and wood pulp. There is a clear trend in declining TSI values for both coniferous sawnwood (decline by 46.43 %) and non-coniferous sawnwood (decline by 68.67 %) during the observed period. The main reason for an

Table 2 Slovakia's mechanical wood products trade performance in 2003-2012
Tablica 2. Rezultati slovačke trgovine mehaničkih drvnih proizvoda u razdoblju 2003. – 2012.

Year *God.*	**Sawnwood (C)** *Piljeno drvo četinjača*				**Sawnwood (NC)** *Piljeno drvo osim četinjača*				**Wood-Based Panels** *Ploče na bazi drva*			
	TSI	EIR	LnEIR	GL	TSI	EIR	LnEIR	GL	TSI	EIR	LnEIR	GL
2003	0.84	1135.97	243.01	16.18	0.83	1069.40	236.97	17.10	-0.11	80.12	-22.16	88.96
2004	0.79	872.06	216.57	20.57	0.80	879.69	217.44	20.41	0.00	99.47	-0.53	99.73
2005	0.81	931.71	223.19	19.39	0.73	645.63	186.51	26.82	0.00	99.93	-0.07	99.97
2006	0.73	631.39	184.28	27.35	0.74	679.36	191.60	25.66	-0.10	81.24	-20.77	89.65
2007	0.51	308.69	112.72	48.94	0.69	539.75	168.59	31.26	-0.10	81.22	-20.80	89.64
2008	0.66	481.78	157.23	34.38	0.71	598.17	178.87	28.65	0.04	107.28	7.02	96.49
2009	0.66	485.11	157.92	34.18	0.38	222.61	80.03	61.99	-0.19	68.70	-37.54	81.45
2010	0.33	197.04	67.82	67.33	0.64	453.01	151.07	36.17	-0.14	74.88	-28.93	85.64
2011	0.54	333.08	120.32	46.18	0.38	223.72	80.52	61.78	-0.22	64.44	-43.95	78.37
2012	0.45	264.86	97.40	54.82	0.26	171.38	53.87	73.70	-0.15	73.40	-30.93	84.66

TSI – Trade Specialisation Index / *indeks specijalizacije trgovine*; EIR – Export/Import Ratio / *omjer izvoza i uvoza*; LnEIR – Natural logarithm of Export/Import Ratio / *prirodni logaritam omjera izvoza i uvoza*; GL – Standard Grubel-Lloyd Index / *standardni Grubel-Lloydov indeks*

Table 3 Slovakia's chemical wood products trade performance in 2003-2012
Tablica 3. Rezultati slovačke trgovine kemijskih drvnih proizvoda u razdoblju 2003. – 2012.

Year God.	**Wood Pulp** / *Drvna pulpa*				**Paper and Paperboard** / *Papir i karton*			
	TSI	EIR	LnEIR	GL	TSI	EIR	LnEIR	GL
2003	-0.06	89.02	-11.63	94.19	0.12	127.50	24.29	87.91
2004	-0.12	78.42	-24.31	87.91	0.22	154.91	43.77	78.46
2005	-0.13	77.66	-25.28	87.42	0.28	178.67	58.04	71.77
2006	-0.08	84.90	-16.36	91.84	0.30	185.11	61.58	70.15
2007	-0.13	77.09	-26.02	87.06	0.29	181.48	59.60	71.05
2008	-0.21	65.13	-42.88	78.88	0.20	149.52	40.23	80.15
2009	-0.18	68.92	-37.23	81.60	0.28	179.00	58.22	71.68
2010	-0.14	75.13	-28.59	85.80	0.32	192.24	65.36	68.44
2011	-0.20	66.43	-40.90	79.83	0.12	126.10	23.19	88.45
2012	-0.05	91.15	-9.26	95.37	0.13	129.57	25.91	87.12

TSI – Trade Specialisation Index / *indeks specijalizacije trgovine*; EIR – Export/Import Ratio / *omjer izvoza i uvoza*; LnEIR – Natural logarithm of Export/Import Ratio / *prirodni logaritam omjera izvoza i uvoza*; GL – Standard Grubel-Lloyd Index / *standardni Grubel-Lloydov indeks*

increase in competitiveness of coniferous sawnwood trade in 2005 was the severe windthrown in 2004 followed by growing production and export of sawnwood products. However, overall declining international trade competitiveness for both sawnwood products was also indicated by changes in LnEIR values, where in case of non-coniferous sawnwood the index dropped more significantly from 236.97 in 2003 to 53.87 in 2012. The analysis of GL indexes indicated gradual trend towards intra-industry trade specialisation for both sawnwood product groups. These changes were more significant for non-coniferous sawnwood rather than coniferous one where the GL index value increased from 17.1 to 73.7 in 10 years. However, compared to other product groups, sawnwood (mainly coniferous) can be still considered as the product considerably traded among industries.

TSI values for wood based panels oscillate around zero but in generally they indicate comparative disadvantage. This is clearly indicated by the development of LnEIR values when comparative advantage was revealed only in 2008 (7.02). The high values of GL index emphasise a balance between the imports and exports of wood based panels (99.73 in 2005), as well as strong intra-industry trade and specialisation in certain types and quality grades of wood based panels.

The intensive production of certain grades of papers causes a lack of wood pulp produced domestically and, therefore, this deficit needs to be supplemented by imports. Thus wood pulp imports dominated over exports during the observed period and TSI index implies no comparative advantage for wood pulp trade in Slovakia. A significant intra-industry trade is also characteristic for this commodity (GL in 2012 = 95.37). On the other hand, Slovakia shows comparative advantage in trading paper and paperboard products with high specialisation in certain paper grades and intra-industry trade.

Tables 4-7 illustrate the competitiveness of the V4 countries for individual products and product groups in the period 2003-2012. Results are mainly discussed on the basis of the analysis of two main indicators – RCA (RSCA) and RC. Table 4 provides an overview of competitiveness indicators for coniferous sawnwood in V4 countries. Results indicate revealed comparative advantage for Slovakia and Czech Republic on one hand and disadvantage for Poland and Hungary on the other hand. RSCA values did not vary significantly and showed slightly increasing trend for the countries with comparative advantage and decreasing trend for the countries with comparative disadvantage. The Czech Republic was gradually gaining comparative advantage in coniferous sawnwood trade and reached the maximum in 2008 and 2009 (RSCA = 0.33), when many large and traditional exporters were losing their position due to the global economic crisis. Owing to low resource endowments, Hungary experienced high degree of revealed comparative disadvantage during the analysed period with the greatest RSCA value of -0.93 in 2012. Compared to other analysed countries, low exported volumes and a high import dependence of Hungary are also confirmed by the development of RC values (RC = -2.70 in 2012). Finally, Poland showed net competitive advantage till 2008, but owing to increasing imports it turned to disadvantage later on (RC = -0.37 in 2012).

Table 5 illustrates the development of competitiveness indicators for non-coniferous sawnwood in V4 countries. RCA index development indicates that Slovakia and Hungary have comparative advantage and Czech Republic and Poland (after 2007 onwards) comparative disadvantage in non-coniferous sawnwood trade. Slovakia is the country with the greatest comparative advantage within the V4 countries reaching the maximum in 2012 (RSCA = 0.51). The analysis also clearly shows that revealed comparative advantages reflect resource endowments of the respective countries (prevailing broadleaved forests). A clear trend towards increasing comparative advantage was also recorded for Hungary, when the RSCA value changed by 75 % during the analysed period.

Competitiveness indicators for wood based panel trade in V4 countries are shown in Table 6. Poland, as a typical wood based panel producer, is the country with the greatest revealed comparative advantage with the trend of values following the economic cycle when RSCA reached its maximum in 2003 (0.53), declined to 0.38 during the economic crisis in 2009 and started to increase with the recovery of economy (0.41 in

Table 4 Competitiveness indicators for coniferous sawnwood for V4 countries in 2003-2012
Tablica 4. Indikatori kompetitivnosti piljenog drva četinjača za zemlje V4 u razdoblju 2003. – 2012.

Year *God.*	**RCA**				**RSCA**				**RC**			
	SK	PL	CZ	H	SK	PL	CZ	H	SK	PL	CZ	H
2003	1.65	0.75	1.87	0.09	0.24	-0.14	0.30	-0.84	2.44	1.38	1.76	-2.69
2004	1.01	0.57	1.76	0.08	0.00	-0.27	0.28	-0.85	2.19	1.00	1.81	-2.59
2005	1.67	0.43	1.73	0.08	0.25	-0.40	0.27	-0.85	2.27	0.31	1.47	-2.44
2006	1.75	0.45	1.75	0.09	0.27	-0.38	0.27	-0.84	1.88	0.36	1.66	-2.35
2007	1.55	0.50	1.80	0.04	0.22	-0.33	0.29	-0.92	1.09	0.03	1.67	-3.10
2008	1.88	0.42	1.99	0.07	0.30	-0.41	0.33	-0.87	1.55	-0.42	1.49	-2.49
2009	1.46	0.43	2.01	0.04	0.19	-0.39	0.33	-0.92	1.52	-0.32	1.49	-3.00
2010	1.81	0.46	1.88	0.05	0.29	-0.37	0.31	-0.91	0.65	-0.18	1.43	-2.61
2011	1.87	0.43	1.70	0.05	0.30	-0.39	0.26	-0.91	1.18	-0.51	1.21	-2.48
2012	1.38	0.43	1.74	0.03	0.16	-0.40	0.27	-0.93	0.91	-0.37	1.02	-2.70

RCA – Revealed Comparative Advantage Index / *indeks ustanovljene komparativne prednosti*; RSCA – Symmetric Revealed Comparative Advantage Index / *simetrični indeks ustanovljene komparativne prednosti*; RC – Revealed Competitiveness / *ustanovljena konkurentnost*

2012). Slovakia showed an increasing trend in revealed comparative advantage until 2008 (RSCA = 0.32), while with the start of the economic crisis these values started to decline and turned into comparative disadvantage in 2012 (RSCA = -0.01). However, when imports are considered, it can be mentioned that negative RC values of Slovakia in certain years (2009 onwards) meant no trade competitiveness (e.g. RC in 2011 = -0.51). The Czech Republic is also a country with comparative advantage in panel trade, while trade disadvantage was recorded in Hungary.

Table 7 shows values of competitiveness indicators for wood pulp trade in V4 countries. All analysed countries had comparative disadvantage in pulp wood trade when RSCA was ranging from -1.0 for Hungary to -0.01 for the Czech Republic in 2006. In general, comparative disadvantages and thus RSCA values were increasing in the periods of economic growth and vice

Table 5 Competitiveness indicators for non-coniferous sawnwood for V4 countries in 2003-2012
Tablica 5. Indikatori kompetitivnosti piljenog drva osim četinjača za zemlje V4 u razdoblju 2003. – 2012.

Year *God.*	**RCA**				**RSCA**				**RC**			
	SK	PL	CZ	H	SK	PL	CZ	H	SK	PL	CZ	H
2003	2.59	1.49	0.32	1.40	0.44	0.20	-0.52	0.16	2.43	0.62	-0.71	1.48
2004	1.92	1.20	0.30	1.22	0.31	0.09	-0.54	0.10	2.25	0.35	-0.81	1.29
2005	2.21	1.09	0.27	0.99	0.38	0.04	-0.57	0.00	2.00	0.10	-1.02	1.07
2006	2.08	1.06	0.31	0.98	0.35	0.03	-0.52	-0.01	2.06	-0.02	-0.81	1.17
2007	1.87	0.92	0.23	1.11	0.30	-0.04	-0.63	0.05	1.81	-0.16	-1.17	1.27
2008	2.06	0.93	0.37	1.27	0.35	-0.03	-0.46	0.12	1.86	-0.19	-0.89	1.38
2009	1.91	0.72	0.92	1.28	0.31	-0.16	-0.04	0.12	0.88	-0.30	-0.42	1.42
2010	2.36	0.85	0.61	1.25	0.40	-0.08	-0.25	0.11	1.61	-0.05	-0.40	0.91
2011	1.24	0.79	0.58	1.59	0.11	-0.12	-0.27	0.23	0.90	-0.21	-0.10	0.76
2012	3.07	0.77	0.49	1.76	0.51	-0.13	-0.35	0.28	0.61	-0.17	-0.34	1.14

RCA – Revealed Comparative Advantage Index / *indeks ustanovljene komparativne prednosti*; RSCA – Symmetric Revealed Comparative Advantage Index / *simetrični indeks ustanovljene komparativne prednosti*; RC – Revealed Competitiveness / *ustanovljena konkurentnost*

Table 6 Competitiveness indicators for wood based panels for V4 countries in 2003-2012
Tablica 6. Indikatori kompetitivnosti ploča na bazi drva za zemlje V4 u razdoblju 2003. – 2012.

Year *God.*	**RCA**				**RSCA**				**RC**			
	SK	PL	CZ	H	SK	PL	CZ	H	SK	PL	CZ	H
2003	1.42	3.29	1.18	0.83	0.17	0.53	0.08	-0.09	-0.19	0.76	0.11	-0.30
2004	1.40	2.93	1.12	0.67	0.17	0.49	0.06	-0.20	0.04	0.61	0.17	-0.16
2005	1.81	2.97	1.12	0.87	0.29	0.50	0.06	-0.07	0.05	0.55	0.15	-0.07
2006	1.55	2.88	1.30	0.84	0.22	0.49	0.13	-0.09	-0.18	0.43	0.26	-0.20
2007	1.47	2.34	1.31	0.83	0.19	0.40	0.14	-0.09	-0.36	0.23	0.16	-0.30
2008	1.96	2.52	1.37	1.12	0.32	0.43	0.16	0.06	0.03	0.28	0.08	-0.05
2009	1.15	2.23	1.51	0.96	0.07	0.38	0.20	-0.02	-0.46	0.26	0.46	-0.20
2010	1.40	2.37	1.33	0.99	0.17	0.41	0.14	-0.01	-0.36	0.26	0.35	0.03
2011	0.99	2.38	1.68	0.87	0.00	0.41	0.25	-0.07	-0.51	0.34	0.45	-0.13
2012	0.99	2.40	1.27	0.79	-0.01	0.41	0.12	-0.11	-0.39	0.50	0.20	-0.16

RCA – Revealed Comparative Advantage Index / *indeks ustanovljene komparativne prednosti*; RSCA – Symmetric Revealed Comparative Advantage Index / *simetrični indeks ustanovljene komparativne prednosti*; RC – Revealed Competitiveness / *ustanovljena konkurentnost*

Table 7 Competitiveness indicators for wood pulp for V4 countries in 2003-2012
Tablica 7. Indikatori kompetitivnosti drvne pulpe za zemlje V4 u razdoblju 2003. – 2012.

Year *God.*	**RCA**				**RSCA**				**RC**			
	SK	PL	CZ	H	SK	PL	CZ	H	SK	PL	CZ	H
2003	0.84	0.12	1.10	0.00	-0.09	-0.79	0.05	-0.99	-0.05	-2.24	0.51	-5.44
2004	0.70	0.12	1.05	0.00	-0.17	-0.79	0.02	-1.00	-0.11	-2.21	0.69	-7.32
2005	0.73	0.11	1.05	0.00	-0.15	-0.80	0.02	-1.00	-0.09	-2.29	0.51	-
2006	0.57	0.07	0.97	0.00	-0.27	-0.86	-0.01	-1.00	-0.03	-2.68	0.52	-5.79
2007	0.65	0.04	0.84	0.00	-0.21	-0.92	-0.09	-1.00	-0.20	-3.06	0.48	-5.84
2008	0.61	0.04	0.80	0.00	-0.24	-0.92	-0.11	-1.00	-0.35	-3.17	0.52	-
2009	0.61	0.05	0.95	0.00	-0.24	-0.91	-0.03	-1.00	-0.35	-3.22	0.63	-
2010	0.81	0.07	0.91	0.00	-0.11	-0.88	-0.05	-1.00	-0.22	-2.88	0.67	-7.95
2011	0.68	0.07	0.70	0.02	-0.19	-0.87	-0.17	-0.97	-0.35	-2.79	0.66	-3.02
2012	0.79	0.03	0.76	0.02	-0.11	-0.94	-0.14	-0.96	-0.09	-3.64	0.66	-2.69

RCA – Revealed Comparative Advantage Index / *indeks ustanovljene komparativne prednosti*; RSCA – Symmetric Revealed Comparative Advantage Index / *simetrični indeks ustanovljene komparativne prednosti*; RC – Revealed Competitiveness / *ustanovljena konkurentnost*

Table 8 Competitiveness indicators for paper and paperboard for V4 countries in 2003-2012
Tablica 8. Indikatori kompetitivnosti papira i kartona za zemlje V4 u razdoblju 2003. – 2012.

Year *God.*	**RCA**				**RSCA**				**RC**			
	SK	PL	CZ	H	SK	PL	CZ	H	SK	PL	CZ	H
2003	1.55	1.53	0.85	0.51	0.22	0.21	-0.08	-0.33	0.27	-0.17	-0.32	-0.67
2004	1.84	1.36	0.79	0.64	0.30	0.15	-0.12	-0.22	0.47	-0.32	-0.44	-0.54
2005	1.85	1.34	0.87	0.62	0.30	0.15	-0.07	-0.23	0.62	-0.34	-0.37	-0.48
2006	1.87	1.34	0.84	1.05	0.30	0.15	-0.09	0.02	0.65	-0.42	-0.39	-0.04
2007	1.97	1.35	0.82	0.75	0.33	0.15	-0.10	-0.14	0.61	-0.40	-0.37	-0.54
2008	1.53	1.26	0.84	0.59	0.21	0.11	-0.08	-0.26	0.42	-0.38	-0.44	-0.76
2009	1.74	1.33	0.78	0.75	0.27	0.14	-0.12	-0.14	0.57	-0.40	-0.54	-0.66
2010	2.64	1.58	0.79	0.82	0.45	0.23	-0.12	-0.10	0.67	-0.33	-0.48	-0.44
2011	1.28	1.75	0.85	0.90	0.12	0.27	-0.08	-0.05	0.22	-0.29	-0.36	-0.40
2012	1.33	1.88	0.83	0.95	0.14	0.30	-0.09	-0.03	0.23	-0.30	-0.35	-0.37

RCA – Revealed Comparative Advantage Index / *indeks ustanovljene komparativne prednosti*; RSCA – Symmetric Revealed Comparative Advantage Index / *simetrični indeks ustanovljene komparativne prednosti*; RC – Revealed Competitiveness / *ustanovljena konkurentnost*

versa decreasing in the period of economic crisis. When Vollrath's index was used to analyse competitiveness, only the Czech Republic's RC index reached positive values indicating net competitive advantage. This is in line with the development of foreign trade when wood pulp exports were growing while imports declined.

Table 8 presents values of competitiveness indicators for paper and paperboard trade in V4 countries. In general, Slovakia and Poland have comparative advantage in paper trade. The trend of RSCA values for Poland was following the economic development and thus was declining in the years of economic crisis. On the other hand, Slovakia's comparative advantage increased in 2010 when RSCA was 0.45. Slovakia is also the only country holding its trade advantage, even if the imports of paper products take into consideration the fact that, when due to quick recovery of exports of office paper and declining imports in 2010, the value of RC was 0.67.

4 CONCLUSION
4. ZAKLJUČAK

Competitiveness is the ability to face competition results in selling products that meet demand requirements ensuring profits. At the national level, it helps to develop export and maintain and expand the incomes of people over the longer term. Trade performance indicators calculated for Slovakia show that the country has a comparative advantage in the trade of coniferous sawnwood, non-coniferous sawnwood and paper and paperboard products, while there is a comparative disadvantage in trade with wood based panels and wood pulp. The indicated comparative advantages for both sawnwood product groups were declining during the observed period followed by the increasing development of intra-industry trade specialisation. The highest degree of intra-industry specialisation is, however, in the trade of other higher added value wood products – wood based panels, wood pulp and paper and paperboard products due to specialised production in the country. Contrary to trade performance indicators, the calculated RCA indicator revealed a low comparative advantage also in wood based panel trade of Slovakia. In comparison with the group of V4 countries, the Slovak Republic is the country that has comparative advantage in most of the analysed products, while Hungary has revealed advantage only in non-coniferous sawnwood trade. In case of trade of certain products (non-coniferous sawnwood), the revealed comparative advantages pointed out the connection to countries' resource endowments. On the other hand, the values of competitiveness indicators, as well as intensity of comparative advantages in the trade of certain wood products followed the economic development of countries.

Acknowledgements - Zahvala

The authors are grateful for the support of the Scientific Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic, and the Slovak Academy of Sciences, Grant No. 1/0385/13, "Modelling substitution changes in timber market under the increasing demand for renewable energy sources," and Grant No. 1/0387/13, "A comprehensive model of wood chain comparative advantages."

5 REFERENCES
5. LITERATURA

1. Balassa, B., 1965: Trade Liberalisation and 'Revealed' Comparative Advantage. The Manchester School, 119 (2): 99-123. http://dx.doi.org/10.1111/j.1467-9957.1965.tb00050.x
2. Balassa, B., 1966: Tariff Reductions and Trade in Manufactures among Industrial Countries. American Economic Review, 56: 466-473.
3. Carvalho, K. H. A. *et al*., 2009: Competitiveness of Brazilian Wood Pulp in the International Market. Cerne, 15 (4): 383-390.
4. Dieter, M.; Englert, H., 2007: Competitiveness in the Global Forest Industry Sector: an Empirical Study with Special Emphasis on Germany. European Journal of Forest Research, 126 (3): 401-412. http://dx.doi.org/10.1007/s10342-006-0159-x
5. Gonuguntla, S., 2007: New Zealand Forestry - An Analysis of Comparative Advantage. New Zealand Journal of Forestry, 51 (4): 21-27.
6. Gries, T.; Hentschel, C., 1994: Internationale Wettbewerbsfähigkeit: Was ist das? Wirtschaftsdienst, (7): 416-422.
7. Grubel, H. G.; Lloyd, P. J., 1975: Intra-Industry Trade: The Theory and Measurement of International Trade in Differentiated Products. The Economic Journal, 85 (339): 646. http://dx.doi.org/10.2307/2230917
8. Jansik, C.; Irz, X.; Kuosmanen, N., 2014: Competitiveness of Northern European Dairy Chaos. Helsinky: MTT Economic Research, Agrifood Research Finland.
9. Kagochi, J. M., 2007: Evaluating the Competitiveness of US Agricultural Market Commodities www.oeko.de/oekodoc/596/2007-142-en.pdf (accessed 17.7.2014)
10. Kaputa, V., 2013: Trh a environmentálne atribúty výrobkov z dreva. Zvolen: Technická univerzita vo Zvolene, 47 p.
11. Latruffe, L., 2010: Competitiveness, Productivity and Efficiency in the Agricultural and Agri-Food Sectors. http://dx.doi.org/10.1787/5km91nkdt6d6-en (accessed 7.7.2014)
12. Laursen, K., 1998: Revealed Comparative Advantage and the Alternatives as Measure of International Specialisation ideas.repec.org/p/aal/abbswp/98-30.html#download (accessed 7.7.2014)
13. Loučanová, E., 2004: Smerovanie invencií a inovácií v drevospracujúcom priemysle. Marketing a obchod. Zvolen, pp. 156-159.
14. Mäkelä, T., 2009: The Russian Forest Industry: A Case Of Competitiveness And Export Taxes epub.lib.aalto.fi/fi/ethesis/pdf/12057/hse_ethesis_12057.pdf (accessed 7.7.2014)
15. Noor, A. Z.; Roda, J. M.; Ahmad, F. P., 2008: Research Report on the Evaluation on Malaysian Wood Products to Europe – a Comparative Advantage Perspective in Regards of Recent Evaluations in European Forest Sector halshs.archives-ouvertes.fr/docs/00/34/41/88/PDF/Report_on_the_evaluation_ on_Malaysian_wood_products_to_Europe_a_comparative_advantage_perspective_in_regards_of_recent_evaluations_in_European_forest_sector_pdf.pdf (accessed 7.7.2014)
16. Oblak, L.; Glavonjić, B., 2014: A Model for the Evaluation of Radio Advertisements for the sale of Timber Products. Drvna industrija, 65 (4): 303-308.
17. Ohlin, B., 1993: Interregional and International Trade. Cambridge: Harvard University Press.
18. Ojurović, R.; Moro, M.; Šegotić, K.; Grladinović, T.; Oblak, L., 2013. Analysis of the investment in wood processing and furniture manufacturing entities by key factors of competitiveness. Drvna industrija, 64 (2): 131-137.
19. Paluš, H.; Kaputa, V., 2009: Survey of Attitudes towards Forest and Chain of Custody Certification in the Slovak Republic. Drewno, 52 (182): 65-81.
20. Paluš, H.; Parobek, J., 2013: Changing Patterns of Roundwood Deliveries in Slovakia. Markets for Wood and Wooden Products. WoodEMA Zagreb, pp. 77-94.
21. Porter, E. M., 1990: The Competitive Advantage of Nations. New York.
22. Prasad, R. N., 2004: Fiji's Export Competitiveness: A Comparison with Selected Small Island Developing States. rbf.gov.fj/docs/2004~06%20WP.pdf (accessed 7.7.2014)
23. Ricardo, D., 1911: Principles of Political Economy and Taxation. London.
24. Song, M.; Gazo, R., 2013: Competitiveness of US Household and Office Furniture Industry. International Journal of Economics and Management Engineering, 3 (2): 47-55.
25. Šupín, M., 2011: The Measurement of Globalization Influence on Pulp and Paper Products International Trade Flows in Slovakia. Intercathedra, 27 (1): 401-412.
26. Vollrath, T. L., 1991: A Theoretical Evaluation of Alternative Trade Intensity Measures of Revealed comparative advantage. Weltwirtschaftliches Archiv, (127): 265-279. http://dx.doi.org/10.1007/BF02707986
27. Wanat, L.; Lis, W., 2012: International competitiveness of the Polish wood industry from the mesoeconomic perspective. Transfer inovácií, 23: 7-12.
28. Wolff, F.; Schmitt, K.; Hochfeld, Ch., 2007: Competitiveness. Innovation and Sustainability – Clarifying the Concepts and Their Interrelations. www.oeko.de/oekodoc/596/2007-142-en.pdf (accessed 7.7.2014)
29. Zhang, J.; Ebbers, H.; Mulder, R., 2012: Competitiveness of Chinese Industries - A Comparison with the EU. Review of European Studies, 4 (1): 203-209. http://dx.doi.org/10.5539/res.v4n1p203
30. *** FAOSTAT 2014a: Forest Products Definitions http://faostat.fao.org/Portals/_Faostat/ documents/pdf/FAOSTAT-Forestry-def-e.pdf (accessed 17.7.2014)
31. *** FAOSTAT 2014b: Forestry Production and Trade faostat3.fao.org/faostat-gateway/go/to/download/F/FO/E (accessed 17.7.2014)
32. *** UN 2014: Comtrade Database http://comtrade.un.org (accessed 17.7.2014)

Corresponding address:

Assoc. prof. HUBERT PALUŠ, Ph.D.

Technical University in Zvolen
Faculty of Wood Sciences and Technology
T. G. Masaryka 24
960 53 Zvolen, SLOVAKIA
e-mail: palus@tuzvo.sk

LABORATORY
FOR HYDROTHERMAL PROCESSING OF WOOD AND WOODEN MATERIALS

1860

SVEUČILIŠTE U ZAGREBU

1669

ŠUMARSKI FAKULTET

Testing of hydrothermal processes of wood and wooden materials

Thermography measurement in hydrothermal processes

Standard and nonstandard determination of moisture content in wood

Determination of climate and microclimate conditions in air drying and storage of wood, organization of lumber storage

Project and development of conventional and unconventional drying systems

Steaming chamber projects

Establishing and modification of kiln drying schedules

Consulting in selection of kiln drying technology

Introduction of drying quality standards

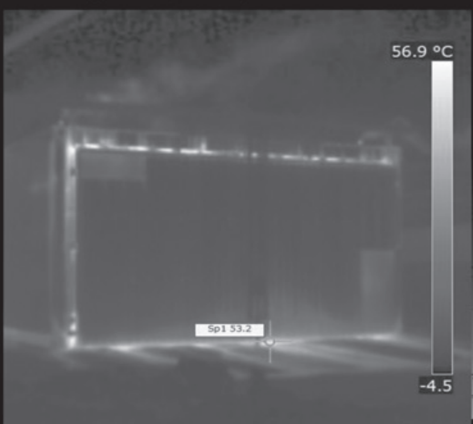
Determination of wood bending parameters

Detection and reducing of hydrothermal processes wood defects

Reducing of kiln drying time

Drying costs calculation

Kiln dryer capacity calculation



ZAGREB UNIVERSITY
FACULTY OF FORESTRY
WOOD SCIENCE AND TECHNOLOGY DEPARTMENT
Svetošimunska c. 25, p.p. 422
HR-10002 ZAGREB
CROATIA

385 1 235 2509 tel
385 1 235 2544 fax
hidralab@sumfak.hr
pervan@sumfak.hr
www.sumfak.hr

Rafael Rodolfo de Melo[1], *Cláudio Henrique Soares Del Menezzi*[2]

Influence of Adhesive Type on the Properties of LVL Made from Paricá (*Schizolobium amazonicum Huber* ex. Ducke) Plantation Trees

Utjecaj tipa ljepila na svojstva LVL ploča izrađenih od plantažnog drva paricá (*Schizolobium amazonicum* Huber ex. Ducke)

Original scientific paper • Izvorni znanstveni rad
Received – prispjelo: 18. 11. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*824.3; 630*833.0; 674.031.738*
doi:10.5552/drind.2015.1438

ABSTRACT • *The work aimed at evaluating the influence of the adhesives on physical and mechanical properties of laminated veneer lumber (LVL) boards made from* Schizolobium amazonicum *plantation trees. This species is native from Amazonia and it is showing fast growing and low density. LVL was produced in three different treatment groups considering the type of adhesive used (Polyvinyl Acetate Crosslinking – PVAc, phenol-formaldehyde – PF and polyurethane – PU). For each treatment, pieces with dimensions of 25 cm x 2.2 cm x 50 cm were produced. The following mechanical and physical properties were then evaluated: static bending modulus of elasticity (E_M), modulus of rupture (f_M), compression strength parallel to grain ($f_{c,0}$), shear strength parallel to glue-line ($f_{v,0}$), shear strength perpendicular to glue-line ($f_{v,90}$), water absorption and thickness swelling for 2 and 24 h of water immersion. The adhesives used in this study significantly influenced the performance of LVL. Polyurethane adhesive presented better results with respect to physical properties. Phenol-formaldehyde provided greater resistance among the adhesives tested.*

Key words: *Wood products, Lumber, Adhesive, Polyvinyl Acetate Crosslinking, Polyurethane, Phenol-Formaldehyde.*

SAŽETAK • *Rad je usmjeren na vrednovanje utjecaja ljepila na fizikalna i mehanička svojstva lameliranih furnirskih ploča (LVL) izrađenih od drva* Schizolobium amazonicum *iz plantažnog uzgoja. Vrsta potječe iz Amazone i ima svojstva brzog rasta i male gustoće drva. LVL ploče proizvedene su primjenom triju vrsta ljepila (polivinil acetatnoga - PVAc, fenol-formaldehidnoga - PF i poliuretanskog ljepila - PU). Dimenzije proizvedenih ploča bile su 25 cm x 2,2 cm x 50 cm. Određivana su ova mehanička i fizikalna svojstva: statički modul elastičnosti pri savi-*

[1] Author is professor at Federal University of Mato Grosso, Institute of Agricultural and Environmental Sciences, Sinop, MT, Brazil. [2]Author is professor at Universisty of Brasília, Faculty of Technology, Brasília, DF, Brazil.
[1] Autor je profesor Saveznog sveučilišta Mato Grosso, Institut poljoprivrednih znanosti i znanosti o okolišu, Sinop, MT, Brazil. [2]Autor je profesor Sveučilišta Brasília, Tehnološki fakultet, Brasília, DF, Brazil.

janju (E_M), modul loma (f_M), čvrstoća na tlak paralelno s vlakancima ($f_{c,0}$), smična čvrstoća paralelno s linijom lijepljenja ($f_{v,0}$), smična čvrstoća okomito na liniju lijepljenja ($f_{v,90}$), apsorpcija vode i debljinsko bubrenje nakon 2 i 24 sata potapanja uzoraka u vodi. Istraživanje je pokazalo da ljepilo upotrijebljeno za izradu LVL ploče znatno utječe na njezina svojstva. Poliuretansko ljepilo utjecalo je na bolja fizikalna svojstva, a fenol-formaldehidno ljepilo pokazalo se najotpornijim među istraživanim ljepilima.

Ključne riječi: *proizvodi od drva, drvo, polivinil acetatno ljepilo, poliuretansko ljepilo, fenol-formaldehidno ljepilo*

1 INTRODUCTION
1. UVOD

The selection of an ideal adhesive to produce structural wood composites depends on different aspects; highlighted among them are the costs, the use of the product, exposure conditions, production method, technology and devices available, the use of treatments and the dimensions and shape of the product (Kurt, 2010). The characteristics of adhesives used in LVL (laminated veneer lumber) production have an important role in the quality of the final product, which can be established based on physical and mechanical properties of the boards. Therefore, the use of a proper adhesive should allow acceptable properties suitable for future use of the panels (Uysal, 2005).

Traditionally, structural wood adhesives are synthetic resins with conditions to promote high durability, resistance and rigidity to structural components produced. The most used resins in LVL production for external use are phenolics, including phenol-formaldehyde and on a smaller scale, resorcinol-formaldehyde (Kol *et al*., 2010). These adhesives are highlighted because of properties such as high humidity resistance, durability and resistance to microorganism attack that enable more durable final products.

The use of non-phenolic adhesives for LVL production is fundamental, mainly for components with semi-structural or non-structural application. In this way, the improvement of adhesives is already provided, as well as the development of new adhesives made considering the application to products that will be used in dry or humid environments. This aspect enables, for example, the manufacturing of products specific for interior or external use with a satisfactory quality and lower cost, since the use of a resin with high humidity resistance that generally costs more is unnecessary for these applications (Uysal, 2005). In this class, the most commonly used adhesives for LVL production are urea-formaldehyde, melanin-urea-formaldehyde (Çolak *et al*., 2004; Kurt, 2010), polyvinyl acetate crosslinking (PVAc) and resins based on polyurethanes (Kilic *et al*., 2006; Kiliç, 2011).

Another relevant aspect to choosing the type of adhesive is the requirement of high temperature for maturing. Hot gluing, necessary for phenol-formaldehyde and urea-formaldehyde adhesives, involves additional costs for board production but accelerates maturing time. Cold gluing (room temperature) used for resorcinol-formaldehyde, polyurethane and PVAc has been used at the industrial level to produce structural components with satisfactory results (Renzo, 2008). Among the main resins used for structural component production, phenol-formaldehyde, and particularly resorcinol-formaldehyde and urea-formaldehyde, have several restrictions on use because of formaldehyde release, even after the adhesive dried (Çolak *et al*., 2004).

A range of PVA based glues can be formulated to fit the requirements and specifications of many products. The use of PVAc in LVL had good results in studies of Aydin *et al*. (2004) and Shukla and Kamdem (2008). According to Kim and Kim (2006), there is an increasing interest in the use of PVAc adhesive because of health risks associated to adhesives that contain formaldehyde. Polyurethane adhesive (PU) is formaldehyde-free. It can be found as a mono- or bi-component adhesive, and can be formulated for achieving satisfactory performance related to maturing speed, type of substrate, moisture resistance and mechanical stress. Studies carried out by Kilic (2006), Kiliç (2011) and Bal and Bektas (2012) highlighted good performances of LVL produced with polyurethane-based resins.

This study evaluated the influence of the type of adhesive on physical and mechanical properties of LVL made from paricá (*Schizolobium amazonicum* Huber ex. Ducke).

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

2.1 Veneer production
2.1. Izrada furnira

Paricá veneers (*Schizolobium amazonicum)* of 2.71 mm x 85 cm x 115 cm in thickness, width and length, obtained from PORTIL® - Portas Itinga Limitada and Rio Concrem Industrial Limitada®, both from Dom Eliseu city, Pará State, were used in this study. Further information about veneer production and yield can be obtained in Melo *et al.* (2014). Fifty 5-7-year-old *Schizolobium amazonicum* Huber ex. Ducke (Leguminosae - Caesalpinioideae) trees were harvested and 170-cm length logs were produced and randomly selected in the yard of a plywood facility located in Northern Brazil. The selected logs were peeled within 72 hours after harvesting, and therefore they were still in wet condition.

The veneers without defects were selected, taken to the laboratory and resized into samples of 2.71 mm x 25 cm x 50 cm. The samples were then acclimated, and mass and dimensions were measured for later calculation of apparent specific mass. At this step, wave propagation speed was also obtained using a Stress

Wave Timer device, which was used in conjunction with specific mass (ρ) results, to determine the dynamic modulus of elasticity (E_{md}).

2.2 Adhesive used
2.2. Primijenjena ljepila

The specifications and features of each resin used for LVL production are described as follows:

Polyvinyl acetate crosslinking (PVAc), bicomponent of Multibond X-080, with catalyzer TSA from *Franklin International®*. The properties observed for this resin were: solid content of 52 %, pH 4.5 and viscosity of 4500 cP, according to the specifications of the producer.

CR-070 Phenol-formaldehyde (PF) was used, formulated in the ratio of 100:5:8:7 of resin, wheat flour, coconut flour and water, according to the specifications of the producer *SI Group Crios ®*. The viscosity observed for the mixture was approximately 840 cP, measured at room temperature with a digital viscometer (spindle #27), pH 11.4 obtained using a pH meter and solid content of 59 %.

Polyurethane based resin (PU) used was Cascola PU, monocomponent from Henkel®, according to the producer ideal for gluing in external areas, as it is waterproof and resistant to different weather conditions and temperatures. According to the producer, resin viscosity is 6000 cP, pH 7.0 and solid content 100 %.

2.3 Manufacturing of panels and sample preparation
2.3. Proizvodnja ploča i izrada uzoraka

LVL was produced in three different treatment groups considering the type of adhesive used (polyvinyl acetate crosslinking, phenol-formaldehyde and polyurethane). For each treatment, pieces with dimensions of 25 cm x 2.2 cm x 50 cm (width x thickness x length) were produced into x-layers LVL. To reduce the variability of properties, boards were assembled through resistance classes according to their E_{md}, with veneers with higher E_{md} at the outer layers, their values decreasing towards the center layer (more resistant veneers at the face and less resistant veneers at the core). The veneer selection within each class for panel assembly was random.

All adhesives used in the experiment were manually applied using a spatula with a gramature of 200 g/m^2. For pressing, a pressure of 1.0 N/mm^2 was used. LVL produced with PVAc and PU was pressed with a hydraulic presser at room temperature for 12 hours. In the case of PF a cold pre-pressing was made, aided by concrete blocks for 30 minutes following adhesive application. The LVL were then taken to the hydraulic presser and pressed for 12 hours at 140 °C.

2.4 Determination of properties
2.4. Određivanje svojstava ploča

For the evaluation of physical properties (specific mass, moisture content, water absorption, thickness swelling and residual swelling) of LVL made from paricá, the recommendations of the ASTM D 1037 standard procedure (1999) were used. Twenty eight samples of wood were used per treatment, with the dimensions of 2.2 cm x 2.2 cm x 10 cm. The samples were acclimated at temperature of 20 °C ±2 and 65 % ±5 relative humidity, until constant mass was achieved and dimensions and mass could be measured. Following this, specimens were submerged in water and mass and dimensions were measured after 2, 24 and 96 hours following immersion. At the end of the trial, the samples were again taken to the climate chamber, where dimensions and mass were stabilized and these parameters re-measured.

Mechanical tests were carried out according to recommendations of the ASTM D 5456 standard procedures (2006). Two positions for bending resistance - *flatwise* and *edgewise*, were evaluated. Twenty one samples were used per treatment and per position in the dimensions of 2.2 cm x 2.2 cm x 40 cm. The load was applied at the speed of approximately 2.5 mm/min. The spacing between supports was 36 cm in length.

For compression testing, 21 samples were used per treatment with dimensions of 2.2 cm x 2.2 cm x 10 cm. The specimen dimensions were determined by the maximum ratio of length/radius gyration (17 times) allowed by the standard procedure. The trial speed was 1 mm/min. Compression for the samples was determined by the force applied at the area subject to stress. For parallel (tension parallel to grain test) and perpendicular (tension perpendicular to grain test) shear stress in relation to glue line, 21 samples with dimensions of 2.2 cm x 2.2 cm x 3.3 cm and an area for the application of the shear stress were used.

2.5 Analysis of results
2.5. Analiza rezultata

The physical tests of water absorption and thickness swelling, and the mechanical trial of static bending were performed using a complete randomized design with factor arrangement. When a significant difference was detected using an F-test, the factors and their interactions were analyzed by the *Scott-Knott* test ($p > 0.05$). Other results were evaluated using ANOVA with later comparison by Tukey test ($p > 0.05$), also with a completely randomized design.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Physical properties
3.1. Fizikalna svojstva

The use of different adhesives for LVL production did not influence the specific mass of the panels (Figure 1). This can be attributed to a pre-classification of the veneers based on E_{md} and to the same amount of resin used for all treatments (200 g/m^2). The specific mass presented greater values than Iwakiri *et al.* (2010) observed for LVL made from paricá produced with different assembly strategies and glued with PF. They ranged between 0.37 g/cm^3 and 0.41 g/cm^3.

Regarding equilibrium moisture content, LVL produced with different resins were observed to be significantly different, as the use of PF promoted higher

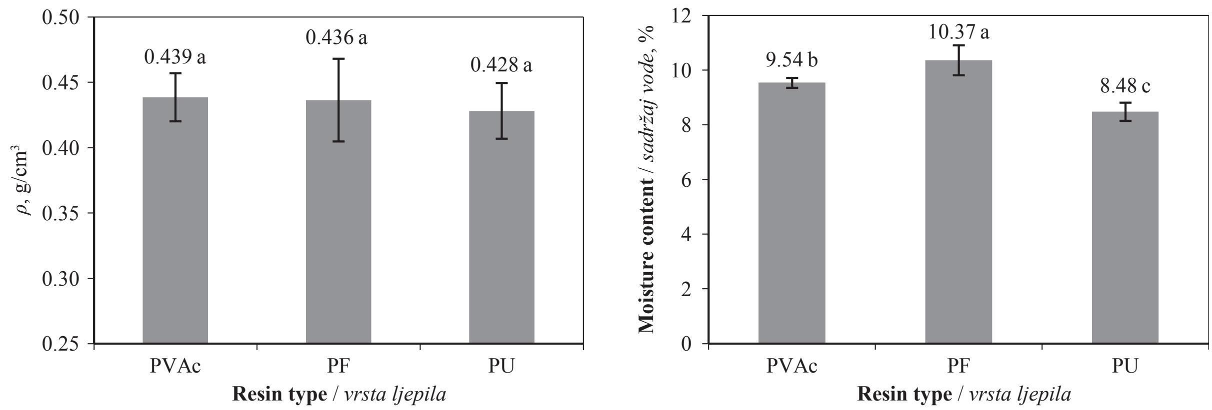


Figure 1 Density (ρ) and equilibrium moisture content observed for LVL panels produced with different adhesives
Slika 1. Gustoća (ρ) i ravnotežni sadržaj vode LVL ploča proizvedenih primjenom različitih ljepila

moisture content, followed by PVAc and finally PU. Renzo (2008) studied different adhesive formulations using resorcinol-formaldehyde (RF), tannin and castor bean-based PU and also observed that the type of resin used significantly influenced the equilibrium moisture content in LVL made from *Eucalyptus grandis*. In addition to the factors that are inherent to the wood itself, aspects related to the manufacturing processes of LVL have an influence on its equilibrium moisture content. Among them, authors mentioned that the type and amount of resin used, and time and temperature of pressing were the factors that differed between the treatments and that could have influenced the results. The same authors also mentioned that equilibrium moisture for reconstituted wood was generally lower in comparison to solid wood for the same temperature and humidity conditions.

Lower moisture content was observed for LVL glued with PU adhesive. This could be explained by the use of water by the adhesive while maturating through the reaction of its isocyanate groups with the water molecules that are present in the wood. This relates to the lower equilibrium moisture content observed in PVAc panels in comparison to PF panels, attributed to a crosslinking process between hydrogen bridges and polyvinyl resin.

For all treatments, the equilibrium moisture content observed was lower than the value from the climate chamber, pre-established at 12 %. A similar behavior was observed by Hashim *et al*. (2011) for LVL made from *Hevea brasiliensis*. This behavior is explained by different hygroscopicity between products made of wood and solid wood, because of the reduction of the wood into veneers and later the incorporation of resins, paraffin and other substances. Another aspect that contributes to hygroscopicity reduction is the use of high temperatures and pressure on the final consolidation of the LVL panels.

LVL performance in water absorption and thickness swelling tests did not present significant interactions for the evaluated factors (Table 1). This means that the type of adhesive used does not show different behavior for the evaluated times. Consequently, the data were analyzed separately.

Table 1 Summary of results of factorial analysis of water absorption (*WA*) and thickness swelling (*TS*)
Tablica 1. Sažetak faktorske analize rezultata apsorpcije vode (*WA*) i debljinskog bubrenja (*TS*)

F.V.	G.L.	*WA*	*TS*
F1: Adhesive	2	**	**
F2: Time	2	**	**
Interaction F1xF2	4	NS	NS
Residue	180		

**Significant at the 1 % level ($p<0.01$) of significance; NS Not significant ($p>0.05$) / **Značajno na razini signifikantnosti 1 % ($p<0,01$); NS nije značajno ($p>0,05$).

Better dimensional stability was observed for LVL produced with PU, followed by the LVL produced with PF (Figure 2). Renzo (2008) proved the efficiency of PU adhesive on dimensional stability for LVL, when it was observed that LVL produced with this resin resulted in a lower percentage of water absorption and thickness swelling when compared with LVL produced using tannin resin, resorcinol resin or a mixture of both. Uysal (2005) compared PU adhesive (D-VTKA) to other kinds of resins (UF, PF and PVAc) and found PF performed better, and PU had similar results to PVAc.

No stabilization of water absorption was observed for the period evaluated. When comparing types of adhesives, LVL produced using PU had lower water absorption, PVAc presented higher water absorption and boards that used PF presented intermediate results (Figure 2). Studies carried out by Uysal (2005) showed different results for LVL made from *Pinus sylvestris*, where LVL glued with PF absorbed less water compared to LVL that used PU, PVAc and urea-formaldehyde (UF).

For thickness swelling, stabilization was observed 24 hours after immersion, which can be attributed to the fibers achieving saturation point (PSF). Where there was no additional water absorption after this period, interference occurred on the dimensional stability of the component.

The use of different kinds of adhesives promoted a significant difference on residual swelling for LVL made from paricá. This was a repetition of what occurred for thickness swelling, where components that

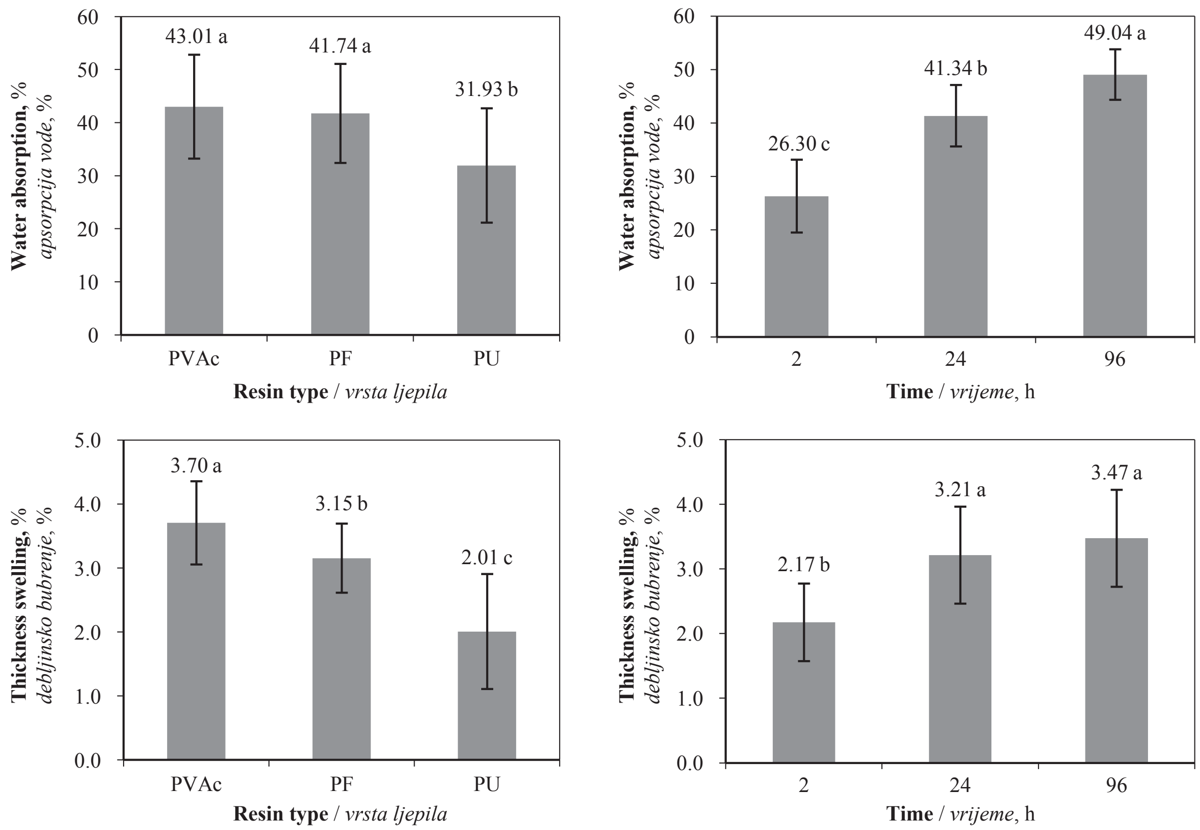


Figure 2 Influence of resin type and immersion time in water absorption and thickness swelling for panels produced with different adhesives
Slika 2. Utjecaj vrste ljepila i vremenskog trajanja potapanja uzoraka u vodi na apsorpciju vode i debljinsko bubrenje LVL ploča proizvedenih primjenom različitih ljepila

used PU presented lower residual swelling. The interrelationships between these parameters were also evidenced by Souza *et al*. (2011); this evidence confirmed a close relation among parameters of water absorption, thickness swelling and residual swelling for LVL made from different species of *Pinus*.

Residual swelling is represented by compression stress (*springback*) to which the samples were exposed during manufacturing (Figure 3). As the pressure used for LVL production was the same for all treatments (1.0 N/mm^2), the results indicate that part of this swelling effect is represented by a loss of adhesion quality that occurred due to long time in which the samples were immersed in water.

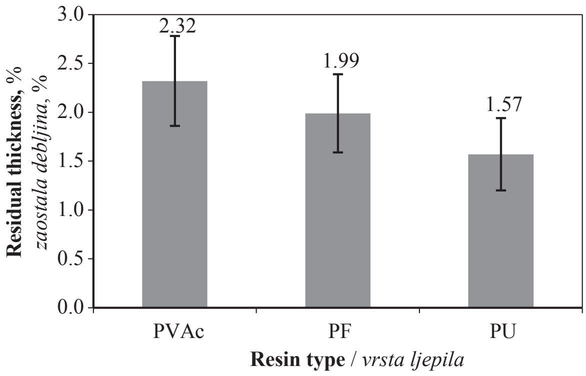


Figure 3 Residual thickness observed for panels produced with different adhesives
Slika 3. Zaostala debljina ploča proizvedenih primjenom različitih ljepila nakon potapanja u vodi

3.2 Mechanical properties
3.2. Mehanička svojstva

No significant interactions were observed for resistance and rigidity to bending of LVL from paricá between different types of adhesives (PVAc, PF and PU) and trials (*flatwise* and *edgewise*). These factors however had a significant influence on LVL performance when analyzed individually (Table 2).

Among the types of adhesives used, PF promoted the highest values for E_m, followed by PVAc. For LVL that used PU as an adhesive, it presented greater elasticity (less rigidity) (Figure 4). According to Broughton and Hutchinson (2001), this elasticity is common for products that use PU as an adhesive, because it presents a less rigid bonding line, usually in the form of foam caused by a reaction between the adhesive and wood moisture, producing CO_2.

Table 2 Summary of results of factorial analysis for elasticity modulus (E_m) and rupture modulus (f_m)
Tablica 2. Sažetak faktorske analize rezultata modula elastičnossti (E_m) i modula loma (f_m)

F.V.	G.L.	E_m	f_m
F1: Adhesive	1	**	**
F2: Type of test	2	**	**
Interaction F1xF2	2	NS	NS
Residue	120		

**Significant at the 1 % level (p<0.01) of significance; NS Not significant (p>0.05) / **Značajno na razini signifikantnosti 1 % (p<0,01); NS nije značajno (p>0,05).

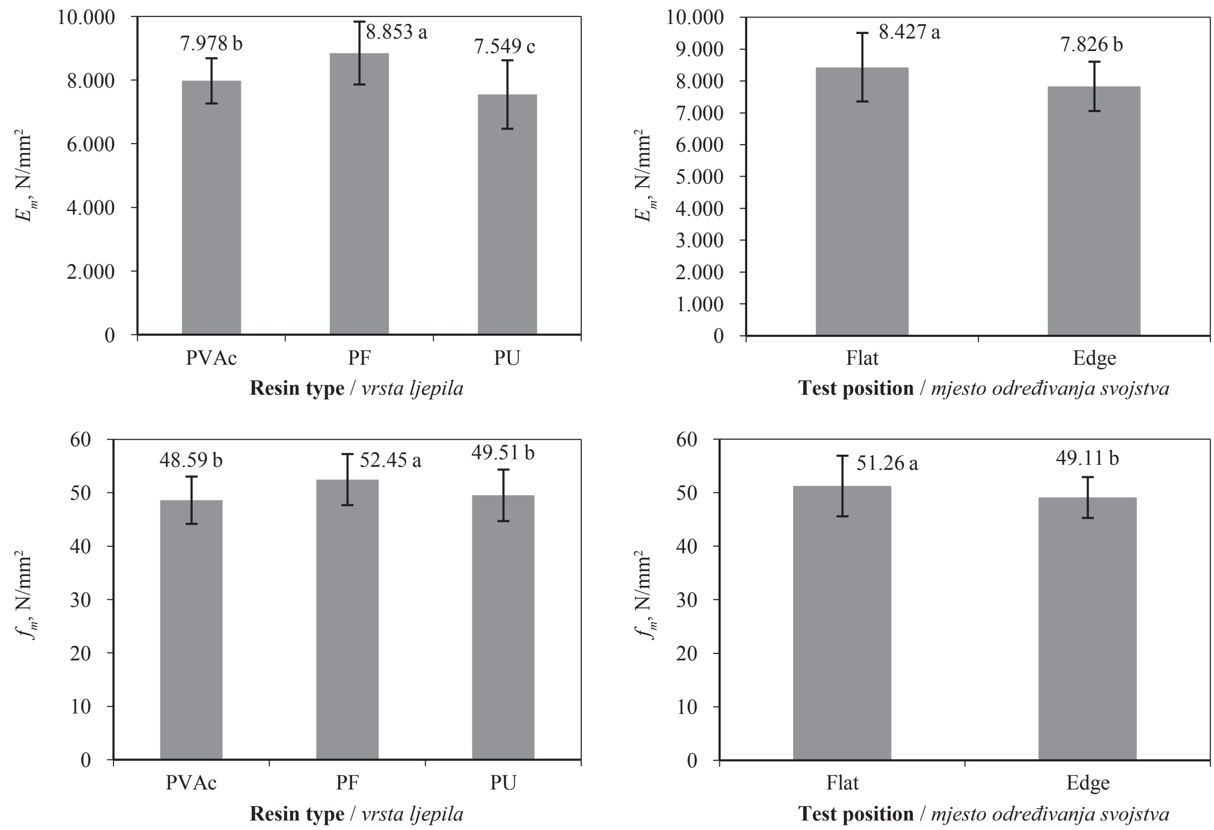


Figure 4 Values of elasticity modulus (E_m) and rupture modulus (f_m) of panels according to resin type and test position
Slika 4. Vrijednosti modula elastičnosti (E_m) i modula loma (f_m) ploča ovisno o vrsti ljepila i poziciji određivanja svojstva

Regarding the f_m parameter, PF was the type of adhesive that was observed to promote a greater bending resistance, while other adhesives presented an equivalent resistance (Figure 4). Kilic et al. (2006) observed for LVL made from *Alnus glutinosa* that the use of PVA promoted superior mechanical resistance compared to PU adhesive, but for physical water resistance the reverse was observed. However, according to the authors, these results do not regard it impossible to use PVA for structural purposes, since it can be applied to structures in an internal environment. In external areas, the use of PU would be preferred compared to PVA.

Samples in a *flatwise* trial presented a greater modulus of elasticity (E_m) and modulus of rupture (f_m) compared with the *edgewise* position (Figure 4). This result can be attributed to veneer classification and board assembly that prioritized more resistant veneers for the external layers of LVL. Horizontal laminated systems (*flatwise*) submitted to bending when more resistant veneers were positioned close to the edges, making it more efficient and resulting in a more resistant laminated component.

Iwakiri *et al*. (2010) observed that mixed LVL made from paricá (core) and *Eucalyptus saligna* (covers) had greater bending resistance for both positions of trial (*flatwise* and *edgewise*) than LVL produced exclusively from paricá veneers. According to these authors, the arrangements of veneers with a higher specific mass at the face of the LVL, where greater traction stress and compression effort occurred on static bending, were responsible for increased performance. In the same study, it was evidenced that the arrangement of more resistant veneers at the core of the panels did not contribute to increased resistance or rigidity in *flatwise* position. Müller (2009) observed similar results for mixed LVL made from *Pinus taeda* and *Eucalyptus saligna*. This occurred because in static bending trials a multi laminated element is placed on a surface supported by the ends with stress applied in the middle of the interspace, and therefore veneers closer to the surface have to support greater traction stress (inferior face) and compression effort (superior face).

LVL produced with PVAc presented superior parallel compression effort ($f_{c,0}$) compared to the ones that used PF. LVL that used PU adhesives obtained interme-

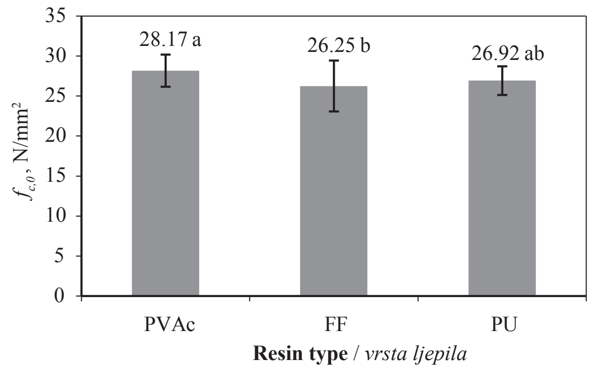


Figure 5 Compression strength ($f_{c,0}$) for panels produced with different adhesives
Slika 5. Čvrstoća na tlak ($f_{c,0}$) ploča proizvednih primjenom različitih ljepila

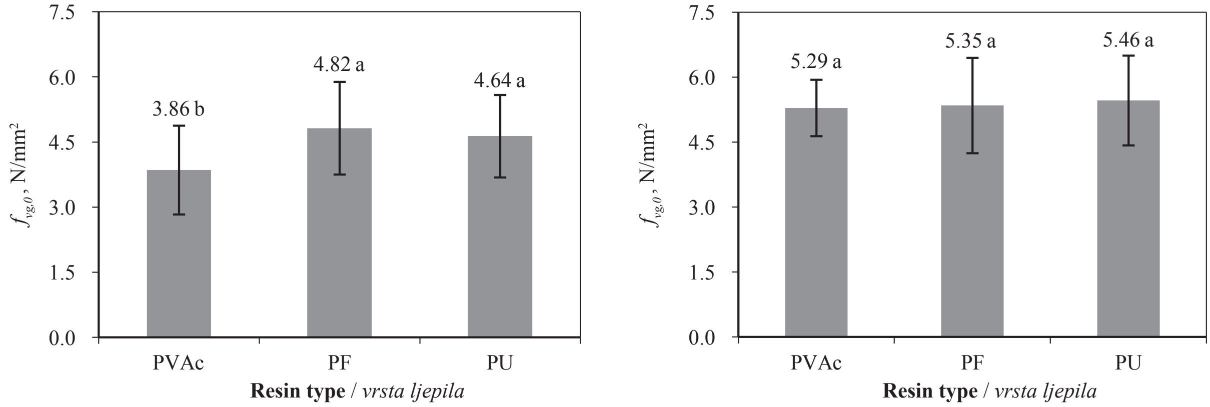


Figure 6 Shear strength parallel ($f_{vg,0}$) and perpendicular ($f_{vg,90}$) line of glue to panels produced with different adhesives
Slika 6. Smična čvrstoća paralelno ($f_{vg,0}$) i okomito ($f_{vg,90}$) na liniju lijepljenja ploča proizvedenih primjenom različitih ljepila

diate results and at the same time equivalent to the other resins (Figure 5). Similar results were observed by Kilic *et al*. (2006), who found that among the resins used to produce LVL, PVAc promoted superior results when samples were submitted to effort $f_{c,0}$. When comparing compression performance of LVL produced with tannin, resorcinol polyurethane or different compositions of these adhesives, Renzo (2008) observed greater compression effort for panels that used PU - 100 %.

Analysis of parallel shear resistance ($f_{vg,0}$) found PF and PU as resins that promoted greater resisting connections (Figure 6). These results indicate that the choice of a proper adhesive is essential to obtain a high quality glue line, which can directly affect the LVL performance for parallel shear stress. An example of this was made by Shukla and Kamden (2008), who used PVAc adhesive to produce LVL made from three different species and observed $f_{vg,0}$ in the range of 1.8-2.5 N/mm². With respect to perpendicular shear stress of the glue line ($f_{vg,90}$), as shown in Figure 6 the type of adhesive had no significant influence. This result can be attributed to homogenous samples with pre-classification of veneers more than to the type of adhesive used in this trial.

Similar results were obtained by Uysal (2005) when analyzing LVL made from *Pinus silvestris* and glued with different kinds of adhesive. He observed a greater $f_{vg,0}$ for PU adhesives, followed by PF, UF and finally PVAc. Mean values observed by the author were 5.36 N/mm² (PU), 4.89 N/mm² (PF), 4.77 N/mm² (UF) and 4.48 N/mm² (PVAc) for a boiling water resistance test. Kilic *et al*. (2006) compared shear stress parallel to glue line for LVL produced with PVA and PU and concluded that the former adhesive provided greater resistance to the panels.

The values observed for mechanical properties evaluated (E_m, f_m, $f_{c,0}$, $f_{vg,0}$, $f_{vg,90}$) for LVL made from paricá can be considered low when compared with results obtained for the same variety of LVL made by different species and glued with many types of resins (Pio, 2002; Uysal, 2005; Souza *et al.*, 2011). It is important to highlight that parallel or perpendicular shear stress does not only depend on adhesive quality but also on the characteristics of the wood used to produce the LVL. Consequently, as observed by Gungor *et al*. (2006) and Shukla and Kamden (2008), even when structural adhesives are used, low resistance values can still be obtained.

Since paricá is a wood species with a low specific mass, the young harvested tree samples (4 to 7 years) normally used for commercial veneer production presented low values of shear resistance. To obtain more resistant wood in a population, it is necessary to harvest older trees because they tend to have a higher percentage of adult wood and consequently, a greater specific mass. An example of this is given by Pio (2002), who studied properties of LVL made by veneers of *Eucalyptus grandis* of different ages (15 to 20 years) and proved that the use of veneers from older trees provided a higher performance on mechanical properties.

4 CONCLUSIONS
4. ZAKLJUČAK

Different kinds of adhesives used in this study significantly influenced the performance of physical-mechanical properties of LVL made from paricá (*Schizolobium amazonicum*). In regards to physical properties, polyurethane adhesive presented better results by having lower percentages of water absorption, thickness swelling and residual swelling. For mechanical properties, in a joint analysis of the results, phenol-formaldehyde provided greater resistance (except in compression) among the adhesives tested, because it provided better performance when submitted to bending and shear stresses.

5 REFERENCES
5. LITERATURA

1. ASTM-D-1037, 1999: Standard test methods of evaluating properties of wood-based fiber and particle panel materials. ASTM, USA.
2. ASTM-D-5456, 2006: Standard specification for evaluation of structural composite lumber products. ASTM, USA.
3. Aydin, I.; Colak, S.; Çolakoğlu, G.; Salih, E., 2004: A comparative study on some physical and mechanical properties of laminated veneer lumber (LVL) produced from Beech (*Fagus orientalis* Lipsky) and *Eucalyptus*

camaldulensis Dehn. veneers. Holz Roh-Werkst., 62 (3): 218-220. http://dx.doi.org/10.1007/s00107-004-0464-3
4. Bal, B. C.; Bektaş, I., 2012: The effects wood species, load direction, and adhesives on bending properties of laminated veneer lumber. BioResour., 7 (3): 3104-3112.
5. Broughton, J. G.; Hutchinson, A. R., 2001: Adhesive systems for structural connections in timber. Int. J. Adhes. Adhes., 21 (3): 177-186. http://dx.doi.org/10.1016/s0143-7496(00)00049-x
6. Çolak, S.; Aydin, Ü.; Demürkir, C.; Olakoúlu, G., 2004: Some technological properties of laminated veneer lumber manufactured from pine (*Pinus sylvestris* L.) veneers with melamine added - UF resins. Turk. J. Agric. For., 28 (2): 109-113.
7. Gungor, N. M.; Ayrilmis, N.; Kantay, R., 2006: Selected physical and mechanical properties of LVL made from *Pterocarya fraxinifolia* (Clam) Spach. For. Prod. J., 56 (5): 82-85.
8. Iwakiri, S.; Matos, J. L. M.; Pinto, J. A.; Viana, L. C.; Souza, M. M., 2010: Produção de painéis laminados unidirecionais - LVL com lâminas de *Schizolobium amazonicum*, *Eucalyptus saligna* e *Pinus taeda*. Cerne, 16 (4): 557-563. http://dx.doi.org/10.1590/S0104-77602010000400015
9. Kiliç, M., 2011: The effects of the force load direction on bending strength and modulos of elasticity in laminated veneer lumber (LVL). BioResour., 6 (3): 2805-2810.
10. Kilic, Y.; Colak, M.; Baysal, E.; Burdurlu, E., 2006: An investigation of some physical an mechanical properties of laminated veneer lumber manufactured from black alder (*Alnus glutinosa*) glued with polyvinyl acetate and polyurethane adhesives. For. Prod. J., 56 (9): 56-59.
11. Kim, S.; Kim, H. J., 2006: Study of miscibility of melamine-formaldehyde resin and poly(vinyl acetate) blends for use as adhesives in engi-neered flooring. J. Adhes. Sci. Technol., 20 (2-3): 209-219. http://dx.doi.org/10.1163/156856106775897739
12. Kol, H. S.; Ozbay, G.; Köse, L.; Kurt, S., 2010: Effects of some impregnation chemicals on combustion characteristics of laminated veneer lumber (LVL) produced with oak and poplar veneers. BioResour., 5 (1): 70-80.
13. Kurt, R., 2010: Suitability of three hybrid poplar clones for laminated veneer lumber manufacturing using melamine urea formaldehyde adhesive. BioResour., 5(3): 1868-1878.
14. Melo, R. R.; Del Menezzi, C. H. S.; Pavan, B. E.; Rodolfo Jr., F., 2014: Rotary peeling yield of *Schizolobium amazonicum* (Leguminosae - Caesalpinioideae). Acta Amaz., 44 (3): 315-320. http://dx.doi.org/10.1590/1809-4392201302926
15. Müller, M. T., 2009: Influência de diferentes combinações de lâminas de *Eucalyptus saligna* e *Pinus taeda* em painéis estruturais LVL. Universidade Federal de Santa Maria, Brazil, 165 p. Master's Thesis.
16. Pio, N. S., 2002: Produção de painéis estruturais de lâminas paralelas (PLP) de *Eucalyptus grandis* Hill ex-Maiden. Universidade Federal do Paraná, Brazil, PhD Thesis, 168 p.
17. Renzo, R., 2008: Painel estrutural de laminas paralelas (PLP) de Eucalyptus grandis utilizando adesivo resorcinólico, taninos e poliuretono derivado de óleo de mamona. Universidade Federal de Lavras, Brazil, Master's Thesis, 115 p.
18. Shukla, S.; Kamdem, D., 2008: Properties of laminated veneer lumber (LVL) made with low density hardwood species: effect of the pressure duration. Holz Roh-Werkst., 66 (2): 119-127. http://dx.doi.org/10.1007/s00107-007-0209-1
19. Souza, F.; Del Menezzi, C. H. S.; Bortolleto Junior, G., 2011: Material properties and nondestructive evaluation of laminated veneer lumber (LVL) made from *Pinus oocarpa* and *P. kesiya*. Holz Roh-Werkst., 69 (2): 183-192. http://dx.doi.org/10.1007/s00107-010-0415-0
20. Uysal, B., 2005: Bonding strength and dimensional stability of laminated veneer lumbers manufactured by using different adhesives after the steam test. Int. J. Adhes. Adhes., 25 (5) : 395-403. http://dx.doi.org/10.1016/j.ijadhadh.2004.11.005

Corresponding address:

Prof. Cláudio Henrique Soares DEL MENEZZI, Ph.D.

Universisty of Brasília
Dept. Forest Engineering, Faculty of Technology
Campus Darcy Ribeiro, PO Box 04357,
70904-970, Brasília, DF, BRAZIL
e-mail: cmenezzi@unb.br

Luka Krajnc[1], Katarina Čufar[2], Robert Brus[1]

Characteristics and Geographical Distribution of Fiddleback Figure in Wood of *Acer pseudoplatanus* L. in Slovenia

Obilježja i geografska rasprostranjenost gorskog javora (*Acer pseudoplatanus* L.) s valovitim vlakancima u Sloveniji

Original scientific paper • Izvorni znanstveni rad
Received – prispjelo: 23. 12. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*113; 630*812.11; 674.031.772.224.3*
doi:10.5552/drind.2015.1447

ABSTRACT • *The wavy grain of wood expressed in fiddleback figure usually enhances its commercial value. The goal of this study was to analyse fiddleback figure and other log characteristics in sycamore maple (Acer pseudoplatanus L.) and their contribution to the price of the timber. We studied sycamore maple logs at the annual auction of the highest quality wood assortments in Slovenj Gradec, Slovenia. Measurements were performed on the logs and wavy grain was analysed in 2013. In addition, data were used on logs auctioned between 2007 and 2012. Using the data collected at the auction in 2013 and a binary logistic regression model, the original sample was expanded considerably. The percentage of fiddleback maple was 7.4 % at the auction in 2013. Larger volume of maple logs was on average linked to higher price; however, the presence of fiddleback figure in a log per se did not guarantee above average price. Prices of more than half of the fiddleback figured maple logs at the auction in 2013 were below average. On the other hand, large fiddleback logs achieved the highest prices. Trees with fiddleback figure proved to be evenly distributed throughout the entire population of sycamore maple in Slovenia. The geographic origin of sycamore maple did not influence the occurrence of fiddleback figure. The presented results appear to be representative of the occurrence of fiddleback figure in Acer pseudoplatanus throughout its entire distribution range.*

Key words: *fiddleback figure, wavy grain, sycamore maple (Acer pseudoplatanus), commercial value, origin, Slovenia*

SAŽETAK • *Valovitost vlakanaca drva obično povećava komercijalnu vrijednost drva. Cilj provedenih istraživanja bio je analizirati valovitost vlakanaca i druga obilježja gorskog javora (Acer pseudoplatanus L.) te njihov*

[1] Authors are student and professor at University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources, Ljubljana, Slovenia. [2]Author is professor at University of Ljubljana, Biotechnical Faculty, Department of Wood Science and Technology, Ljubljana, Slovenia.
[1] Autori su student i profesor Sveučilišta u Ljubljani, Biotehnički fakultet, Odjel šumarstva i obnovljivih šumskih resursa, Ljubljana, Slovenija. [2]Autorica je profesorica Sveučilišta u Ljubljani, Biotehnički fakultet, Odjel za znanost o drvu i drvnu tehnologiju, Ljubljana, Slovenija.

doprinos cijeni drva. Proučavani su trupci gorskog javora ponuđeni na godišnjoj dražbi najkvalitetnijih drvnih sortimenata u Slovenj Gradecu u Sloveniji. Mjerenja na trupcima i analiza valovitosti vlakanaca provedeni su 2013. godine. Osim toga, u radu se navode i analiziraju i podaci o trupcima koji su bili na aukciji između 2007. i 2012. godine. Korištenjem podataka prikupljenih na aukciji 2013. godine i primjenom binarnoga logističkog regresijskog modela izvorni je uzorak znatno proširen. Na aukciji 2013. godine postotak javorovih trupaca s valovitim vlakancima iznosio je 7,4 %. Veći obujam trupaca javora po pravilu je povezan s višim cijenama trupaca. Međutim, valovitost vlakanaca ne jamči iznadprosječnu cijenu trupca. Na aukciji 2013. godine više od polovice trupaca s valovitim vlakancima imalo je cijenu nižu od prosječne. Nasuprot tome, veliki trupci s valovitošću vlakanaca postigli su najviše cijene. Stabla gorskog javora s valovitim vlakancima ravnomjerno su raspoređena u cijeloj populaciji gorskog javora u Sloveniji. Zemljopisno podrijetlo gorskog javora nije utjecalo na pojavu valovitosti vlakanaca. Prikazani rezultati mogu se smatrati reprezentativnima za pojavu valovitosti vlakanaca u stabala gorskog javora u cijelom njegovu arealu.

Ključne riječi: *valovita tekstura drva, valovitost vlakanaca, gorski javor (Acer pseudoplatanus), komercijalna vrijednost, podrijetlo, Slovenija*

1 INTRODUCTION
1. UVOD

Axial elements in wood are normally oriented more or less parallel to the tree axis, which is called straight grain. Deviations from straight grain, such as spiral or wavy grain, are fairly common. Wavy (also curly) grain results from waves in the direction of the grain with respect to the longitudinal axis of the tree (Figure 1a). Split faces of such logs show waves on the radial or tangential faces (Panshin and de Zeeuw, 1980). Wavy grain in the wood of different tree species is considered to be a desirable "natural defect", as it often greatly enhances the commercial value of the timber. Such grain can be observed locally or over the entire tree stem (Harris, 1989). The distinctive pattern can be observed on the longitudinal radial surface as a series of alternately bright and dark stripes shading into one another and thus producing the illusion of waves (Beals and Davis, 1977). The resulting pattern of wavy grain can be seen on boards (or veneer) and is called fiddle back figure (Figure 1b).

Wavy grain is commonly found near the limbs and roots, localized in small areas in many tree species. Well-developed wavy grain resulting in fiddleback figure is rare in trees of most species (Bucur, 2006; Harris, 1989; Beals and Davis, 1977). Nevertheless, fiddleback figure is frequently observed in maple (*Acer*), ash (*Fraxinus*), birch (*Betula*), and walnut (*Juglans*) (Harris, 1989; Beals and Davis, 1977; Pillow 1955). The beauty of the wavy grain structure is often the most important criterion when selecting among fiddleback maples, but commercially valuable wood rarely occurs in trees with diameters less than 25 cm (Beals and Davis, 1977).

Sycamore maple or sycamore (*Acer pseudoplatanus* L.) wood with fiddleback figure, also known as fiddleback maple, curly maple or tiger maple, is often used for furniture and musical instruments for its favourable decorative and acoustic properties. Historically, the term "fiddleback" comes from the extensive use of such wood for the back plates, ribs, necks, and scrolls of stringed instruments such as violins and guitars (Figure 1b). It is not only decorative, but it is also considered a resonance wood in terms of its acoustic properties (Beals and Davis, 1977; Bucur, 2006).

Since the occurrence of fiddleback figure in maple is relatively infrequent, regular non-figured maple wood is often worth considerably less than that figured. Rieder (1998) reports that the presence of fiddleback figure in maple increases wood value from 150 % to 200 %. Sycamore maple assortments have consistently achieved the highest prices among wood assortments over the last ten years. The highest prices have also seen a constant increase (e.g., Kobal *et al.*, 2013). Analysis of the data from log auctions that took place from 2007 to 2014 in Slovenj Gradec, Slovenia, showed that fiddleback maple consistently achieves significantly higher prices than any other wood. Most of the auctioned wood was bought for use by instrument makers in Western Europe (Krajnc, 2013).

The exact percentage of maple trees with fiddleback figure in the entire population is unknown. Some authors report that fiddleback figure occurs in 3 % of the sycamore maple population (Rieder, 1998; Conrad, 1957), while others estimate its frequency at 4 % (Maurer, 1982) or 6 % (Wedel, 1964). All authors suggest that wavy grain in maple is heritable, but there are apparently no reliable research results confirming this. Walters (1951), for instance, reported that *Juglans nigra* L. with wavy grain could be propagated by grafting. Later research disputed these results (MacDaniels, 1953). Recently, Aubakirova and Kalashnikova (2011) have developed a useful technology for clonal micropropagation of curly birch. Fan *et al.* (2013) experimented on curly aspen and concluded that figure in aspen wood can be genetically heritable. However, according to the current state of knowledge, grain orientation does not seem to be governed by simple genetic regulation. Consequently, there are no commercial plantations of fiddleback maple and no methods for producing figured wood or artificially inducing its occurrence.

The occurrence of fiddleback figure in wood also seems to be independent of soil type, climate, geographical position or any other known factor. Most of the best figured wood develops in well formed, straight and healthy trees. Tree size also has little effect on figure. The best developed figure occurs in the outer areas of tree stems, outside of the inner juvenile zone (Beals and Davis, 1977). Due to grain deviations, fiddleback figured wood has a lower modulus of elasticity and compressive strength in the axial direction and higher longitudinal shrinkage compared to straight-grained wood (Vintoviv, 1981; Wedel, 1964).

Beals and Davis (1977) noted that, in general, forests in certain geographical areas produced more fiddleback figured trees than others. However, to our knowledge there has been no detailed research on the possible geographical distribution of fiddleback figure in sycamore maple in Europe.

As valuable maple trees with fiddleback figure are scarce in forests, scientists have often been motivated either to find a wood species to substitute fiddleback maple or to provide a means to detect wavy grain in standing trees (Bucur, 2006). Such detection is possible using various methods. Wavy grain in *Acer* can be detected to some degree by removing bark and examining the wood underneath (Beals and Davis, 1977; Pillow, 1955). Wave lengths in fiddleback maple range between 0.7 and 2.0 cm, reaching a maximum height near 0.3 cm. However, the expression of the waves is often more obvious on the radial split face than on the tangential surface below the bark.

Furthermore, non-destructive detection of wavy grain in maple is claimed to be possible by using ultrasound. This method is based on measuring the time of ultrasound transition through the wood, as its velocities significantly differ in trees with wavy grain and in those without it. In fiddleback maple the velocities are generally higher than in normal wood. Literature reports suggest that differences in velocity can also be caused by very abundant radially oriented rays (Bucur, 2005; Bucur, 1987).

The lack of recent studies on the formation of fiddleback figure can be ascribed to difficulties arising from its rarity, scattered spatial distribution, and long-term processes of its accumulation. Some aspects were studied some decades ago on relatively small sample sizes (Wedel, 1964; Vintoviv, 1981). Knowledge on its formation can therefore be considered fragmentary, making it difficult to generalize about larger populations. However, ongoing advances in genetics and various non-destructive detection methods could offer new possibilities to investigate the occurrence of fiddleback maple.

To our knowledge, there is also a lack of reports on the apparently stable relationship between fiddleback figure and higher timber prices, and on the possible existence of a predetermined geographic distribution of fiddleback occurrence in the sycamore maple population.

The aim of this study was, therefore, to elucidate the relationship between wavy grain / fiddleback characteristics expressed on the surface of sycamore maple logs and the influence of various measurable log characteristics on their prices. The origin of the logs was also studied to discover whether there exists any predetermined geographic distribution.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The study was carried out at a timber yard during the annual auction of the highest quality wood assortments in Slovenj Gradec, Slovenia, in 2013. The data collected in 2013 were enhanced with available data from auctions held at the same location from 2007 to 2012. The auctions are open for any participant, either as a seller or a buyer. Every year the sellers, mainly Slovenian forest owners, transport their logs to the auction site, where all logs are measured and numbered by the company organizing the auction. Afterwards, potential buyers inspect the logs on site and give individual offers for those they are interested in purchasing. After the auction closes, all offers are collected and for each of the logs the highest offer wins. In this way, price negotiations between buyers and sellers are avoided. Each year, a large portion of the logs belonged to the genus *Acer*, specifically to *Acer pseudoplatanus*.

Figure 1 (a) Wavy grain on split radial surface of wood and (b) the back plate of a violin made from fiddleback maple
Slika 1. (a) Valovitost vlakanaca na radijalnoj površini drva; (b) leđa violine izrađena od drva javora valovitih vlakanaca

First, we investigated all sycamore maple (*Acer pseudoplatanus*) logs in the 2013 auction. For analysis, each log was divided into three parts, and on each of them a randomly placed sample plot was defined, sized approximately 210 cm² (21 cm × 10 cm) (Figure 2). The bark was removed from each plot and the wood beneath was examined for signs of wavy grain, as proposed by Beals and Davis (1977). If wavy grain was identified, three waves were randomly selected and their lengths and heights measured. Three random pairs of adjacent waves were selected and the distances between the pairs were measured. In this way the number of waves on the 210 cm² surface (21 cm × 10 cm) was recorded. Each measurement was repeated at least twice to reduce the effect of human error. All wave heights and lengths were measured with a Vernier caliper with a precision of 0.01 mm. The average wave length was calculated from the number of waves per plot.

If the wavy grain was present in at least one of the three plots, a strip of bark was removed along the whole length of the log and the total length of the portion with wavy grain was measured. If no signs of wavy grain were found on any of the three sample plots, no further measurements were conducted on that particular log.

The orientation of the wavy grain varied among the logs. About one third of the logs exhibited wavy grain on the radial surface (Figure 1a); therefore, the inspected surface of the log (i.e. tangential surface of

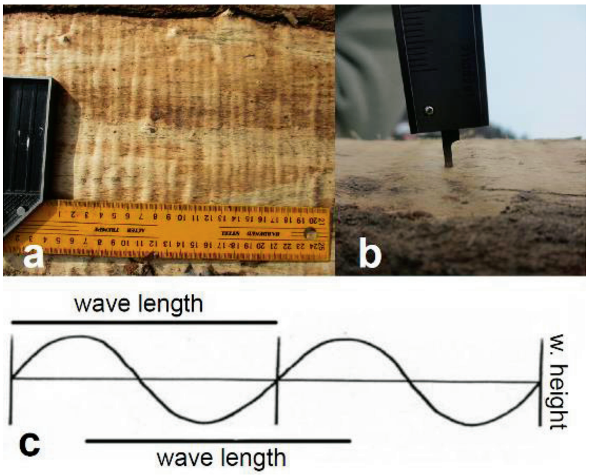


Figure 2 (a) Sample plot (21 cm × 10 cm) on the log, where the bark was removed, (b) height measurement of the waves and (c) measured wave characteristics
Slika 2. (a) Uzorak trupca s valovitim vlakancima na mjestu gdje je skinuta kora; (b) mjerenje visine valova; (c) mjerena obilježja valova

the wood) was flat. Such logs were analysed as well, but the wave heights could not be measured.

The following data were also collected for all the logs at the 2013 auction: log dimensions (length, mid diameter), log grade (based on five quality-based categories ranging from veneer (best quality) to sawn wood (lowest quality)), as well as price offers and the final price achieved for each log. Similar data were also obtained for the auctions held from 2007 to 2012. In this case the data included log dimensions, log grade, price achieved per log and per cubic meter, number of offers received per log and residence (address) of each individual seller.

The data from the 2007-2012 auctions allowed us to expand the 2013 data set by using binary logistic regression.

After digitalization of the recorded data, the normality of the distribution was checked for each recorded numeric variable using the Kolmogorov-Smirnov test. Comparisons between sampled variables were made using different methods (Mann-Whitney U or Analysis of variance) depending on the normality and homogeneity of variances in different variables by using SPSS (IBM, 2012). Correlations between them were estimated using Spearman's rank correlation coefficient.

Using the 2013 auction data and binary logistic regression, a model was developed to predict the probability of wavy grain occurrence in any sycamore maple log based on its mid diameter, volume, achieved price per cubic meter and per log, number of offers received and log grade. Log grade entered the regression as a categorical value. Since the model was used for the logs of the previous auctions, all the data which entered the regression were standardized to avoid shortcomings deriving from different data distributions in previous auctions.

As the predicted probability of wavy grain in a log was not sufficient to conduct further analysis, a binary classifier was employed to assign each log into one of two categories – wavy grain present (1) / not present (0). The threshold of the probabilistic classifier was determined using an ROC curve (Curk *et al.*, 2006). The threshold of probability between the two categories was set to 0.192 as our binary classifier had optimal classification accuracy there. Our classifier was accurate in 93.5 % of cases, which was considered satisfactory for further use.

Using the data from the 2007-2012 auctions, the original sample of 31 logs was expanded with wavy grain in the 2013 auction to 199 logs, and the number of all included sycamore maple logs was increased from 417 to 3184.

Each of the logs was assigned an area of its probable origin in Slovenia. This was estimated based on the location of the owner's residence with 10-kilometre radius buffer zone. The assumption on log origin was based on previous research of Slovenian forest owner characteristics (Medved, 2000; Oršanič, 2005; Oršanič, 2007; Žepič, 2010) showing that over 95 % of the private forest properties in Slovenia were located within a radius of 10 kilometres around the owners' residence. To this purpose, each residence location was geocoded and the coordinates were used to prepare maps of probable log origin in ArcGis. Due to frequent overlap of the areas, maps of relative densities of probable origin were made for easier interpretation.

3 RESULTS
3. REZULTATI

Logs with wavy grain / fiddleback figure and those without it showed no statistically significant differences in dimensions (length, mid diameter), grades and minimal price offers. On the other hand, the prices per m^3 and per log, as well as the number, mean and sum of the offers (Table 1) were significantly different for the logs with fiddleback grain compared to those without it. Fiddleback maple achieved higher prices on average with a larger range and different distribution (higher coefficients of variation and larger standard deviations). The differences can be attributed to a higher number and variance of the offers for fiddleback maple. The comparisons between fiddleback and regular maple apply to data from the 2013 auction only, as there are no reliable sources differentiating the two groups in previous years. However, the data from 2013 were deemed reliable as each of the logs was inspected individually.

No significant differences were found in wavy grain characteristics of logs having waves on the tangential or radial surface (Table 2). Maximum wave height (amplitude) was 1.6 mm, measured wave lengths ranged from 4 to 13.26 mm, and the calculated wave lengths ranged from 7.5 to 52.5 mm.

No significant correlations were found between the variables related to the number and length of waves, length of logs and portion with fiddleback figure, volume, prices and number of received offers. However, the achieved price per log moderately correlated with the absolute length of the portion of detected wavy

Table 1 Differences between maple logs with (1) and without (0) wavy grain / fiddleback figure (auction 2013). The differences are significant if $p < 0.05$ (Mann–Whitney U)
Tablica 1. Razlike između javorovih trupaca s valovitim vlakancima (1) i bez valovitosti (0); razlika je značajna ako je $p < 0,05$ (Mann-Whitneyjev U-test)

Variable / *Varijabla*			**Asymp. Sig.** (2-tailed)	**Mean** *Srednja vrijednost*	**St. dev** *Stand. dev.*	**Range** *Raspon*
Price per m^3 (€) *cijena po m^3 (€)*	Fiddleback f. present	0	.000	206.0	281.7	3440.0
		1		1160.5	1519.9	6121.0
Price per log (€) *cijena po trupcu (€)*	Fiddleback f. present	0	.000	219.8	371.0	3073.6
		1		1411.5	2382.1	11881.2
Number of offers *broj ponuda*	Fiddleback f. present	0	.000	3.0	1.0	8.0
		1		4.0	3.0	10.0
Offer mean (€) *prosjek ponuda (€)*	Fiddleback f. present	0	.000	133.3	107.6	899.4
		1		467.2	619.3	3069.3
Offer sum (€) *zbroj ponuda (€)*	Fiddleback f. present	0	.000	473.3	730.4	7142.5
		1		3361.3	7064.3	37387.0
Coefficient of variation (%) *koeficijent varijacije (%)*	Fiddleback f. present	0	.000	28.8	25.2	176.5
		1		62.0	40.9	155.3

Table 2 Means and standard deviations of measured wave characteristics (fiddleback maple, 2013)
Tablica 2. Srednje vrijednosti i standardne devijacije izmjerenih obilježja valovitosti vlakanaca

Variable / *Varijabla*	**Mean** *Srednja vrijednost*	**St. dev.** *Stand. devijacija*
Average measured number of waves per plot, mm *prosječan broj izmjerenih valova na mjernoj površini, mm*	16.75	4.78
Average measured wave length, mm / *prosječna izmjerena duljina vala, mm*	13.26	2.42
Average measured wave height, mm / *prosječna izmjerena visina vala, mm*	0.51	0.33
Average calculated wave length per log, mm / *prosječna izračunata duljina vala, mm*	14.45	7.58

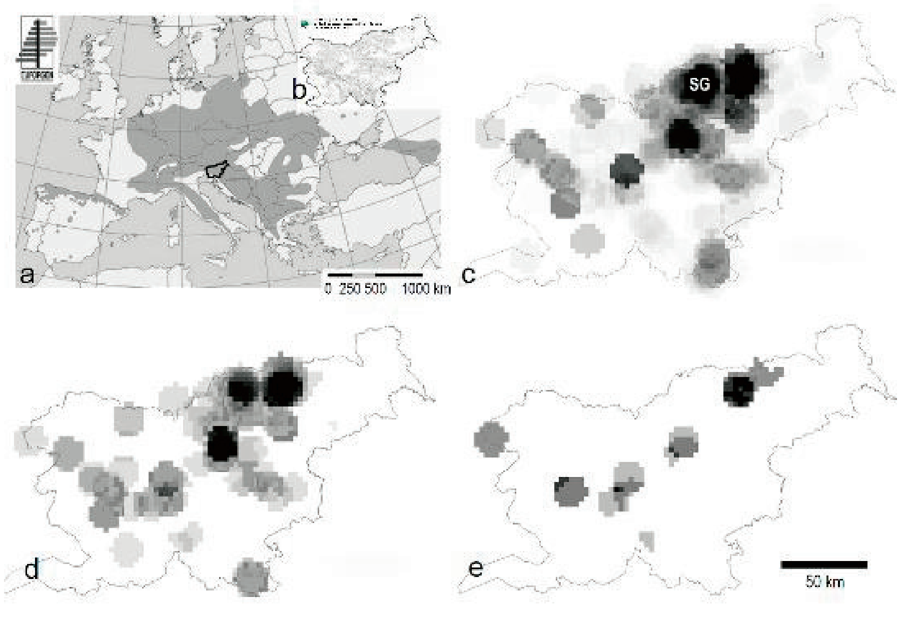


Figure 3 Distribution of sycamore maple (*Acer pseudoplatanus*) in (a) Europe and (b) Slovenia, and maps of Slovenia with (c) relative densities of probable origin of all sycamore maple logs from the 2007-2013 auctions in Slovenj Gradec (SG) (n=3121), (d) relative densities of probable origin of expanded fiddleback maple samples from the 2007-2013 auctions (n=199) and (e) relative densities of probable origin of fiddleback maple at the 2013 auction (n=31). Distribution maps of sycamore maple (*Acer pseudoplatanus*) in Europe (EUFORGEN, 2009) and in Slovenia (Pisek 2010, Zavod za gozdove Slovenije)
Slika 3. Rasprostranjenost gorskog javora (*Acer pseudoplatanus*) u (a) Europi i (b) Sloveniji; (c) karte Slovenije s relativnom gustoćom vjerojatnosti podrijetla svih trupaca gorskog javora koji su bili na aukciji u razdoblju 2007. – 2013. u Slovenj Gradecu (SG) (n = 3121), (d) relativna gustoća vjerojatnosti podrijetla gorskog javora s valovitošću vlakanaca u proširenom uzorku s aukcijom iz razdoblja 2007. – 2013. godine (n = 199); (e) relativna gustoća vjerojatnosti podrijetla gorskog javora s valovitošću vlakanaca u uzorku s aukcije 2013. godine (n = 31). Karte rasprostranjenosti gorskog javora (*Acer pseudoplatanus*) u Europi (EUFORGEN, 2009.) te u Sloveniji (Pišek, 2010., Zavod za gozdove Slovenije).

Table 3 Differences between sycamore maple prices of the group (1) achieving above mean (above s. m.) and (2) below mean (below s. m.) prices of fiddleback maple (auction 2013). In all cases differences are statistically significant (Mann-Whitney U; p<0.05)
Tablica 3. Razlike između cijena javorovih trupaca s valovitim vlakancima koji postižu iznadprosječnu (above s. m.) (1) i ispodprosječnu cijenu (below s. m.) (2) (uzorak trupaca s aukcije 2013. godine); razlike su značajne u svim slučajevima (Mann-Whitneyjev U-test; $p < 0,05$)

Variable / *Varijabla*		**Asymp. Sig.** (2-tailed)	**N**	**Mean** *Srednja vrijed.*	**Median** *Medi-jan*	**Modus** *Modus*	**St. dev.**
Average number of waves per log *prosječan broj valova po trupcu*	Below s. m.	.030	16	13.5	13.3	9.0	5.5
	Above s. m.		15	17.7	16.7	14.0	3.2
Maximum number of waves per log *najveći broj valova po trupcu*	Below s. m.	.041	16	14.8	14.5	9.0	6.6
	Above s. m.		15	19.3	19.0	14.0	4.4
Minimum number of waves per log *najmanji broj valova po trupcu*	Below s. m.	.021	16	12.2	12.0	9.0	5.1
	Above s. m.		15	16.1	16.0	14.0	2.6
Mean calculated wave length (mm) *prosječna vrijednost izračunate duljine valova (mm)*	Below s. m.	.028	16	19.7	16.1	23.3	11.9
	Above s. m.		15	12.3	13.1	15.0	2.1
Log length (m) *duljina trupca (m)*	Below s. m.	.046	16	4.0	4.0	2.5	1.3
	Above s. m.		15	5.7	6.0	3.4	2.3
Length of fiddleback figure on log (m) *duljina valovite teksture na trupcu (m)*	Below s. m.	.004	16	2.2	1.7	3.0	1.6
	Above s. m.		15	4.1	3.9	2.3	2.0
Percentage of log length with f.f. (%) / *postotak duljine trupca na kojemu se nalaze valovita vlakanca (%)*	Below s. m.	.031	16	53.2	41.7	100.0	27.2
	Above s. m.		15	74.7	66.7	100.0	26.9
Volume (m^3) *volumen (m^3)*	Below s. m.	.005	16	0.7	0.7	0.5	0.3
	Above s. m.		15	1.2	1.1	0.5	0.5
Price per cubic meter (€) *cijena po kubičnome metru (€)*	Below s. m.	.000	16	146.1	142.0	127.0	51.8
	Above s. m.		15	2242.6	1718.0	411.0	1586.4
Price per log (€) *cijena po trupcu (€)*	Below s. m.	.000	16	109.8	112.2	13.6	57.2
	Above s. m.		15	2800.0	2080.7	263.5	2855.5
Number of received offers *broj primljenih ponuda*	Below s. m.	.000	16	2.9	3.0	3.0	0.7
	Above s. m.		15	6.1	5.0	4.0	2.8

grain (ρ=0.541, p<0.01), the achieved price per cubic meter with relative (percentage of log length) length of the detected portion of wavy grain (ρ=0.448, p<0.05) and log volume with achieved price per cubic meter (ρ=0.571, p<0.01).

Prices of more than a half (51 %) of the sycamore maple logs at the auction in 2013 with fiddleback figure were below average. Differences between the two groups achieving below and above average prices are listed in Table 3; all of them are significant.

Comparison of the means of the measured characteristics of wavy grain showed no significant differences between plot location on the stem and parameter means. If wavy grain is present, homogeneity of its characteristics can be expected.

Finally, three maps were constructed of the relative densities of the probable origin of fiddleback sycamore maple in Slovenia within its natural range (Figure 3 a, b). They show the most probable origin of all sycamore maple logs auctioned in Slovenj Gradec between 2007 and 2013 (Figure 3c), the origin evaluated based on the expanded sample (2007-2013) obtained with binary logistic regression (Figure 3d), and the origin of the logs auctioned in 2013, which served as a control (Figure 3e).

The distribution in Figure 3e is very similar to the one in Figure 3d; therefore, it may be concluded that the method used can be considered adequate for further comparisons.

4 DISCUSSION
4. RASPRAVA

The measured characteristics expressed on the outer surface of individual logs are fairly homogenous in a particular log; thus, in future research there is no need to increase the number of plots per log to measure wavy grain characteristics. It also appears that it is not necessary to measure fiddleback characteristics along the whole length of its appearance.

Contrary to the general consensus, the sole presence of fiddleback figure in a log does not guarantee that its price will be above average. The logs with fiddleback figure that had above average prices were as a rule longer, had greater diameters and volumes, and had a larger portion of wavy grain and a higher number of waves per log (Table 3). As such, the sole presence of wavy grain/fiddleback figure did not prove to be sufficient to increase the value of the log. Higher prices were only achieved when the log had a sufficient amount and quality of wavy grain.

As seen on the presented maps, relative densities of sycamore maple log origin show multiple local and one regional culmination. The regional maximum can be observed in the proximity of Slovenj Gradec, where the auctions were held. The higher density around Slovenj Gradec is probably due to the higher participation rate of local forest owners since they have lower transport costs. They are also better informed and motivated to attend the auction compared to owners from other areas in Slovenia. Nevertheless, local culminations are not evenly distributed throughout the country. They agree well with the general distribution of the sycamore maple population in Slovenia (Figure 3b), which shows that different habitats are suitable for this species. To a lesser extent, some local culminations could also be a result of the regular participation of the same owners or owner associations in the auctions, which is also related to their awareness and motivation. Comparison of the map in Figure 3c with those in Figures 3d and 3e shows no notable differences between geographic origin or concentration of sycamore maple with or without fiddleback figure. Based on this, it can be concluded that the occurrence of fiddleback figure in sycamore maple trees is not locally limited or conditional. Fiddleback figure is apparently evenly distributed in the entire sycamore maple population and is probably not directly affected by environmental factors. As our research was conducted over a relatively large geographic area and included a large sample, the general findings can also be applied to the wider geographic area within the general distribution range of sycamore maple (EUFORGEN, 2009).

Since there is a lack of notable research on the spatial distribution and characteristics of fiddleback maple, it is difficult to compare the data from Slovenia with those of other areas. The percentage of sycamore maple trees with expressed fiddleback figure among all auctioned sycamore maple logs was 7.4 % at the auction in 2013, slightly more than the 3-6 % reported by Rieder (1998), Conrad (1957), and Wedel (1964). However, log selection could have led to biased observations given that presumably only the most valuable logs were selected for auction. On the other hand, most owners, when selecting the logs for auction, hope that they are of high quality but due to lack of knowledge and detection methods in standing trees, they often cannot exactly estimate whether fiddleback figure is present in the selected logs or not. Due to this, one could argue that the sycamore maples at the auction are, nevertheless, more or less randomly selected out of the general sycamore maple population, and that as such, the analysed sample is suitable for drawing general conclusions.

Current biotechnology knowledge and sylvicultural measures do not make it possible to induce wavy grain or to manipulate its characteristics in sycamore maple at this moment. However, this is not the case for log volume, as one can generally influence tree age at felling. Larger log volumes proved to be linked to higher prices, so early selection of fiddleback trees as crop trees and releasing them with tending or specially cultivating them would likely pay off considerably. Bearing this in mind, it would make sense to invest more resources for further research into the non-destructive detection of wavy grain in standing trees.

The results of this study indicate recommended directions of future research. Since fiddleback figure seems to occur regularly through space and time, there could be a common cause or trigger that has yet to be discovered. To study wavy grain and fiddleback figure *in situ*, reliable non-destructive methods of its detection in standing trees are needed. The use of ultrasound seems promising, but further research is needed to validate this or other non-destructive methods through different sycamore maple subpopulations. As we are not aware of any current ongoing research on the development of wavy grain and the factors influencing it, this topic appears to remain relatively unexplored.

5 CONCLUSION
5. ZAKLJUČAK

Inspection of sycamore maple logs at the auction of the highest quality wood assortments in Slovenj Gradec in 2013 showed that the percentage of fiddleback maple was 7.4 %. This is slightly more than reported by other studies, mainly because logs of above average quality were selected for auction.

The presence of fiddleback figure in a log *per se* did not guarantee above average price. Higher price was mainly affected by larger log diameters and volumes.

Trees with fiddleback figure proved to be evenly distributed throughout the entire population of sycamore maple in Slovenia. The results appear to be representative of the occurrence of fiddleback figure in *Acer pseudoplatanus* throughout its distribution range.

Acknowledgments - Zahvale

This research was financially supported by the Pahernik Foundation, the Slovenian Research Agency (ARRS), research programmes P4-0059 and P4-0015, and the Ministry of Agriculture, Forestry and Food and ARRS, project V4-1419. We thank Primož Grudnik for supplying log data from auctions 2007-2013 and gratefully acknowledge the technical assistance of Andraž Poljšak. We thank Rok Pisek for help with the map and Jan Nagel for language editing.

6 REFERENCES
6. LITERATURA

1. Aubakirova, L. S.; Kalashnikova, E. A., 2011: Experimental morphogenesis in a curly birch tissue culture. Plant Industry, 37 (2): 15-16. http://dx.doi.org/10.3103/S1068367411020030
2. Beals, H.; Davis, T., 1977: Figure in wood – an illustrated review. Auburn, Alabama. Auburn University, Agricultural experiment station.
3. Bucur, V., 2006: Acoustics of wood, 2nd ed. Springer-Verlag, Berlin.
4. Bucur, V., 2005: Ultrasonic techniques for nondestructive testing of standing trees. Ultrasonic, 43: 237-239. http://dx.doi.org/10.1016/j.ultras.2004.06.008
5. Bucur, V., 1987: Wood characterization through ultrasonic waves. In: Alippi, A., Mayer, W. G. (eds.). Ultrasonic methods in evaluation of inhomogeneous materials. NATO ASI Ser E Appl Sci no 126. Nijhoff, Dordrecht, pp. 323-342. http://dx.doi.org/10.1007/978-94-009-3575-4_23

6. Conrad, J., 1957: Plusbaumauswahl unter besonderer Berücksichtigung der Holzqualität. Forstarchiv, 28 (7): 133-137.
7. Curk ,T.; Vuk, M., 2006: ROC curve, lift chart and calibration plot. Advances in Methodology and Statistics, 3 (1): 89-108.
8. Fan, Y.; Rupert, R.; Wiedenhoeft, A. C.; Woeste, K.; Lexer, C.; Meilan, R., 2013: Figured grain in aspen is heritable and not affected by graft-transmissible signals. Trees - Structure and Function, 27 (4): 973-983. http://dx.doi.org/10.1007/s00468-013-0849-1
9. Harris, J. M., 1989: Spiral grain and wave phenomena in wood formation. Berlin, Springer-Verlag Berlin Heidelberg New York. http://dx.doi.org/10.1007/978-3-642-73779-4
10. Kobal, M.; Kristan, S.; Grudnik, P.; Vilhar, U., 2013: Supply and demand at auctions of value wood assortments in Slovenj Gradec. Gozdarski Vestnik, 71 (10): 462-470.
11. Krajnc, L., 2013: Rebrasta tekstura v lesu gorskega javorja (*Acer pseudoplatanus* L.) = Fiddleback figure in wood of sycamore maple (*Acer pseudoplatanus* L.): B. Sc. Thesis. University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources. Ljubljana.
12. MacDaniels, L. H., 1953: Some aspects of the problem of producing curly-grained walnut. In: Proceedings of the 44th annual report of the northern nut growers association, Rochester.
13. Maurer, E., 1982: Der Ahorn. In: Bäume und Wälder in Bayern. Bayerischer Forstverein, W. Ludwig Verlag: 17-21.
14. Medved, M., 2000: Consequences of property structure on forest management in Slovenian small scale private forests: dissertation thesis. University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources. Ljubljana.
15. Oršanič, T. H., 2005: Conservation of nature and forest ownership – a case study of Posavje area: M.Sc.Thesis University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources. Ljubljana.
16. Oršanič, T. H., 2007: Ohranjanje narave v zasebnih gozdovih Posavja. Varstvo narave, 20: 35-50.
17. Panshin, A.; De Zeeuw, C., 1980: Textbook of wood technology. New York, Mc Graw-Hill.
18. Pillow, M. Y., 1955: Detection of figured wood in standing trees. Research Paper No. 2034. USDA Forest Service, Forest Products Laboratory, Madison.
19. Pisek, R., 2010: Distribution of sycamore maple (*Acer pseudoplatanus*) in Slovenia. Zavod za gozdove Slovenije, Oddelek za gozdno gospodarsko načrtovanje. http://www.zgs.si/fileadmin/zgs/main/img/CE/gozdovi_SLO/Karte/Gorski_javor_2.JPG
20. Rieder, A., 1998: Ahorn-Wertholzproduktion in kurzen Umtrieben. AFZ, Der Wald, 15: 776-779.
21. Vintoniv, I. S., 1981: Some physical and mechanical properties of wavy-grain wood of sycamore maple. Lesnoi Zhurnal, 6: 56-58.
22. Walters, C. S., 1951: Figured walnut propagated by grafting. Journal of Forestry, 49: 917.
23. Wedel, K., 1964: Untersuchungen über Eigenschaften, Verwertung und Verwendung des Ahornholzes: Diss. Göttingen, Forstl. Fak. Univ. Göttingen.
24. Žepič, V., 2010: Presoja možnosti za uvajanje načrtov za zasebno gozdno posest na Gozdnogospodarskem območju Kranj = The evaluation of possibilities for introduction of private forest property plans in the Kranj forest management region: graduation thesis. University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources. Ljubljana.
25. *** EUFORGEN, 2009: Distribution map of Sycamore (*Acer pseudoplatanus*). www.euforgen.org
26. *** IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.

Corresponding address:

Professor ROBERT BRUS, Ph.D.

University of Ljubljana
Biotechnical Faculty
Department of Forestry and Renewable Forest Resources
Jamnikarjeva 101
SI-1000 Ljubljana, SLOVENIA
e-mail: robert.brus@bf.uni-lj.si

Mostafa Kohantorabi[1], Mohammad Ali Hossein[1], Mahdi Shahverdi[2], Mehran Roohnia[3]

Vibration Based NDT Methods to Verify Wood Drying Efficiency

Nedestruktivne metode na bazi vibracija za provjeru učinkovitosti sušenja drva

Preliminary paper • Prethodno priopćenje
Received – prispjelo: 20. 9. 2013.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*812.75; 630*847.23; 674.047.3*
doi:10.5552/drind.2015.1352

ABSTRACT • *The capability of application of flexural vibration test in nondestructive evaluation of wood drying was studied. Poplar timbers were conventionally kiln dried under three different drying schedules down to the final moisture content of 12 ±2 %. Dynamic Modulus of Elasticity, damping (internal friction), acoustic coefficient, and acoustic converting efficiency of each sample were evaluated using free flexural vibration test of both-ends free bars before and after the drying, while dynamic responses in each individual step were also monitored. Results revealed that emerging of some defects in the dried timber caused significant changes through the studied parameters of samples by different extents. Cracks were amongst the most prevalent defects influencing the studied factors. The desired schedule, which caused the least abundance of defects in the dried timber, was then identified using this technique. It can be stated that the existing destructive and traditional methods could be replaced by the free vibration method to evaluate the final drying quality accurately.*

Key words: *acoustic, defect, non-destructive-test, wood drying*

SAŽETAK • *U radu se ispituje mogućnost primjene vibracijskog testa savijanja pri nedestruktivnoj procjeni kvalitete sušenja drva. Drvo topole sušeno je u konvencionalnoj sušionici pri tri različita režima sušenja do konačnog sadržaja vode 12 ± 2 %. Dinamički modul elastičnosti, prigušivanje (unutarnje trenje), akustični koeficijent i učinkovitost akustične konverzije svakog uzorka ocijenjeni su uz pomoć vibracijskog testa slobodnog savijanja poluge, slobodne na oba kraja, prije i nakon sušenja, dok je dinamički odgovor praćen u svakom pojedinom koraku. Rezultati su pokazali da je postojanje nekih grešaka osušenog drva prouzročila znatne promjene istraživanih svojstava uzoraka u različitim omjerima. U najčešće greške osušenog drva koje utječu na ispitivana svojstva ubrajaju se pukotine. U radu je identificiran poželjni režim sušenja koji je prouzročio najmanje grešaka osušenog drva. Na temelju rezultata provedenih istraživanja može se zaključiti da je postojeće destruktivne i tradicionalne metode za procjenu kvalitete sušenja moguće zamijeniti metodom slobodnih vibracija, kojom se postiže dobra procjena konačne kvalitete sušenja.*

Ključne riječi: *akustika, greške drva, nedestruktivna metoda, sušenje drva*

[1] Authors are PhD candidates at Department of Wood and Paper Science and Technology, College of Agriculture and Natural Resources, Science and Research Branch, Islamic Azad University, Tehran–Iran. [2]Author is graduate student at Department of Wood Science, University of British Columbia, Vancouver, BC, Canada. [3]Author is associate professor at Department of Wood and Paper Science and Technology, College of Agriculture and Natural Resources, Karaj Branch, Islamic Azad University, Karaj–Iran.

[1] Autori su doktorandi Odjela za znanost i tehnologiju drva i papira, Fakultet agronomije i prirodnih resursa, Islamsko sveučilište Azad, Tehran, Iran. [2]Autor je student Odjela za znanost o drvu, Sveučilište British Columbia, Vancouver, BC, Kanada. [3]Autor je izvanredni profesor Odjela za znanost i tehnologiju drva i papira, Fakultet agronomije i prirodnih resursa, Islamsko sveučilište Azad, Karaj, Iran.

1 INTRODUCTION
1. UVOD

Nondestructive testing (NDT) techniques have recently been implemented by many researchers for quality assessment of materials or for identifying their defects (Lee, 2001; Axmon *et al*., 2004; Baskaran and Janawadkar, 2007; Roohnia *et al*., 2011a; Biechele *et al*., 2011). These techniques are effective means of testing and evaluating the properties of materials, which do not destroy the physical, chemical, and mechanical properties of materials and have no influence on their future performance. The exploitation and application of this technology have also been quickly developed in wood and wood-products fields for its evident advantages. Appropriate correlation between modulus of elasticity and other mechanical properties of wood (Bodig and Jayne, 1993) has encouraged researchers to engage dynamic modulus driven by non-destructive tests to estimate the mechanical properties of wood and wood products (Wang *et al*., 2008).

In the process of timber manufacturing, drying is the single most demanding step in terms of energy consumption and time. A reduction in drying time and/or an improvement in the quality of the dried timber offers potential economic benefits. Improvements in the wood drying process are accompanied by the better understanding of the drying process (Watanabe *et al*., 2008). Hence, many studies have been conducted to investigate the effect of different wood drying conditions on characteristics of the dried timber (Möttönen, 2006; Milić and Kolin, 2008; Mugabi *et al*., 2011; Tarmian *et al*., 2010; Oltean and Teischinger, 2011). All of these researches imply the importance of being aware of wood properties affected by the drying processes.

In general, destructive methods are used for quality controlling of the dried timber (Perré and Roger, 2006). In addition to being time-consuming, destructive nature of these methods makes them infeasible to be applied for the control and inspection of the entire timber. Consequently, common methods do not provide researchers and industrialists with sufficient information on properties of every individual sample. Meanwhile, some of the defects induced by wood drying schedules, such as occurrence of surface and internal cracks, which are among the most prevalent defects in wood drying processes, cannot be detected by these methods or they might be insufficient in precision.

Given the application of non-destructive tests create no change in the properties of wood, the possibility of timely evaluation of each single sample is provided. Measurement of moisture content has been investigated during drying by means of non-destructive methods (Watanabe *et al*., 2008; Tanaka *et al*., 2009; Lazarescu *et al*., 2010; Watanabe *et al*., 2012). However, the potential of the vibration-based NDT method was extended here for evaluation of the wood properties subjected to different drying conditions. Following the previous studies, this paper aims to identify the vibrational properties of drying timber influenced by different drying conditions.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Materials
2.1. Materijali

Freshly-cut logs of poplar (*Populus alba* L.) with approximately 17-20 years of growth and 30-35 cm diameter, belonging to the Taleghan region in Iran were selected for the study. The logs were cut through the tangential direction to produce uniform timbers with a nominal thickness of 7 cm, a length of 220 cm, and a width of 14 cm. Some sound samples (i.e. without any crack, knot, etc.) were selected before the drying for flexural vibration test for each schedule; 6, 6, and 5 samples for three different schedules, respectively, named A, B and C.

Next, their cross sections were immediately completely covered with oil paint in order to prevent moisture loss and occurrence of end cracks. A conventional semi-automatic kiln with the capacity of 3 m^3 was used. Estimation of the current moisture content of kiln stacks was done by means of samples that were provided from the kiln stack and identified as control samples. From each side of the control samples, cookies for the moisture content measurement with a length of 2.5-cm were cut and immediately weighed with an electric balance. Finally, they were oven-dried at 103 ±2 °C to a constant weight

2.2 Drying Procedure
2.2. Proces sušenja

Three different moisture-based drying schedules were used, including schedule A (T_5-D_2), schedule B (T_5-D_4), and schedule C (T_5-D_6). Drying process terminated when the final moisture content (MC) of 12 ± 2 % was reached. To introduce the new conditions in the kiln, the control samples, depending on the drying rate, were weighed at least once a day. This change was made based on the average MC of the wettest half of the control samples (Simpson, 1991). Finally, the drying process was terminated without any conditioning treatment for all of the drying runs.

2.3 Flexural Vibration Procedure
2.3. Vibracijski test savijanja

The cut samples were maintained in the open air for 2 days prior to drying. Then, flexural vibration in free-free bar test was conducted on wet specimens in order to have primary information for further investigations of the acoustic properties of the dried timber (Fig. 1). This test was also carried out immediately after completion of drying process.

Based on Timoshenko's improved theory of flexural free vibration test, as described in the literature (Bordonné, 1989; Brancheriau and Baillères, 2002; Roohnia *et al*. 2011a, b), after obtaining the n^{th} modal frequency through Fast Fourier Transform (FFT), based on coordinates of evaluated spots from at least three initial modes of vibration, longitudinal specific modulus of elasticity was determined through a linear regression (Equation 1).

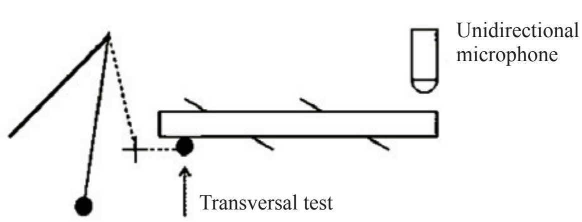


Figure 1 Experimental setup of flexural (transversal) free vibration test (Brancheriau *et al*., 2010; Roohnia *et al*., 2012)
Slika 1. Provedba slobodnoga vibracijskog testa savijanja (poprečno) (Brancheriau *et al*., 2010.; Roohnia *et al*., 2012.)

$$a_n = \left(\frac{E}{\rho}\right) - \left(\frac{E}{K \times G_{ij}}\right) \cdot b_n, R^2 \leq 1 \quad (1)$$

where the intercept (E/ρ) is flexural specific modulus of elasticity, G_{ij} is shear modulus in LR or LT plane (not followed in present approach), K is shape coefficient, equivalent to 0.833 (Brancheriau and Baillères, 2002), a_n and b_n are the coordinates of the evaluated spots from at least three initial modes of flexural vibration, n corresponds to mode number and R is the correlation coefficient of the Timoshenko's linear trend. The origin and background to the derivation of the Equation (1) were presented in details in the above introduced group of literature. NDT-lab® Portable System Setup for flexural free vibration test developed using MATLAB® 7.1 (Roohnia *et al*., 2006; Roohnia, 2007) was used here to obtain Fast Fourier Transform and related vibrational parameters (Fig. 1).

Damping due to internal friction (tanδ) was calculated from logarithmic decrement (Bodig and Jayne, 1993; Brémaud, 2008).

Acoustic coefficient (K) and acoustical converting efficiency (ACE) were calculated based on modulus of elasticity, density, and damping factor using Equations 2 and 3:

$$K = \sqrt{\frac{E}{\rho^3}} \quad (2)$$

$$ACE = \frac{K}{\tan \delta} \quad (3)$$

Where, K is the acoustic coefficient ($m^4 \cdot s^{-1} \cdot kg^{-1}$), E is the modulus of elasticity (Pa), ρ is the density of wooden specimens ($kg \cdot m^{-3}$), ACE is the acoustical converting efficiency ($m^4 \cdot s^{-1} \cdot kg^{-1}$).

The recording rate for the audio files was adjusted to 44100 Hz with 16 bits encoded (bit depth).

The scatter plots were used to compare the acoustical properties and their related change patterns.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

It seems critical to have an idea about the acoustic coefficient and acoustical converting efficiency. Acoustic coefficient (K) is an indicative of the proportion of elasticity of wood to its density, and in combination with damping due to internal friction is crucial in computing acoustic converting efficiency (ACE). Either of factors (K or ACE) were applied as a criterion in selection of woods used in musical instrument industry and it is highly believed that as much the rate of these two factors in wood is higher, that wood will be more appropriate for the musical instrument industry (Roohnia *et al*., 2011b; Rujinirun *et al*., 2005). This phenomenon would surely benefit from a better quality of wood with lower amounts of defects.

Drying-induced cracks were of the most important and major defects during the wood drying processes. They increase the internal friction, which consequently leads to the increase of the damping factor in the wood. In fact, as much the damping factor is lower and the acoustic coefficient is higher, the wood would have better resonance properties. Therefore, by considering the acoustic coefficient combined with damping in the shape of acoustical converting efficiency (ACE), the impact of defects for investigating the wood drying efficiency seems to become more and more facilitated.

Fig. 2 denotes that all the three drying schedules led to an increase in dynamic modulus of samples after the drying process, and schedule A resulted in a higher increase than the others, however, a lower correlation coefficient was observed.

The effect of each schedule on damping factor is shown in Fig. 3. Drying schedules of B and C led to an increase in damping factor, which was higher in the latter one. Conversely, schedule A, unlike B and C, decreased the damping factor. As the final moisture content was the same for all the schedules, it might inspire the preferences of schedule A.

Fig. 4 shows that the acoustic coefficient of samples dried under all the three schedules has been higher than the corresponding figure before the drying process. Schedule A experienced a higher increase than schedules C and B, respectively. All the three drying schedules led to an increase in acoustic converting efficiency in samples and the rate of increase in schedule A was higher than in schedule B and C, respectively (Fig. 5). It can be observed that not only the samples applied in this test showed unequal dynamic response, but the rate of these changes was also different depending on the schedule applied.

All the three drying schedules led to an increase in Dynamic Modulus of Elasticity of dried timber as against the non-dried ones, which can be attributed to mass reduction of samples due to moisture loss during the drying process (equation 1). In addition, dynamic modulus of samples dried by schedule A showed a higher increase than those dried by the schedule C and B, respectively. Although, changes in dynamic modulus are considered as one of the most important factors in qualitative evaluation of wood products, it should be born in mind that the place of defects, especially cracks, on wooden bars is highly effective on dynamic modulus of elasticity. Hence, we could not just rely on changes of this factor for judging and distinguishing the schedules applied.

In addition to the role of defects on damping factor, wood species (density, extractive contents, wood

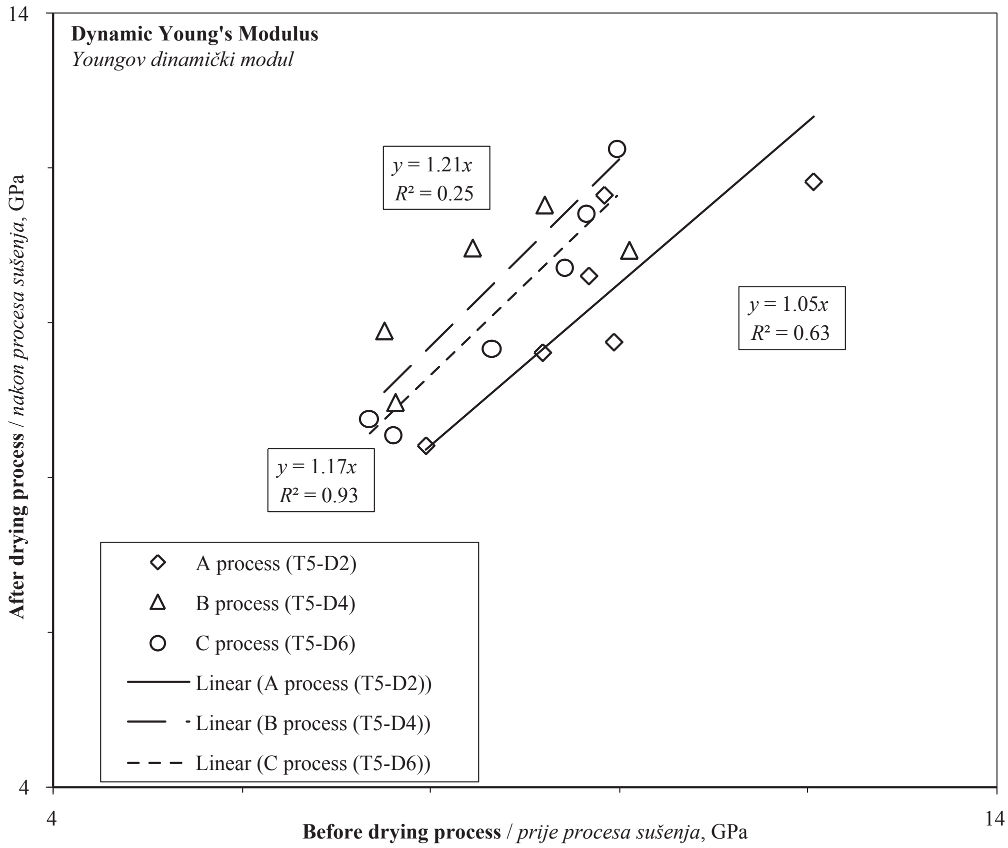


Figure 2 Effect of drying schedule on Dynamic Modulus of Elasticity
Slika 2. Utjecaj režima sušenja na dinamički modul elastičnosti

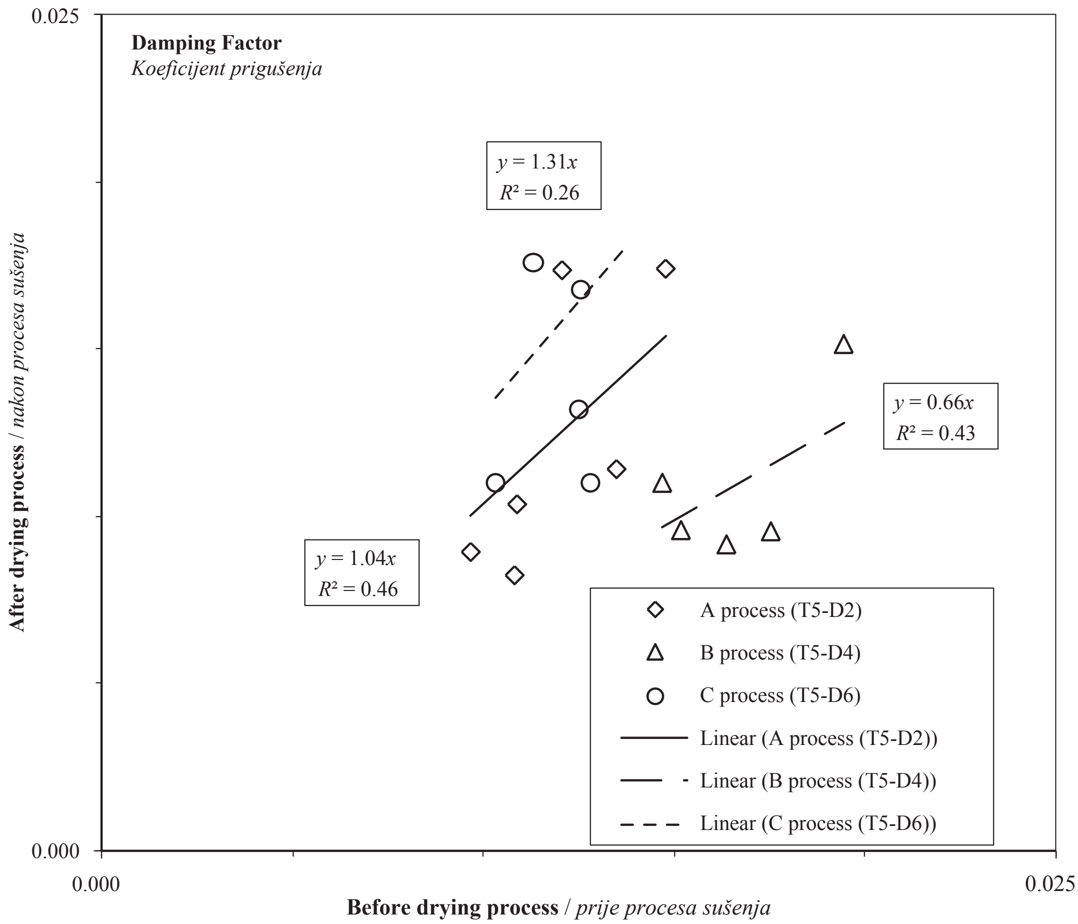


Figure 3 Effect of drying schedule on damping factor
Slika 3. Utjecaj režima sušenja na koeficijent prigušenja

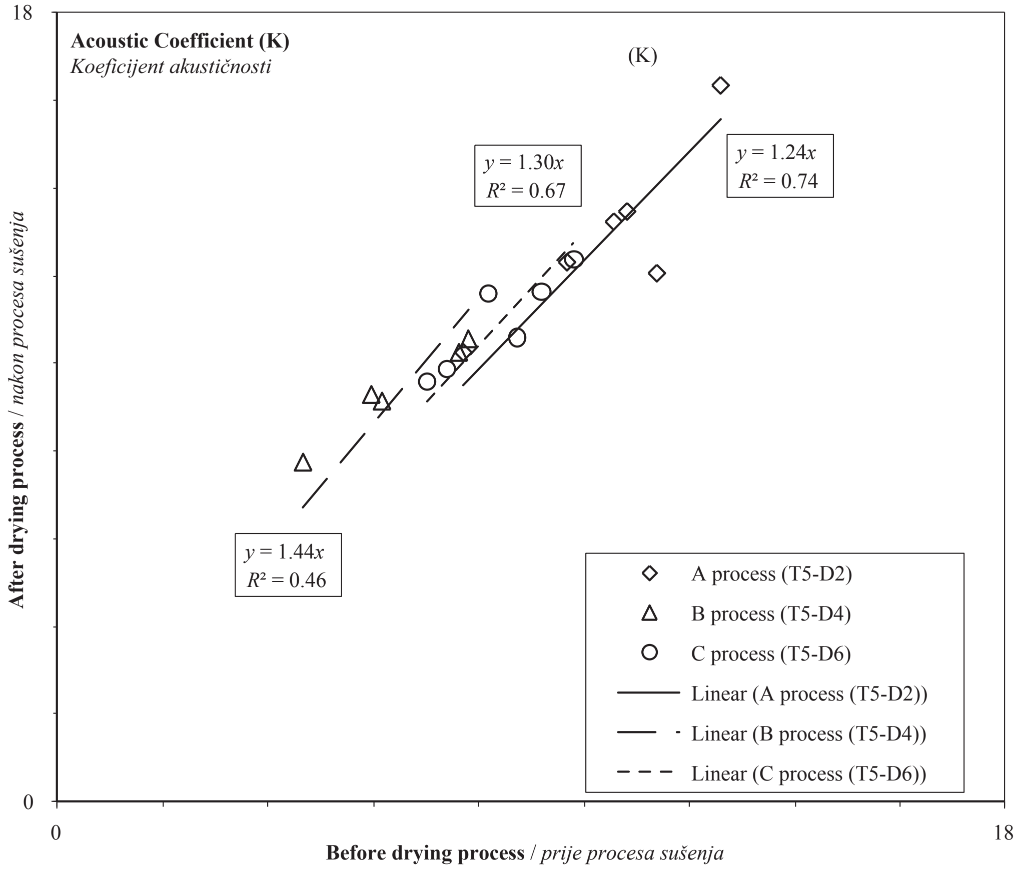


Figure 4 Effect of drying schedule on acoustic coefficient ($m^4 \cdot s^{-1} \cdot kg^{-1}$)
Slika 4. Utjecaj režima sušenja na akustični koeficijent ($m^4 \cdot s^{-1} \cdot kg^{-1}$)

texture, etc.) and moisture content are also influential (Tsoumis 1991). By reducing the moisture content of samples, the damping factor is expected to be reduced in the dried samples. However, this only happened in schedule A; and in the other two schedules (B and C) this factor increased and its rate was higher in schedule C than in schedule B. In this regard, existence of cracks in wood could be considered as a culprit in increasing of damping factor (Ouis, 2004; Roohnia *et al*., 2010; Hossein *et al*., 2009; Roohnia *et al*., 2011a). Therefore, the reduction in damping factor in schedule A, unlike the other two schedules, can be attributed to less formation of defects. In the preliminary stage of the present research, Shahverdi *et al*. (2012) reported a table, which has been extended (Table 1), to demonstrate the amount of visually recognized cracks attributed to the drying schedules A, B and C.

The rate of internal defect propagation due to drying processes severity has been higher in schedules B and C than in schedule A. In addition, considering total crack lengths and their abundance, schedule A has resulted in smaller amounts of drying defects i.e. crack (Table 1).

As mentioned before, acoustic coefficient is one of the most important parameters in estimating the acoustic specifications of a material, which is only in-

Table 1 Intensity of internal cracks in dried timber under three schedules
Tablica 1. Intenzitet unutarnjih pukotina u uzorcima drva sušenim pri tri različita režima sušenja

Crack length *Duljina pukotine* (mm)	**Abundance in schedule A** *Broj pukotina pri režimu sušenja A*	**Abundance in schedule B** *Broj pukotina pri režimu sušenja B*	**Abundance in schedule C** *Broj pukotina pri režimu sušenja C*
1-10	7	76	40
11-20	8	47	24
21-30	4	6	18
31-40	6	3	14
41-50	0	0	8
51-60	0	0	2
61-70	0	0	2
Total abundance *Ukupan broj*	25	132	108
Total Crack Length* *Ukupna duljina pukotina*	365	812	1668

* A summation based on the minimum value in crack length ranges. / *Zbroj se temelji na najmanjoj vrijednosti iz raspona duljine pukotine.*

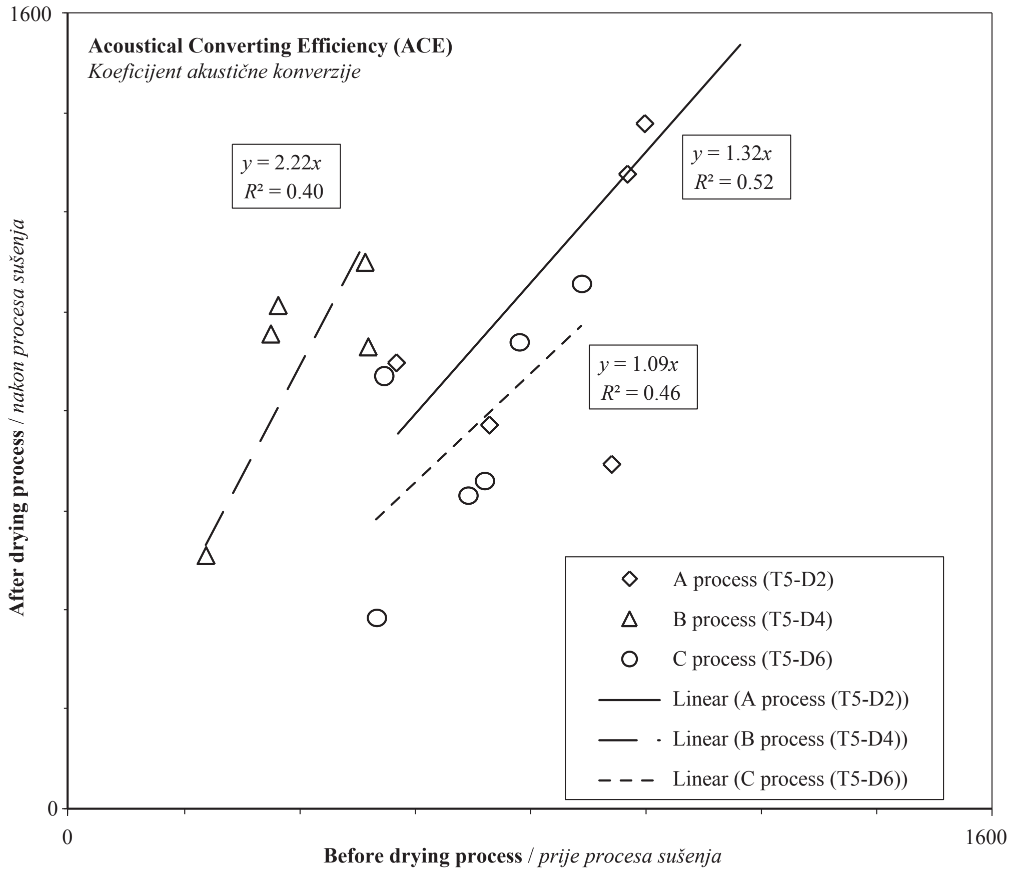


Figure 5 Effect of drying schedule on acoustical converting efficiency
Slika 5. Utjecaj režima sušenja na koeficijent akustične konverzije

fluenced by modulus of elasticity and density. Therefore, observing a trend like that observed in modulus of elasticity has not been a sufficient criterion. By considering the explanations expressed about modulus of elasticity, the changes that occurred in this factor cannot be solely a basis for judgment between the drying schedules used. Especially not in case when the trend R squares were not sufficiently high. Though, this correlation was strengthened in *ACE* comparisons.

As shown in equation 2, there is a direct relationship between acoustic coefficient and dynamic modulus of elasticity and, on the other hand, the same relationship can be found between dynamic modulus of elasticity and mechanical properties of wood. Since acoustic converting efficiency is a proportion of acoustic coefficient to damping factor (equation 5) and damping factor itself might be under the influence of cracks, it can be predicted that acoustic converting efficiency would be a proportion of wood resistance to the extent of defects induced by the drying process. The amount of this factor in the wood dried by schedule A was over twice as much as the non-dried one; whereas, in the wood dried by schedules B and C, this amount showed a 32 and 9 % increase, respectively.

The increasing trend of acoustic converting efficiency in the dried timber as opposed to non-dried one in all the three drying schedules was predictable due to a reduction of MC during drying followed by the reduction of damping factor. However, the increasing rate of this factor indicates that each schedule was applied to the extent to which secondary defects could be caused in timber. Hence, schedule A caused the least abundance of cracks in the dried samples as against schedule B and C, respectively.

It could be concluded that the free vibration method has the potential to substitute the existing destructive and traditional methods in qualitative non-destructive grading of dried timber, especially in determining the effect of the drying schedule on the development of cracks as the most common defect in the drying processes. Meanwhile, the acoustical converting efficiency (*ACE*), which is used as a criterion for wood quality in musical instrument industry, can be introduced as one of the key factors in grading of the dried timber under different drying conditions. A visual or destructive traditional inspection of wood drying quality may neglect hidden defects, unlike the proposed non-destructive evaluation.

4 CONCLUSIONS
4. ZAKLJUČAK

This research evaluated the potential of the vibration-based non-destructive testing method of timber influenced by the wood drying process. Different dynamic responses of samples before and after each drying schedule provided the ability to determine the importance of either internal or external defects in wood.

1) The least amount of cracks was observed in the samples dried by the schedule A (T_5-D_2), in com-

parison to the schedules B (T_5-D_4) and C (T_5-D_6), respectively. In other words, non-destructive testing methods are capable of being used in sorting strategies of timber as they are more and more sensitive in detecting the defects.

2) There was a significant difference between samples concerning the dynamic modulus of elasticity, damping factor, acoustic coefficient, and acoustic converting efficiency before and after the drying process.
3) Dynamic modulus of elasticity and acoustic coefficient may not be exclusively sufficient for choosing between the drying schedules applied.
4) Considering the negative impact of cracks on damping factor and acoustic coefficient, it was shown that changes in acoustic converting efficiency could be considered as an effective way for evaluating the drying schedules.

5 REFERENCES
5. LITERATURA

1. Axmon, J.; Hansson, M.; Sornmo, L., 2004: Experimental study on the possibility of detecting internal decay in standing *Picea abies* by blind impact response analysis. Forestry, 77 (3): 179-192. http://dx.doi.org/10.1093/forestry/77.3.179
2. Baskaran, R.; Janawadkar, M. P., 2007: Imaging defects with reduced space inversion of magnetic flux leakage fields. NDT&E International, 40: 451-454. http://dx.doi.org/10.1016/j.ndteint.2007.01.002
3. Biechele, T.; Chui, Y. H.; Gong, M., 2011: Comparison of NDE techniques for assessing mechanical properties of unjointed and finger-jointed lumber. Holzforschung, 65: 397-401. http://dx.doi.org/10.1515/hf.2011.038
4. Bodig, J.; Jayne, B., 1993: Mechanics of wood and wood composites (Persian translation by Ebrahimi. Gh.). Tehran University press. 686 pp.
5. Bordonné, P. A., 1989: Module dynamique et frottement intérieur dans le bois: Mesures sur poutres flottantes en vibrations naturelles. Thèse de doctorat de l'INP de Lorraine soutenue à Nancy, 154 p.
6. Brancheriau, L.; Baillères, H., 2002: Natural vibration analysis of clear wooden beams:a theoretical review. Wood Science and Technology, 36: 347-365. http://dx.doi.org/10.1007/s00226-002-0143-7
7. Brancheriau, L.; Kouchade, C.; Bremaud, I., 2010: Internal friction measurement of tropical species by various acoustic methods. J. Wood Sci., 56 (5): 371-379. http://dx.doi.org/10.1007/s10086-010-1111-8
8. Bremaud, I., 2008: Caracterisation mecanique des bois et facture: origins et recensement de la variabilite. Acte de la Journee d'etude Le bois: Instrument du Patrimoine Musical – Cite de la Musique, 24-46.
9. Hossein, M. A.; Roohnia, M.; Shahverdi, M., 2009: Some footprints of wood internal defects on three first mode-shapes of free vibration‹16th international symposium on nondestructive testing and evaluation of wood. Beiging, China.
10. Lazarescu, C.; Watanabe, K.; Avramidis, S., 2010: Density and Moisture Profile Evolution during Timber Drying by CT Scanning Measurements. Drying Technology, 28: 460-467. http://dx.doi.org/10.1080/07373931003613478
11. Lee, S. J., 2001: Free-vibration analysis of plates and sheels with a nine-node assumed natural degenerated shell element. Journal of Sound and vibration. 241 (4): 605-633. http://dx.doi.org/10.1006/jsvi.2000.3313
12. Milić, G.; Kolin, B., 2008: Influence of Duration of the Conditioning Process on the Reduction of Case-Hardening Level in Kiln-Dried Beech and Oak lumber. Drying Technology, 26: 1225-1231. http://dx.doi.org/10.1080/07373930802307035
13. Möttönen, V., 2006: Variation in Drying Behavior and Final Moisture Content of Wood during Conventional Low Temperature Drying and Vacuum Drying of Betula pendula Timber. Drying Technology, 24: 1405-1413. http://dx.doi.org/10.1080/07373930600952750
14. Mugabi, P.; Rypstra, T.; Vermaas, H. F.; Nel, D. G., 2011: Effect of kiln drying schedule on the quality of South African grown Eucalyptus grandis poles. Eur. J. Wood Prod., 69: 19-26. http://dx.doi.org/10.1007/s00107-009-0392-3
15. Oltean, L.; Teischinger, A., 2011: Influence of low and moderate temperature kiln drying schedules on specific mechanical properties of Norway spruce wood. Eur. J. Wood Prod., 69: 451-457. http://dx.doi.org/10.1007/s00107-010-0467-1
16. Ouis, D., 2004: Assessment of severity and localization of a transversal crack in a wood beam through a study of its natural modes of vibration. Holz Roh Werkst, 62: 17-22. http://dx.doi.org/10.1007/s00107-003-0442-1
17. Perré, P.; Roger, B. K., 2006: Drying of Wood: Principles and Practices. Text book, 57 p.
18. Roohnia, M.; Bremaud, I.; Guibal, D.; Manouchehri, N., 2006: NDT-LAB; Software to evaluate the mechanical properties of wood. In: M. Fioravanti and N. Macchioni: International Conference on Integrated Approach to Wood Structure Behaviour and Applications – Joint meeting of ESWM and Cost Action E35. 15-17 May, Florence – Italy, DISTAF – University of Florence, 213-218.
19. Roohnia, M., 2007: NDT-LAB, System to evaluate the mechanical properties of wood. IR-Patent No. 44032/22-08-1386. Iranian official Journal.
20. Roohnia, M.; Yavari, A.; Tajdini, A., 2010: Elastic Parameters of Poplar Wood with End-Cracks. Annals of Forest Science, 67 (4): 1-6. http://dx.doi.org/10.1051/forest/2009129
21. Roohnia, M.; Alavi-Tabar, S. E.; Hossein, M. A.; Brancheriau, L.; Tajdini, A., 2011a: Dynamic modulus of elasticity of drilled wooden beams. Nondestructive Testing and Evaluation, 26 (2): 141-153. http://dx.doi.org/10.1080/10589759.2010.533175
22. Roohnia, M.; Tajdini, A.; Manouchehri, N., 2011b: Assessing wood in sounding boards considering the ratio of acoustical anisotropy. NDT&E International, 44: 13-20. http://dx.doi.org/10.1016/j.ndteint.2010.09.001
23. Roohnia, M.; Kohantorabi, M.; Jahan-Latibari, A.; Tajdini, A.; Ghaznavi, M., 2012: Nondestructive assessment of glued joints in timbers applying vibration-based methods. Eur. J. Wood Prod., 70 (6): 791-799. http://dx.doi.org/10.1007/s00107-012-0616-9
24. Rujinirun, C.; Phinyocheep, P.; Prachyabrued, W.; Laemsak, N., 2005: Chemical treatment of wood for musical instruments. Part I: acoustically important properties of wood for the Ranad (Thai traditional xylophone. Wood Science and Technology, 39: 77-85. http://dx.doi.org/10.1007/s00226-004-0275-z
25. Shahverdi, M.; Dashti, H.; Hossein, M. A., 2012: Establishing a kiln drying schedule for poplar (*Populus alba* L.) lumber of 7cm thickness. BioResources, 7 (1): 26-37.
26. Simpson, W. T., 1991: Dry Kiln Operator's Manual. USDA Forest Service. Agriculture Handbook. 188 p.

27. Tanaka, T.; Avramidis, S.; Shida, S., 2009: Evaluation of moisture content distribution in wood by soft X-ray imaging. J Wood Sci, 55: 69-73. http://dx.doi.org/10.1007/s10086-008-0997-x
28. Tarmian, A.; Eshagh, S.; Gholamiyan, H., 2010: The contradictory effect of drying internal checks and moisture changes on the ultrasonic propagation in poplar wood (Populous nigra). J Indian Acad Wood Sci, 7 (1-2): 43-48. http://dx.doi.org/10.1007/s13196-011-0009-4
29. Tsoumis, G., 1991: Science and technology of wood. Van Nostrand Reinold.
30. Wang, S.; Chen, J.; Tsai, M.; Lin, C.; Yang, T., 2008: Grading of Softwood Lumber Using Non-destructive Techniques. Journal of Material Processing Technology, 208: 149-158. http://dx.doi.org/10.1016/j.jmatprotec.2007.12.105
31. Watanabe, K.; Saito, Y.; Avramidis, S.; Shida, S., 2008: Non-destructive Measurement of Moisture Distribution in Wood during Drying Using Digital X-ray Microscopy. Drying Technology, 26 (5): 590-595. http://dx.doi.org/10.1080/07373930801944796
32. Watanabe, K.; Lazarescu, C.; Shida, S.; Avramidis, S., 2012: A Novel Method of Measuring Moisture Content Distribution in Timber during Drying Using CT Scanning and Image Processing Techniques. Drying Technology, 30: 256-262. http://dx.doi.org/10.1080/07373937.2011.634977

Corresponding address:

Assoc. Prof. MEHRAN ROOHNIA, Ph.D.

Karaj Branch, Islamic Azad University
Shahid Moazen BLVD.
Rajaee-shahr, KARAJ – IRAN
e-mail: mehran.roohnia@kiau.ac.ir

Dragica Vilotić[1], Jasmina Popović[1], Suzana Mitrović[2], Mirjana Šijačić-Nikolić[1], Mirjana Ocokoljić[1], Jelena Novović[1], Milorad Veselinović[2]

Dimensions of Mechanical Fibres in *Paulownia elongata* S. Y. Hu Wood from Different Habitats

Dimenzije libriformskih vlakanaca *Paulownia elongata* S. Y. Hu s različitih staništa

Preliminary paper • Prethodno priopćenje
Received – prispjelo: 11. 12. 2013.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*11; 630*.811.155.1; 674.031.951.62*
doi:10.5552/drind.2015.1365

ABSTRACT • *Paulownia elongata S. Y. Hu, has exceptionally fast growth in juvenile stage (more than 3 m in the second year). Due to its characteristic of easy generative and vegetative propagation (tissue culture) and renewal, it currently presents the most suitable plant for biomass production in our region, with short rotation time. Poplar clones provide raw material for paper and pulp industry at the moment, and this industry is the biggest softwood consumer in Serbia. Anatomical properties of wood mechanical fibres in Paulownia elongata S. Y. Hu juvenile wood have not been researched in Serbia, since this species has been recently introduced from China (1993). The aim of this paper is to explore the impact of habitats (soil) and fertilisation on wood fibre dimensions in juvenile wood of Paulownia elongata S. Y. Hu. Samples for research of wood fibres originate from experimental plantations of Paulownia elongata S. Y. Hu, 2 years of age, from two different sites: Obrenovac-Veliko polje and Ub-Pambukovica. Based on research of wood anatomy, it has been concluded that there are significant statistical differences in wood fibre dimensions in Paulownia elongata S. Y. Hu from different habitats. Research of wood fibre dimensions in Paulownia elongata S. Y. Hu juvenile wood from two different sites contributes to determine its use for the pulp industry, which supports cultivation of this fast growing species (Table 3, 4 i 5).*

Key words: *wood fibre, Paulownia elongata S.Y.Hu, soil, wood anatomy*

SAŽETAK • *Paulownia elongata S. Y. Hu svojim svojstvom iznimno brzog rasta u juvenilnoj fazi razvoja, kao i mogućnostima jednostavnoga generativnoga i vegetativnog razmnožavanja (kultura tkiva) i obnove nasada trenutačno je najprikladnija vrsta s kratkom ophodnjom za proizvodnju biomase u našoj regiji. U ovom su trenutku klonovi topola sirovina za industriju celuloze i papira, koja je najveći potrošač mekih listača. Anatomska svojstava libriformskih vlakanaca Paulownia elongata S. Y. Hu u juvenilnoj fazi razvoja još nisu istražena u Srbiji jer je Paulownia elongata S. Y. Hu uvezena iz Kine u Srbiju tek 1993. godine. Cilj ovog rada bio je istražiti utjecaj staništa (tla) i utjecaj gnojidbe na dimenzije libriformskih vlakanaca Paulownia elongata S. Y. Hu u juvenilnoj fazi razvoja. Uzorci za istraživanje dimenzija libriformskih vlakanaca podrijetlom su iz pokusnih nasada Paulownia elongata S. Y. Hu starih dvije godine s dva različita mjesta: Obrenovac - Veliko Polje i Ub - Pambukovica. Na*

[1] Authors are professor, assistant, professor, assistant professor and assistant at University of Belgrade, Faculty of Forestry, Belgrade, Serbia. [2]Authors are research associate and senior research fellow at Institute of Forestry, Belgrade, Serbia.
[1] Autori su profesor, asistent, profesor, docent i asistent Sveučilišta u Beogradu, Šumarski fakultet, Beograd, Srbija. [2]Autori su znanstveni suradnik i znanstveni savjetnik Šumarskog instituta, Beograd, Srbija.

temelju rezultata istraživanja anatomske strukture zaključeno je da postoje statistički značajne razlike u dimenzijama libriformskih vlakanaca u Paulownia elongata S. Y. Hu. s različitih staništa te da je stanište imalo utjecaja na te različitosti (tabl. 3., 4. i 5.). Istraživanja dimenzija drvenih vlakana juvenilnog drva Paulownia elongata S. Y. s dva različita staništa pridonijela su potvrdi njezine uporabe za industriju celuloze, što podržava uzgoj te brzorastuće vrste.

Ključne riječi: *libriformska vlakanca, Paulownia elongata S. Y. Hu, tlo, anatomija drva*

1 INTRODUCTION
1. UVOD

Paulownia elongata S. Y. Hu is characterised by its excessively fast growth in the juvenile phase (vertical growth is up to 4 m during the second year and within the same period the growth in diameter is about 5 - 7 cm), as well as by its easy generative and vegetative propagation (tissue culture) and plantation renewal (Šoškić *et al.*, 2003). *Paulownia elongata* characteristics show that the species is recommended for biomass production. (Vilotić *et al.*, 2011).

There are many factors, such as soil and climate, that affect the anatomical properties of wood (Zhang, 1992; Vilotić and Knežević, 1994; Vilotić, 2000; Hacke and Sperry, 2001). Esteban *et al.* (2010) and Vilotić and Knežević (1994) state that ecological environmental circumstances have affected significantly not only the properties of the tree, but also the dimensions of its conductive cells. Venugopal and Liangkuwang (2007) state that there is an obvious correlation between climatic parameters, activities of vascular cambium and xylem formation. Research has shown that the physical and chemical characteristics of soil have a great influence on macroscopic characteristics, microscopic structure, density, and physical, mechanical and technological properties of wood (Vilotić, 1992; Vilotić *et al.*, 2005; Šoškić *et al.*, 2003).

Paulownia elongata S. Y. Hu was introduced from China to Serbia in 1993. Anatomical characteristics of its wood fibres in juvenile wood have not been researched so far. The goal of this paper was to examine: a) the influence of habitat (soil) on juvenile wood fibre dimensions in *Paulownia elongata* S. Y. Hu; and b) the influence of fertilisation on juvenile wood fibre dimensions of *Paulownia elongata* in different habitats.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

Samples used for research of the influence of habitat and feeding on the dimensions of wood fibres were taken from experimental 2-year-old plantations of *Paulownia elongata* S. Y. Hu, at two different sites: Obrenovac-Veliko polje and Ub-Pambukovica.

2.1 Climate
2.1. Klima

Obrenovac is located almost in the middle of a northern, moderate continental strip, with the climate milder than the typical Pannonian continental one. The climate in Pambukovica is a moderately continental one, with certain distinctive characteristics. The basic climate factors for the areas of Obrenovac and Pambukovica are given as the average monthly temperatures (Figure 1) and the average monthly precipitations (Figure 2), for the period from 1948 to 2012. The climate data for Obrenovac and Pambukovica areas were taken from the monitoring stations in Belgrade and Valjevo, respectively. Both monitoring stations are supervised by the Republic Hydrometeorological Service of Serbia.

Figures 1 and 2 show similar climate for the areas of Obrenovac and Pambukovica, in terms of the average monthly temperatures and the average monthly precipitations. The annual distribution of precipitations is very favourable for the agricultural production (the precipitation increases throughout the whole spring) (Pavlović *et al.*, 2011).

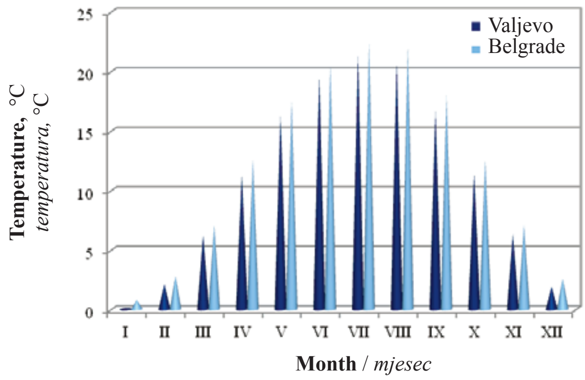


Figure 1 Average monthly temperatures (°C) measured at the monitoring stations in Valjevo and Belgrade
Slika 1. Srednje mjesečne vrijednosti temperature (°C) za postaje Valjevo i Beograd

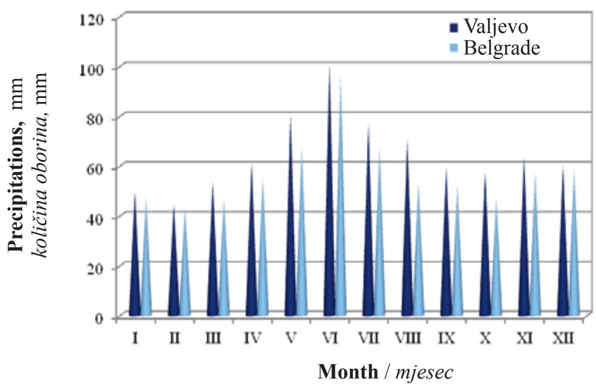


Figure 2 Average monthly precipitations (mm) measured at the monitoring stations in Valjevo and Belgrade
Slika 2. Srednje mjesečne vrijednosti oborina (mm) za postaje Valjevo i Beograd

Table 1 Basic characteristics of soils in Obrenovac and Pambukovica areas
Tablica 1. Osnovna svojstva tla s područja Obrenovca i Pambukovice

Site *Mjesto*	**Soil texture** Tekstura tla	**Hydraulic permeability** *Propusnost tla za vodu*	**Aeration** *Kapacitet tla za zrak*	**pH value in H_2O** *pH u H_2O*	**Total humus content** *Sadržaj humusa*
Obrenovac	clay / *glina*	poor / *slaba*	poor / *slab*	5.7	low / *nizak*
Pambukovica	clay / *glina*	poor / *slaba*	poor / *slab*	5.0	low / *nizak*

2.2 Soil
2.2. Tlo

Table 1 shows physical and chemical soil characteristics in Obrenovac and Pambukovica. The low level of humus content in soils suggests that the total nitrogen content is also low. In addition, the lack of the organic substances and phosphorous is also notable, although potassium is present in satisfactory amounts.

2.3 Treatments
2.3. Tretmani

In order to improve the nutritive values of these soils, the organic fertilizer was used at both sites. Three sample groups were taken from each site. Two sample groups (from each site) were treated with the combination of fertor (chicken fertilizer) and polimer (the quantities of the components are given in Table 2). In addition, the sand and the Sunoko calcification agent were used at the Pambukovica site. The sand was added to improve the physical properties of the soil, while the Sunoko calcification agent was added to decrease the soil acidity. The effects of the treatments on both sites were evaluated in regard to the control sample group (from each site), which has not been treated.

Fertor is an organic fertiliser, composed of 100 % of chicken fertiliser, improved by other organic substances of plant origin, increasing and enhancing the fertiliser nutritive value. In addition to main elements (N, P, K, Ca and Mg), it also contains microelements (Fe, Mn, B, Zn, Cu). Part of the macro and micro elements is easily accessible and readily available for the plant, while the remainder is gradually released (Web Source 1).

Sunoko calcification agent is an inorganic improving agent for the soil, suitable for all plant culture as a fertiliser and agent for the enhancement of soil properties. It is recommended for all types of soil, whose pH value is lower than 5.5, as is the case with Pambukovica soil. With a content of minimum 70 % of $CaCO_3$ and $MgCO_3$, but also P, K, Fe, as well as Mn, Zn, Cu, Co and pH value of 8.22, it improves the structure and pH value of acidic soils, and returns microelements into the soil, thus improving soil fertility (Web Source 2).

2.4 Sampling and preparation of samples
2.4. Uzorkovanje i priprema uzoraka

The samples were taken from root collars, as rolls 1 cm thick. These were chopped into match-size pieces and macerated in order to obtain individual cells of wood tissue suitable for measuring mechanical fibre dimensions.

Wood tissue maceration of *Paulownia elongata* samples was carried out using Franklin's reagent (Franklin, 1945), a mixture of 30 % of hydrogen peroxide and glacial acetic acid in the ratio 1:1.

2.5 Measuring wood fibre dimensions
2.5. Mjerenje dimenzija drvnih vlakanaca

Measurement of length and width of mechanical fibres of *Paulownia elongata* was carried out at the Institute for Forestry in Belgrade, using an optical microscope, augmenting the sample magnified 40 times, using the "Image Tool" programme.

The mean fibre length and the mean fibre width were obtained from 30 measurements (30 fibres) on each of the three samples that made one sample group. The results were statistically analyzed by the single factor ANOVA test.

Table 2 Coding of samples and applied treatments
Tablica 2. Prikaz označivanja uzoraka i primijenjenih tretmana

Site *Mjesto*	**Sample group** *Oznaka grupe uzorka*	**Sample age (year)** *Starost uzoraka (godina)*	**Number of samples** *Broj uzoraka*	**Treatment** *Tretman*	
Obrenovac	OB.1	2	3		25 g polimer 250 g fertora
	OB.2	2	3		25 g polimer 125 g fertor
	OB.3 (Control)	2	3	/	
Pambukovica	P.1	2	3	1250 g sand 1 kg Sunoko calcification agent	25 g polimer 250 g fertor
	P.2	2	3		25 g polimer 125 g fertor
	P.3 (Control)	2	3	/	

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Wood fibres are the mechanical elements present in the *Paulownia elongata* tree. These are prosenchima elements, very sharp at the ends.

Statistical analysis of measured lengths and widths of mechanical fibre samples from juvenile sprouts enabled an overview of the influences of feeding and habitat on the dimensions of *Paulownia elongata* wood fibre. By the analysis of measured values within each of the sampling groups, minimum and maximum measured and mean values were obtained for lengths and widths of fibres. From the mass of 90 measurements per sample, minimum and maximum values were selected for each group. Mean values for fibre lengths and widths were obtained as arithmetic mean values of those measured in each sampling group. This procedure was applied to all sampling groups and both habitats.

Minimum, maximum and mean values, as well as standard deviations of fibre length in *Paulownia elongata* control and treated samples taken from these two habitats are shown in Table 3. The results of the multiple range tests for both fibre length and fibre width of the *Paulownia elongata* are given in Table 4.

3.1 Influence of habitats on the length of wood fibre
3.1. Utjecaj staništa na duljinu drvnih vlakanaca

The influence of habitat on the dimensions of wood fibres can be seen through the comparison of values of fibre length of *Paulownia elongata* control samples (those without fertilising) and the researched habitats.

Tables 3 and 4 show significant statistical differences in the fibre length of the control samples (OB.3 and P.3) from these two sites. Fibre length of samples of *Paulownia elongata* cultivated in Obrenovac have a mean value of 0.459 mm, while the mean value of samples of the same age taken from the site of Pambukovica is 0.371 mm.

In addition, it is interesting to compare maximum measured lengths of fibres from these two sites. It can be seen that the maximum measured fibre length of 1.25 mm recorded for a plant cultivated in Obrenovac is twice as long as the maximum measured fibre length of 0.57 mm measured in a plant cultivated in Pambukovica.

This discrepancy in mean and maximum values of fibre length in control samples from these sites indicates that the habitats and their properties greatly influenced the fibre length.

Research conducted by Popović and Radošević (2011) showed that mean mass and mean numerical length of fibres measured on a 12-year old *Paulownia elongata* cultivated in an experimental plantation in Bela Crkva, ranged between 0.985 and 1.022 mm, while values measured on *Paulownia fortunei* (the same age, from the same location) in terms of mass and numerical length of fibres were somewhat smaller and ranged between 0.783 and 0.818 mm (Popović and Radošević, 2008). Similar values for *Paulownia elongata* fibre length of 0.96-1.19 mm were stated by Cheng (1983). Having in mind that the 2-year old *Paulownia elongata* (Table 3), cultivated in the Republic of Serbia, has the average fibre length in the range between 0.371 and 0.459 mm, it could be assumed that

Table 3 Fibre length values for *Paulownia elongata* for different treatments
Tablica 3. Vrijednosti duljina vlakanaca *Paulownia elongata* za različite tretmane

Site / *Mjesto*	**Obrenovac (OB)**				**Pambukovica (P)**			
Sample group *Oznaka grupe uzoraka*	**min** mm	**max** mm	**Mean value** *Srednja vrijednost* mm	**Standard deviation** *Standardna devijacija*	**min** mm	**max** mm	**Mean value** *Srednja vrijednost* mm	**Standard deviation** *Standardna devijacija*
OB.3/P.3 (Control)	0.15	1.25	0.459	0.1700	0.21	0.57	0.371	0.0850
OB.1/P.1	0.21	0.64	0.441	0.0976	0.22	0.77	0.457	0.1002
OB.2/P.2	0.21	0.70	0.409	0.0973	0.22	1.29	0.478	0.1529

Table 4 Statistical analysis of results obtained by measuring fibre length and fibre width (ANOVA)
Tablica 4. Rezultati statističke analize rezultata mjerenja duljine i širine vlakanaca (ANOVA)

Pairs of sample groups *Parovi grupa uzoraka*	**Fibre length** *Duljina vlakanaca*			**Fibre width** Širina vlakanaca		
	F	F crit	*P*-value	F	F crit	*P*-value
OB.3 - P.3	19.14094	3.894232	*2.06E-05	4.537981	3.894232	*0.034524
OB.1 - OB.2	0.889036	3.894838	0.347031	2.460193	3.894838	0.118561
OB.1 - OB.3	3.193978	3.894232	0.075612	0.792211	3.894232	0.374634
OB.2 - OB.3	5.473616	3.894838	*0.020428	6.152337	3.894838	*0.014064
P.1 - P.2	3.334355	3.894232	0.069523	20.219635	3.894232	*1.24E-05
P.1 - P.3	39.496385	3.89364	*2.41E-09	17.711687	3.894232	*4.07E-05
P.2 - P.3	11.522480	3.89364	*0.000846	6.05E-13	3.894232	0.999999

* denotes a statistically significant difference / *označava statistički značajnu razliku*

Table 5 Fibre width values for *Paulownia elongata* for different treatments
Tablica 5. Vrijednosti širine vlakanaca *Paulownia elongata* pri različitim tretmanima

Site *Mjesto*	**Obrenovac (OB)**				**Pambukovica (P)**			
Sample group *Oznaka grupe uzoraka*	**min** µm	**max** µm	**Mean value** *Srednja vrijednost* µm	**Standard deviation** *Standardna devijacija*	**min** µm	**max** µm	**Mean value** *Srednja vrijednost* µm	**Standard deviation** *Standardna devijacija*
OB.3/P.3 (Control)	10	50	21	7.3	10	30	23	7.9
OB.1/P.1	10	40	22	6.7	10	40	27	5.2
OB.2 / P.2	10	40	23	6.2	10	40	24	6.5

there is an increasing trend in fibre length with the increasing age, for this wood species.

3.2 Influence of fertilising on the length of wood fibres
3.2. Utjecaj gnojidbe na duljinu drvnih vlakanaca

Statistical analysis of the length and width of the mechanical fibres of *Paulownia elongata* samples provide the possibility to determine the influence of various treatments on the fibre dimensions. For that purpose, the results of the treated samples were compared with the results obtained from the control sample group at the related site (Table 4).

Based on the analysis of fibre length mean values for the Obrenovac site, presented in Table 3, it can be concluded that the fibre length mean value of 0.459 mm in the control sample is higher than the fibre length of samples treated by fertiliser (0.441 and 0.409 mm), which indicates that fertilising did not positively affect the length of wood fibres in this habitat.

Table 3 also shows mean values for *Paulownia elongata* fibre lengths from the Pambukovica site. In addition, it can be noticed that fibre length mean value of 0.371 mm in a control sample (P.3 sample) has the lowest value, while mean values of fibres taken from fertilised samples (P.1 and P.2) of 0.457 mm and 0.478 mm, respectively, are significantly higher (Table 4). Based on that, it can be concluded that fertilising had a positive influence on fibre length in the Pambukovica site.

Table 5 shows mean values and standard deviation, as well as maximum and minimum values measured for fibre width in control and fertilised samples of *Paulownia elongata* from these two habitats.

3.3 Influence of habitat on width of wood fibres
3.3. Utjecaj staništa na širinu drvnih vlakanaca

It can be observed that mean values of fibre width measured in control samples of *Paulownia elongata* cultivated in Obrenovac and Pambukovica, shown in Table 5, do not show statistically significant differences (Table 4). The maximum measured value of fibre width in control samples cultivated in Obrenovac of 50 µm is somewhat higher than fibre width in control samples cultivated in Pambukovica of 30 µm, while the minimum measured values of fibre width in control samples cultivated in these two habitats are identical. These results suggest that the site itself had no influence on the fibre width.

3.4 Influence of fertilising on width of wood fibres
3.4. Utjecaj gnojidbe na širinu drvnih vlakanaca

Treated sample group OB.1 (Obrenovac site) showed 1 µm higher values of mean fibre width in comparison to non-treated samples (OB.3), which is not a statistically significant difference. Mean fibre with of the treated sample group OB.2 was significantly higher in regard to the control samples (Table 5 and Table 4).

The differences of the mean fibre values between the treated and the control samples are higher at the Pambukovica site (in regard to Obrenovac site), and they are statistically significant when comparing the P.1 sample group with the other two.

Minimum values of fibre width measured in fertilised and untreated samples taken from both habitats are the same. As for maximum values of measured fibre width, control samples taken from the Obrenovac site are a little bit higher than fertilised ones, while maximum measured values of fibre width in control samples taken from the Pambukovica site are a little bit lower than in fertilised samples. However, the statistical analysis of the results does not provide the confirmation that the observed differences occurred as the consequence of the treatments.

4 CONCLUSIONS
4. ZAKLJUČAK

Based on the conducted research, it can be concluded that there are differences in fibre lengths measured in control samples of *Paulownia elongata* from different habitats, indicating that habitat with its properties (climate, soils, and so on) affects the fibre length.

Taking into account that fibre length measured in control samples from Pambukovica shows significantly lower values compared to the ones from Obrenovac, it can be concluded that habitat in Pambukovica is not suitable for this plant species.

Differences in fibre width measured in control samples of *Paulownia elongata* from different habitats are not significant, which leads to the conclusion that habitat did not affect the fibre width.

The treatments performed at the Obrenovac site did not have a positive influence on the fibre length, according to the statistical analysis of the fibre length values for the control and the treated samples.

Significant difference in the fibre length was found between both treated sample groups in regard to the control group from the Pambukovica site. The lowest mean value of fibre length of 0.371 mm was recorded with the control sample group (P.3), while sample groups of P.1 and P.2 which were treated, had higher mean values of fibre length of 0.457 and 0.478 mm, respectively, indicating that fertilising influenced the fibre length of *Paulownia elongata* at the Pambukovica site.

Significant differences in fibre width on both sites were only recorded between the treated and the relative control sample group (OB.2 – OB.3 i P.1 – P.3). Therefore, it cannot be confirmed that there was a significant influence of the fertilizing treatments on the fibre width of *Paulownia elongata*.

Tests conducted in relation to the juvenile wood fibre length of *Paulownia elongata* S. Y. Hu from two different sites confirmed that its very young wood could be used as raw material for pulp production, and that cultivation of this plant species was possible in our country.

Acknowledgements - Zahvala

The research was financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. Research results have been partly produced in the framework of the project III43007 and partly in the framework of the project TR31041.

5 REFERENCES
5. LITERATURA

1. Cheng, J. Q., 1983: Studies on the wood properties of the genus *Paulownia* I. Scienta Silvae Sinicae, 19(1): 57-63.
2. Esteban, L. G.; Martín, J. A.; de Palacios, P.; Fernández, F. G.; López, R., 2010: Adaptive anatomy of *Pinushalepensis* trees from different Mediterranean environments in Spain. Trees Struct Funct, 24: 19-30. http://dx.doi.org/10.1007/s00468-009-0375-3
3. Franklin, G. L., 1945: Preparation of thin sections of synthetic resins, and woodresin composites, and a new macerating method for wood. Nature, 155: 51. http://dx.doi.org/10.1038/155051a0
4. Hacke, U. G.; Sperry, J. S., 2001: Functional and ecological xylem anatomy. Perspect Plant Ecol Evol Syst, 4: 97-115. http://dx.doi.org/10.1078/1433-8319-00017
5. Pavlović, M.; Radivojević, A.; Dimitrijević, Lj., 2011: Climate of Sokobanja Basin and its influence on the development of agriculture. Journal of the Geographical Institute “Jovan Cvijić”, 61(1): 13. http://dx.doi.org/10.2298/IJGI1101013P (Available online at www.gi.sanu.ac.rs)
6. Popović, J.; Radošević, G., 2008: Anatomsko-hemijske karakteristike drvnih vlakana vrste *Paulownia fortunei* Seem. Hemsl. Šumarstvo, 4: 71-77.
7. Popović, J.; Radošević, G., 2011: *Paulownia elongata* S. Y. Hu - Anatomical and Chemical Properties of Wood Fibers. Prerada drveta, 9(34-35): 15-22.
8. Šoškić, B.; Vukovojac, S.; Lovrić, A., 2003: Istraživanje nekih fizičkih svojstava drveta *Paulownia elongata* i *Paulownia fortunei*. Glasnik Šumarskog fakulteta, 87: 211-221.
9. Venugopal, N.; Liangkuwang, M. G., 2007: Cambial activity and annual rhythm of xylem production of elephant apple tree (*Dyllenia indica* Linn) in relation to phenology and climatic factor growing in sub-tropical wet forest of northeast India. Trees Struct Funct, 21: 101-110. http://dx.doi.org/10.1007/s00468-006-0101-3
10. Vilotić, D., 1992: Anatomical structure of trees Virginia Live Oak (*Quercus virgiliana* Ten./Ten.) at different sites of the Deliblato sand. PhD, University of Belgrade, Faculty of Forestry, Belgrade, Serbia, 1-117.
11. Vilotić, D., 2000: Comparative anatomy of wood. University of Belgrade, Faculty of Forestry, Belgrade, Serbia, p. 176.
12. Vilotić, D.; Knežević, M., 1994: Study of Virginia Live Oak (*Quercus virgiliana* /Ten./Ten.) width of vessel elements at different sites of the Deliblato sand. The Deliblato sands – Proceedings, VI (2): 299-306.
13. Vilotić, D.; Radošević, G.; Vukovojac, S., 2005: Comparative studies of anatomic structures of *Paulownia elongata* and *Paulownia fortunei*. Proceedings of the Symposium - Forestry and sustainable development, 5-6 November 2004, Belgrade, 1-6.
14. Vilotić, D.; Šijačić-Nikolić, M.; Vukovojac, S., 2011: Basic characteristics of the species *Paulownia elongata* S.Y. Hu and *Paulownia fortunei* Seem. Hemsl. and the possibility of their use in the conservationof agricultural protection area. Proceedings of the meeting: Let’s help Serbia to breathe easier, 29 September 2011, Belgrade, 99-107.
15. Zhang, S. Y., 1992: Wood anatomy of the Rosaceae. Rijskherbarium Hortus Botanicus, Faculty of Science, University Leiden, Leiden, Netherlands, 81-158.
16. ***Web Source 1: http://www.mrf-garden.com/?cat=35&page=167 (Accessed May 11, 2015)
17. ***Web Source 2: http://www.sunoko.rs/agroservis/brosure/ (Accessed May 11, 2015)

Corresponding address:

Senior research fellow MILORAD VESELINOVIĆ, Ph.D.

Institute of Forestry
Kneza Višeslava 3
11000 Belgrade, SERBIA
e-mail: mvcetiri@ikomline.net

Miloš Hitka[1], Zuzana Závadská[2], Denis Jelačić[3], Žaneta Balážová[1]

Qualitative Indicators of Company Employee Satisfaction and Their Development in a Particular Period of Time

Kvalitativni pokazatelji zadovoljstva uposlenika kompanije i njihova razvoja u promatranome vremenskom razdoblju

Preliminary paper • Prethodno priopćenje
Received – prispjelo: 24. 6. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*79; 65.015*
doi:10.5552/drind.2015.1420

ABSTRACT • *One of the most challenging and, at the same time, the most important skills of experienced managers of these days is the ability to motivate their employees to meet the required job performance in the workplace. At the present time, employee motivation is an atmosphere that meets the interests and needs of employees in the company, stimulates and influences their work performance in order to meet the needs of the organisation as well as their personal needs. This paper deals with the changes in employee motivation in the Slovak furniture manufacturing company and determines which changes in motivation programme should be made in the company in future.*

Key words: *Employee motivation, motivation programme, analysis of motivation, t-test, wood industry company.*

SAŽETAK • *Jedan od najvažnijih izazova i istodobno, jedna od najvažnijih vještina iskusnih menadžera u današnjem trenutku jest sposobnost motiviranja uposlenika za postizanje očekivanih radnih rezultata u poslu koji obavljaju. Danas motivacija uposlenika označava atmosferu koja povezuje interese i potrebe uposlenika u poduzeću, stimulira ih i potječe na učinkovitiji rad kako bi se dosegnule potrebe organizacije u kojoj rade i njihove osobne potrebe. Članak prikazuje promjene u motivaciji uposlenika u poduzećima za proizvodnju namještaja u Slovačkoj i predlaže potrebne promjene u motivacijskim programima unutar poduzeća u budućnosti.*

Ključne riječi: *motivacija uposlenika, motivacijski program, analiza motivacije, t-test, kompanija drvne industrije*

[1] Authors are assistant professor and Master of Science at Technical University, Faculty of Wood Science and Technology in Zvolen, Slovakia. [2]Author is Doctor of Science at University Matej Bel, Faculty of Economics in Banska Bystrica, Slovakia. [3]Author is professor at University of Zagreb, Faculty of Forestry, Zagreb, Croatia.

[1] Autori su docent i magistar znanosti Tehničkog sveučilišta u Zvolenu, Fakultet drvne tehnologije i znanosti, Slovačka. [2]Autorica je doktorica znanosti Sveučilišta Matej Bel u Banskoj Bystrici, Ekonomski fakultet, Slovačka. [3]Autor je profesor Sveučilišta u Zagrebu, Šumarski fakultet, Zagreb, Hrvatska.

1 INTRODUCTION
1. UVOD

Times, when the main role of a manager or supervisor in the workplace was to assign tasks to employees, are over. Nowadays, employees want to be familiar with the business process and not only to be paid. To provide higher productivity, they are expected to work with responsibility and to contribute to successful achievement of the company goals. For an effective management of human resources in an organisation, it is necessary to establish an adequate organisational structure including the existence of a human resources management department (Stacho *et al*., 2013*)*. Employees want to discuss their performance results with managers more often and they want to be aware of the importance of their tasks within the company. According to Forsyth (2003), if a manager does not find the right way to motivate staff, workplace absenteeism and fluctuation will rise and taking breaks in an inappropriate way (surfing the Internet, private phone calls), interruption, intrigues, conflicts, dissatisfaction with management will be more obvious. At the same time interest in work, quality and productivity at work, willingness to become responsible, level of submitting proposals, concentration at work, personal participation of an employee and punctuality are declining.

The main condition to motivate staff successfully and at the same time to meet the interests and needs of the employees in the workplace is to make each employee feel valued, empowered and engaged (Jelačić *et al*. 2012).

This paper presents the analysis of the manufacturing company with respect to the level of motivation.

An essential role of human resource management and its development is to provide positive behaviour of employees and managers. It is a goal-directed behaviour that should enable the organisation to achieve top goals successfully and effectively. The organisation must motivate employees systematically to ensure that the staff work effectively and therefore it must come up with motivational processes *(*Halík, 2008*)*. Employee motivation can be considered the nature of human resource management. Motivation should be carried out independently of the management system orientation – functional, process or project orientation *(*Závadský and Droppa, 2013*)*. Goals of the organisation cannot be set and achieved without the appropriate level of employee motivation – their behaviour and productivity. Motivational programmes are an inseparable part of motivation at work (Jelačić *et al*. 2008, 2012*)*.

Individual as well as team motivational programmes are used in companies as a part of programmes to keep the required level of employee productivity. Motivational programme must be adapted to corporate culture and the company itself. Detailed motivational programmes can very rarely be seen in our companies. It is necessary to change the general approach to the role of employees within the company to carry out this programme and incorporate it in the internal rules of the company. The ideal state would be to develop a tailor-made programme for each employee, but it is very time- and money-consuming (Šatanova *et al*., 2004). On the other hand, team motivational programme can be ineffective because of differences in motivation of individual employees. In many cases, there are only minor differences within the motivation profile of an employee but they can affect the job performance of an employee essentially. (Hitka and Sirotiaková, 2011).

Further to the above, creativity, motivation and professionalism is the root for improving the effectiveness of job performance of specialists, managers and employees. They present stimulators encouraging employees, and the whole organisation as well, to make processes in the company more dynamic. One of the most challenging and, at the same time, the key managers' ability is to motivate themselves, workmates and also subordinates to achieve higher employee productivity (Galajdová *et al*., 2007).

The aim of this paper is to identify changes in employee motivation within the company between 2011 and 2013, to determine changes in preferences for motivation factors of employees in a two-year period and, according to these changes, to suggest appropriate solution for the company in the area of motivation at work in the future.

Nowadays, in times of economic crisis, motivational programmes are focused not only on financial incentives but very often also on non-financial incentives, such as –rebuilding teams, providing education and trainings within the company, offering qualifying training courses, language courses, managerial and IT courses, seminars or using different outsourcing market tools *(*Kampf, 2005; Potkány, 2008*)*. These incentives can be used by the company to cope with the economic crisis. Sport activities and different events organised by the company are other examples of team building. Internal communication within the company is a part of motivation that must not be missed.

Another non-financial method of motivation is to make employees feel appreciated and empowered (Lucas, 2004). Non-monetary incentive preferences should depend on the employee. Motivational programmes and benefits effective for employees are those that can meet their needs for self-actualisation, perhaps even their economic requirements. Tools effective for the employers are those that can help them develop employee potential at low costs.

It is very time- and money-consuming to develop the motivational programme for each company. Deep and goal-directed analysis of the employees is an essential condition for its effectiveness. Based on the present analyses (Vetráková *et al*., 2007; Hitka *et al*., 2007; Blašková, 2010; Kropivšek *et al*., 2011), it can be concluded that the motivational programme in the company can be, based on the average significance of individual motivation factors, unifiable at present. In the future motivation and requirements of employees may change.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The research was conducted in a wood processing company specialised in furniture and wood product manufacturing. Manufacturing of furniture is carried out in four factories in the town.

A questionnaire, based on asking directed questions, was used to determine the level of motivation and to analyse motivation factors in the selected company. The questionnaire consisted of 30 closed questions (Hitka, 2009). The questionnaire was divided into two parts. Socio-demographic and qualification characteristics of employees were searched in the first part. Basic data about respondents relating to their age, sex, seniority, completed education and job position were obtained in this part. The second part consisted of individual motivation factors through which information was collected about work environment, working conditions, applied appraisal and reward system, about personnel management, health and social care system and system of employee benefits as well as information about employee satisfaction or dissatisfaction, value orientation, relation to work and the company or co-workers' relationship in the company. Motivation factors were placed in alphabetical order so as not to affect the respondents. Respondents evaluated individual motivation factors by one of five levels of significance from a pre-defined 5-point rating scale, where 5 was the most important and 1 was unimportant.

The questionnaires were evaluated by the computer programme STATISTICA 7. Descriptive statistics was used to describe the basic samples. Statistical characteristics, which compressed information about the observed basic samples into smaller number of numerical characteristics and made mutual comparison of samples (2011 and 2013) easy for each motivation factor, were computed. Each motivation factor (quantitative feature) was described summarily by basic characteristics: levels – average $\bar{x}$ and variability - standard deviations s_x and coefficients of variation. Subsequently the results were compared by means of inductive statistics.

Besides simple comparison of descriptive characteristic values, considering the selected type of obtained data, testing was carried out of the equality of averages and standard deviations of basic samples. The purpose of testing is to verify statistical significance of differences in averages and standard deviations of individual motivation factors in analysed companies so that the possibility was eliminated that detected differences of descriptive characteristics at the selected level of significance α = 0.05 were not caused only by mistake made by representative sampling. The null hypothesis vs. the alternative hypothesis was tested; they were as follows:

$$H_0 : \mu_1 = \mu_2 \quad \text{vs.} \quad H_1 : \mu_1 \neq \mu_2$$

H_0: Means of basic samples of examined motivation factors in the observed time are equal.

H_1: Means of basic samples of examined motivation factors in the observed time are not equal.

The Student's t distribution was as follows (if variances are equal):

if $\sigma_1^2 = \sigma_2^2$; X_1 and X_2 are independent,

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1 \,.\, s_1^2 + n_2 \,.\, s_2^2}{n_1 + n_2 - 2} \cdot \frac{n_1 + n_2}{n_1 \,.\, n_2}}}$$

and in case that variances are different if $\sigma_1^2 \neq \sigma_2^2$; X_1 and X_2 are independent, $t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

In 2011, the sample of 152 employees was inquired out of a total of 1253 employees. In 2013, 156 employees were inquired out of 1197 employees.

3. RESULTS AND DISCUSSION
3 REZULTATI I DISKUSIJA

Current motivational programme of the company uses different financial incentives, education, job rotation, career growth, social policy and employee benefits in the area of human resource management. The aim of the motivational programme is to follow managerial activities in the company and to affect the work behaviour and the attitude of staff to strategic goals of the organisation in order to ensure harmony between the interests of the company and employees and to provide career growth and self-development of employees.

Research of the level of motivation and changes in motivation factors in 2011 and 2013 was carried out among production workers in the company. Databases were formed regarding the basic characteristic – the year, on the basis of acquired data relating to the motivation assessment. Significance was determined of respondent preferences for individual motivation factors depending upon the year. The differences between means of individual motivation factors in the particular years were searched. The aim was to consider whether the differences between averages of individual groups were significant or only random.

There were no significant differences between most of means of individual motivation factors acquired in 2011 and subsequently in 2013. The differences between means are not considered statistically significant. It can be observed that employees of the company are as satisfied with most of the motivation factors as in 2011. Significant differences between means in 2011 and 2013 can be seen only in two factors - job security and social benefits. These factors have P-value < 0.05. It means that the null hypothesis H_0 can be partly accepted.

Within our analysis, employees were asked to consider their motivation requirements in the observed period of time despite the economic crisis. The analysis clearly showed that in the company Bučina, Inc. Zvolen (Hitka and Blašková, 2006), no significant changes were observed in motivation in a four-year period.

Based on the findings in the company Slovenské elektrárne Mochovce (Hitka, 2005), it can also be

Table 1 *t*-test results of motivation factor means
Tablica 1. Rezultati *t*-testa prosječnih motivacijskih čimbenika

	***t* –test** / *t-test*	**value *p* /** *vrijednosti p*
Atmosphere in the workplace / *atmosfera na radnome mjestu*	3.56	0.06
Good work team / *dobar radni tim*	1.53	0.22
Further financial reward / *buduće financijske nagrade*	0.04	0.84
Workload and type of work / *radno opterećenje i vrsta rada*	0.73	0.39
Physical effort at work / *fizički napor pri radu*	0.56	0.45
Job security / *sigurnost zaposlenja*	24.53	0.00
Information about performance results / *informacije o postignutim rezultatima*	0.29	0.59
Communication in the workplace / *komunikacija na radnome mjestu*	0.93	0.34
Name of the company / *ime kompanije*	2.62	0.11
Opportunity to apply own ability / *mogućnost primjene svojih sposobnosti*	1.66	0.20
Working time / *radno vrijeme*	3.05	0.18
Work environment / *radno okruženje*	3.05	0.28
Moving up corporate ladder / *napredovanje u poslu*	0.63	0.43
Competences / *kompetencije*	0,58	0,45
Supervisor's approach / *pristup nadređenoga*	1.54	0.22
Individual decision making / *osobno donošenje odluka*	0.01	0.91
Social benefits / *socijalne povlastice*	18.16	0.00
Fair appraisal system / *pravedni sustav nagrađivanja*	0.91	0.34
Job safety / *sigurnost na radu*	1.30	0.26
Mental effort / *umni napor*	1.07	0.30
Education and personal growth / *obrazovanje i osobno napredovanje*	0.52	0.47
Company relation to the environment / *odnos kompanije prema okolišu*	1.62	0.20
Free time /*slobodno vrijeme*	1.22	0.27
Recognition / *priznanja*	0.00	0.97
Basic salary / *osnovna plaća*	1.23	0.27

Note: Significant motivation factors are in bold / *Napomena: Važni su motivacijski čimbenici podebljani.*

stated that the fundamental change in motivation in all job positions only occurred after five years. However, this period of time does not have to be the same in other companies. Following our experience, the analysis of motivation should be carried out periodically, once a year. In order to ensure objectivity, the analysis must be carried out systematically and acquired data must be compared with the company achievements and set goals.

4 CONCLUSION
4. ZAKLJUČAK

The most important requirement for employees' long-term productivity, their willingness and satisfaction is to make employees feel that their work is meaningful, important for the company and also interesting for them, reasonably difficult and with possibilities of personal development. If employees have a clear picture of the situation and opportunities for professional growth and development, if they are satisfied with the rewarding system based on productivity and quality of the work done, long-term productivity and high-quality work can be expected. However, staff must be supported and motivated continuously. Seeing that the development of motivation during a particular period of time is variable, it is necessary to analyse employee motivation continuously and to update motivational programmes of the company according to the needs. Through the analysis of the motivation factors of employees of the company, it was found that almost all motivation factors were the same during the particular period of time. Significant differences were determined only in two factors - job *security* and *social benefits*. The ongoing economic crisis, when employees are obliged to keep their job, can be regarded as the cause of both factors. Seeing that companies do not have enough sources for meeting financial requirements of employees, they offer them different social benefits.

The approach chosen to motivate employees within human resource management is the responsibility of company managers. The system that reveals motivation factors in the company must be monitored constantly and evaluated periodically in order to find information about the current state of employee motivation and mainly to predict the development of motivational programmes.

Economic factors should be observed in longer period of time (2 – 6 years) along with the monitoring of the total economic and social situation of the environment depending upon the development of value orientation of employees that may change during a particular period of time.

Acknowledgement – Zahvala

This paper represents a partial result of the grant task of the project VEGA 1/0268/13, "Perspective use of facility management for the increased competition of forestry and woodworking companies in the context of outsourcing principles".

5 REFERENCES
5. LITERATURA

1. Blašková, M., 2010: Creative Proactive-Concluding Theory of Motivating. Business: Theory and Practice, 11 (1): 39-48. http://dx.doi.org/10.3846/btp.2010.05
2. Forsyth, P., 2003: Jak motivovat lidi. Brno: Computer Press, p. 117.
3. Galajdová, V., et al. 2007: Rozvoj ľudských zdrojov I. Zvolen: Technická univerzita vo Zvolene, p. 227.
4. Halík, J., 2008: Vedenie a riadenie ľudských zdrojov. Praha: Grada Publishing, p. 128.
5. Hitka, M., 2005: Vecná a časová zmena motivácie riadiacich zamestnancov v Slovenských elektrárňach a. s. Mochovce. On-line odborný časopis Manažment v teórii a praxi. EU Bratislava, PHF Košice. 1/2005.
6. Hitka, M.; Blašková, M., 2006: Vývoj motivácie zamestnancov Bučina, a. s. Zvolen. Ekonomika a manažment podniku 1/2006. Výskumný ústav stavebnej informatiky, s.r.o. Košice. pp. 69-82.
7. Hitka, M.; Potkány, M.; Benková, E., 2007: The analysis of motivation factors of wood-working company employees in the field of personnel controlling. Drewno wood, 50 (178), Poznan.
8. Hitka, M., 2009: Model analýzy motivácie zamestnancov výrobných podnikov. Vedecká monografia, ES TU Zvolen. Zvolen, p.150.
9. Hitka, M.; Sirotiaková, M., 2011: Impact of economic crisis on change of motivation of Ekoltech s. r. o. Fiľakovo employees. Drewno Wood, 54 (185):119-126.
10. Jelačić, D.; Grladinović, T.; Sujová, A.; Galajdová, V., 2008: Motivirajući čimbenici u preradi drva i proizvodnji namještaja, Drvna industrija, 59 (1): 11-21.
11. Jelačić, D.; Moro, M.; Drábek, J.; Sujová, A., 2012: Motivation factors in wood processing plants. Wood Research, 57 (2): 317-330.
12. Kampf, R., 2005: Personal Outsourcing and Controlling. In.: Manažment ludského potenciálu v podniku, vyd. Žilina: Žilinská univerzita, pp. 111-116.
13. Kropivšek, J.; Jelačić, D.; Grošelj, P., 2011: Motivating employees of slovenian and croatian wood industry companies in times of economic downturn. Drvna industrija, 62 (2): 97-103. http://dx.doi.org/10.5552/drind.2011.1040
14. Lucas, R.; Marinová, M.; Kučerová, J.; Vetrákov Á, M., 2004: HRM practice in emerging economies: A long way to go in the Slovak hotel industry? International Journal of Human Resource Management, 15 (7): 1262-1279. http://dx.doi.org/10.1080/0958519042000238446
15. Potkány, M., 2008: Personnel outsourcing processes. Ekonomie a management, 11 (4): 53-62.
16. Stacho, Z.; Urbancová, H.; Stachová, K., 2013: Organisational arrangement of human resources management in organisations operating in Slovakia and Czech Republic. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, LXI (7): 2787–2799. http://dx.doi.org/10.11118/actaun201361072787
17. Šatanová, A.; Potkány, M., 2004: Controlling - Modern tool of company control. Ekonomický časopis, 52 (2): 148-165.
18. Vetráková, M.; Hitka, M.; Sedmák, R., 2007: Analýza vývoja motivácie robotníkov v Slovenských elektrárňach a. s. Mochovce z časového a vecného hľadiska. Ekonomie a management, 1/2007: 84-97.
19. Závadský, J.; Droppa, M., 2013: Organization maturity through consistency of its management system. Advances in Management, XI (12): 1-8.
20. *** StatSoft, Inc. 2004. STATISTICA (data analysis software system), version 7. www.statsoft.com.

Corresponding author:

Prof. DENIS JELAČIĆ, Ph.D.

University of Zagreb
Faculty of Forestry
Svetosimunska 25
HR-10000 Zagreb, CROATIA
e-mail: djelacic@sumfak.hr

Martina Merková, Josef Drábek, Denis Jelačić

Evaluation of Investment Management and Business Performance in Wood Processing Industry in Slovakia

Vrednovanje upravljanja investicijama i poslovanjem u drvoprerađivačkoj industriji u Slovačkoj

Preliminary paper • Prethodno priopćenje
Received – prispjelo: 21. 11. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*79; 658.5*
doi:10.5552/drind.2015.1439

ABSTRACT • *The aim of this paper was to analyze certain parameters of investment measurement and management of companies in Slovakia, especially in wood processing industry compared with other industrial sectors. Statistical analysis was made of relationships between investment trends and performance given by the indicator Return on Equity. The goal was to identify differences in investment management of analyzed industries and consequently define relevant determinants as critical areas with the impact on performance of wood processing companies. In the results of research, special interest is focused on crucial investments with the emphasis on the preparation of investment projects.*

Key words: *enterprise investment, investment trends, business performance, wood processing industry, Slovakia*

SAŽETAK • *Provedena istraživanja bila su usmjerena na parametre mjerenja investicija i upravljanja poduzećima u Slovačkoj, posebice u drvoprerađivačkim poduzećima u usporedbi s drugim industrijskim sektorima. Statistički je analizirana međusobna ovisnost investicijskih trendova i rezultata poslovanja dobivenih putem indeksa točke povrata. Cilj rada bio je odrediti razlike u upravljanju investicijama između promatranih industrijskih grana i slijedom toga odrediti relevantna obilježja kao kritična područja koja utječu na poslovne rezultate drvoprerađivačkih poduzeća. U rezultatima istraživanja posebna je pozornost pridana ključnim investicijama, s naglaskom na pripremi investicijskih projekata.*

Ključne riječi: *investicije u poduzeću, investicijski trendovi, poslovni rezultati, drvoprerađivačka industrija, Slovačka*

[1] Authors are assistant and associate professor at Technical University in Zvolen, Faculty of Wood Sciences and Technology, Department of Enterprise Management, Zvolen, Slovak Republic. [2]Author is professor at University of Zagreb, Faculty of Forestry, Zagreb, Croatia.

[1] Autori su asistentica i izvanredni profesor Tehničkog sveučilišta u Zvolenu, Fakultet za znanost o drvu i tehnologiju, Zavod za poslovno upravljanje, Zvolen, Slovačka. [2]Autor je profesor Sveučilišta u Zagrebu, Šumarski fakultet, Zagreb, Hrvatska.

1 INTRODUCTION
1. UVOD

Also due to the significant factors in the context of global economic crisis, the wood processing industry (WPI) has to face the fall in demand for timber and timber products not only in Slovakia. Consequently, many small businesses were lost. If demand is not stimulated in the short term, the performance of WPI as a whole will clearly decrease, which will of course adversely affect the WPI share in the GDP of Slovakia in future (min. 5 years), as well as balanced regional development (availability of raw materials), with negative impact on social stability of individual regions in Slovakia (Merková and Drábek, 2011).

Slovakia currently exports large quantities of raw wood, much of which is renewable raw material, this being a significant comparative advantage for the WPI of SR. The wood stock in Slovak forests has been continuously increasing. Wood harvesting in Slovakia is also growing. The maximum annual volume of wood harvest was reached in 2005 as the result of unusually strong wind storm in 2004. The increase of harvest increases also the economic potential of Slovak forests (Moravčík, 2007, SARIO). In case of foreign capital invested in new technologies for processing of domestic raw materials, potential effects from foreign direct investment would especially result in a higher value added in the WPI, and in the growth of the WPI share in the GDP of Slovakia.

Woodworking and furniture industry is developed in Slovakia and it is more than necessary. Forests and sophistically used wood constantly produced by forests are the basis for the development of WPI, which may be a strategic issue for the Slovak economy. Increased consumption of wood in the Slovak Republic and focus on domestic production can best help companies to find solutions in a currently difficult situation.

Recent development in most enterprises suggests that the effects of the global economic crisis have a significant impact on the performance of enterprises, with direct impact on the level of economy as well as the level of investment. The development of each sector or company requires appropriate investment. Without investment, economic objectives of the business cannot fully be met (Merková *et al*., 2011).

Investment decision-making is one of fundamental parts in performance management of companies (Ojurović *et al*., 2013). However, to meet the strategic goals, a company needs to apply successful methods for management and measurement of business performance (Merková and Drábek, 2010; Merková and Drábek, 2013). The allocation of available financial resources to fixed assets or investments in modernization of production technologies are possible ways when a company can ensure its prosperity. Implementation of process principles into management brings a lot of changes with positive effects as higher competitiveness, productivity and performance (Sujová *et al*., 2014).

"A lively discussion on the relevance of the application of selected indicators for measuring the businesses performance" is nowadays conducted between representatives of the theory, consulting firms and business. Different opinions and views are based on two facts as follows:

- normal, so far commonly used performance indicators are related to the past and it is highly questionable whether they sufficiently reflect the company's future competitiveness,
- used indicators do not sufficiently reflect the quality of customer relationships.

It can be concluded that the economic experience quite often results in financial management based on the accounting profit and common indicators such as profitability or activity ratios. These indicators are presently considered as insufficient, which is also one of the reasons for the significantly poor competitiveness of enterprises. Traditional methods of measuring business performance (for example in Knápková and Pavelková, 2010 or Kislingerová, 1999) are based primarily on maximizing profits (which is also in line with the objectives of business activity). Absolute and relative indicators are used for measuring the performance (Kislingerová, 2010). However, in recent years objections to the traditional performance measurement indicators, such as profitability, can be seen.

In evaluating an investment, attention is focused on suitability, efficiency and feasibility of a specific project. Moreover, the impact of the project on the total effectiveness, prosperity and financial stability of the company is evaluated (Polách *et al*. 2012;Rajnoha *et al*., 2014 and others). Discounted cash-flow methods for investment valuation take time factor into consideration. In economic life, time factor makes things more serious, it enables the change of money evaluation. Based on a wrong change, a wrong decision can be made, which would have significant influence on project effectiveness and enterprise stability (Drábek and Jelačić, 2007). Discounted cash-flow methods underlie two basic rules of financing (see more in Brealey and Myers, 1999 or Brealey and Myers, 2003) considering time changes of money values. While discounted cash flow valuation is only one of the three ways of approaching valuation, it is the foundation on which all other valuation approaches are built (Damodaran, 2012).

Business performance was analyzed by our research team recently with the objective to determine the extent of the use of traditional and modern indicators, methods and models of performance management on a sample of randomly selected companies in various industries of Slovakia. Rajnoha *et al*. (2013) published the research results and demonstrated the impact of selected factors in the performance of surveyed companies.

There is the possibility to consider the prices. However, investors will not certainly decide for the lowest current price – such as low production costs and cheap labor or low tax cost - but primarily on the lowest cost throughout the life cycle of the investment (Merková *et al.*, 2012). Apart from the quality of infrastructure, size of the domestic market or access to regional and international markets, foreign investors particularly take into account the factors such as energy costs, availability of suppliers and customers, sufficient qualified and skilled workforce, predictability of economic development, stability of legislative conditions, security of companies and others.

The aim of this paper is to analyze the investment measurement and management of companies in Slovakia by investigating the investment trends and decisions such as routing, types, direction and objectives of investment activity, investment development and preparation of investment projects.

The research objective was to analyze certain parameters of investment measurement and management, and consequently statistically analyze the relationships and differences between investment trends and performance given by the indicator Return on Equity. The goal was to find out relevant determinants as critical areas with the impact on performance of wood processing companies. The results were analyzed based of the questionnaire.

Selected results of the research presented in this paper analyze as follows:

– Obtained business performance in research samples,
– Share of development investment in companies,
– Investing directions and crucial investments,
– Emphasis on preparation of investment projects.

This paper gives a comparison of the current investment management in the wood processing industry of the Slovak Republic (WPI SR) and other industrial sectors.

2 METHODOLOGY OF RESEARCH
2. METODOLOGIJA ISTRAŽIVANJA

Methodologically, an on-line questionnaire was developed (more in *Questionnaire Survey*) through internet application to collect data from companies in Slovakia. Complete anonymity of participating firms was granted. The size of research sample was 164 counts.

The research was primarily focused on wood processing companies. Statistical classification of Economic Activities (NACE Rev. 2) in the Statistical Office of the Slovak Republic defines as follows:

– Manufacture of wood (Wood industry – WI)
– Manufacture of pulp and paper products (Pulp and paper industry – PPI)
– Manufacture of furniture (Furniture industry – FI).

The aim was also to analyze specific sectors included in wood processing, e.g. the pulp and paper industry (2 companies), the furniture industry (11 companies) would cause low relevance of the results for the two-dimensional statistics, because these sectors were individually assessed only by means of univariate descriptive statistics. For two-dimensional statistics for qualitative (nominal) variables, the related sectors were put together. In this case, the sample included all sectors of the wood processing industry (WPI) covering 34 companies. Basic information about research samples used in this part of research is presented in Tab. 1.

Companies were initially analyzed according to the distribution of the achieved performance of 6 particular groups (group 0-5, group 0 – the worst performance with negative ROE, group 5 - the best performance with ROE over 10 %).

Mathematical and statistical methods were used in the research of interdependencies and impacts of individual factors on achieved performance of companies.

One-dimensional inductive statistics:

In the research, selected descriptive statistics was analyzed for one variable – absolute and relative frequencies, cumulative frequency and cumulative relative frequency, mean, median and mode. The following statistical methods were used: frequency tables showing the frequency by categories, histograms, pie charts, bar and cumulative bar charts, time series and trends.

Two-dimensional inductive statistics between categorical variables

The research consisted of qualitative – nominal variables, their relationship cannot adequately describe the correlation analysis, so the association between variables was examined with contingency (first used by Pearson, 1904).

Cumulative bar graph represents the best way to present graphically the relationship between a pair of categorical variables. In fact, it is a graphical representation of row or column percentages in contingency table (Rimarčík, 2007).

Table 1 Research samples
Tablica 1. Poligoni istraživanja

Research sample / Industry *Poligon istraživanja / Industrijske grane*	**Sample size** *Veličina uzorka*
Sample of all tested companies *Veličina uzorka svih ispitanih poduzeća*	164 companies *164 poduzeća*
Sample of WPI companies - Industries included in WPI: WI, FI, PPI *Veličina uzorka drvoprerađivačkih poduzeća uključujući primarne proizvode, finalne proizvode te proizvodnju celuloze i papira*	34 companies *34 poduzeća*
Sample of automotive companies *Veličina uzorka poduzeća za proizvodnju automobila*	16 companies *16 poduzeća*
Sample of engineering companies *Veličina uzorka poduzeća u metaloprerađivačkoj industriji*	30 companies *30 poduzeća*
Sample of other companies (all other industries except WPI, automotive and engineering) *Veličina uzorka ostalih poduzeća (sve ostale industrijske grane bez drvoprerađivačke, automobilske i metaloprerađivačke)*	84 companies *84 poduzeća*

Chi-squared test was applied. It is commonly used for testing the independence between two categorical variables. Results of chi-squared tests describe selected statistics: Pearson's chi-square and significance *p*-value „*p*", Maximum-Likelihood chi-square and p-value, Pearson's Contingency Coefficient (*CC*), Adjusted Contingency Coefficient (Adj. *CC*) and degrees of freedom (*df*).

Pearson's Chi-square:

$$\chi^2=\sum_{i=1}^{k}\left[\left(f_{o_i}-f_{e_i}\right)^2/f_{e_i}\right];$$

$$\text{while} \quad \sum\left(f_o-f_e\right)=0 \qquad (1)$$

Pearson's contingency coefficient *CC*:

$$CC=\sqrt{(\chi^2/\chi^2+N)} \qquad (2)$$

Maximum contingency coefficient CC_{max}:

$$CC_{max}=\sqrt{(q-1)/q} \qquad (3)$$

Adjusted contingency coefficient

$$\text{Adj.}CC = CC/CC_{max}; \text{ while } CC \le CC_{max} \qquad (4)$$

Where:

f_{o_i} – observed frequency in a field of the table,

f_{e_i} – expected (theoretical) frequency in a field of the table,

k – number of cells in the table

N – sample size

q – number of rows or columns (in square tables).

MS Office Excel and Statistic software from Stat Soft, Inc. was used for statistical analysis, and numeric and graphical presentation of the research results.

3 RESEARCH RESULTS
3. REZULTATI ISTRAŽIVANJA

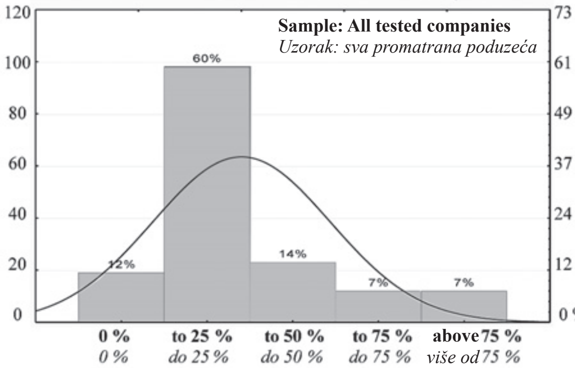
3.1 Development investment
3.1. Razvojne investicije

Development investments (expansion, starting of new production, etc.) were analyzed in contrast with recovery investments. Development investments were divided into 5 categories. It can be seen from the descriptive statistical results (Figure 1) that most enterprises in both presented samples implement development investment in the share of 25 % of the total investment in company (60 % of respondents in all enterprises and 62 % of WPI businesses).

Low abundance (6 %) speaks in favor of WPI in the category with zero share of expansion investment, while a relatively high number of enterprises (21 %) was recorded with development investments in the range of 25-50 %. In all enterprises, more negative representation (12 %) of the category without development investments was evaluated. On the other hand, the highest category – massive expansion investments with a 75 % share was recorded in 7.32 % of all tested enterprises, but only in 2.94 % of WPI businesses. The observed frequencies and relative frequencies in different six performance groups are presented in Tab. 2 and 3.

The observed frequencies presented in both samples show that firms realizing a high share of expansion investments above 75 % reach lower performance (mostly in the performance group 0 with negative ROE indicator). At currently implemented investments, return and higher business performance are expected later in the long term. By applying statistical methods, no significant relationship has been shown between the share of development investment and performance of businesses in any research sample.

The average performance was also analyzed in each category (Tab. 4). The results revealed growing performance based on a higher percentage of expansion investments between categories of 25 %, 50 % and 75 % of all enterprises. It can, therefore, be stated that development investments proportionally influence the growth of business performance, but only to a certain extent. As companies invest in the development more than 75 %, they are inefficient in the initial period. The data averages, however, also showed that firms without development investments achieve the performance level of enterprises with 25 and 50 % share of development investments. This performance is probably only temporary and companies without investing in development in the coming years will be less powerful. Testing the differences in the averages of categories showed no statistically significant relationship between the investments in the development and performance of businesses.



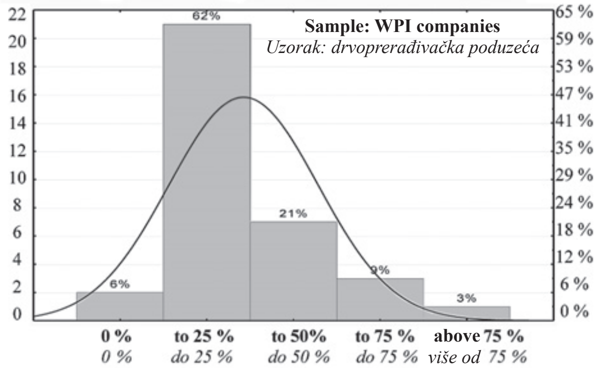


Figure 1 Histograms: Share of development investment
Slika1. Histogrami: Udio razvojnih investicija

Table 2 Observed frequencies: Share of development investment – all tested companies
Tablica 2. Učestalost: Udjeli razvojnih investicija u svim promatranim poduzećima

Share of development investment *Udio razvojnih investicija*	**Group 0 ROE<0** *Skupina 0, točka povrata <0*	**Group 1 ROE: 0-2 %** *Skupina 1., točka povrata 0-2 %*	**Group 2 ROE: 2-4 %** *Skupina 2., točka povrata 2-4 %*	**Group 3 ROE: 4-7 %** *Skupina 3., točka povrata 4-7 %*	**Group 4 ROE: 7-10 %** *Skupina 4., točka povrata 7-10 %*	**Group 5 ROE>10 %** *Skupina 5., točka povrata >10 %*	**Row Totals** *Ukupno*
0 %	5	3	2	5	2	2	19
Share in category *Udio po kategoriji*	26.32 %	15.79 %	10.53 %	26.32 %	10.53 %	10.53 %	100 %
Share in total *Udio u ukupnosti*	3.05 %	1.83 %	1.22 %	3.05 %	1.22 %	1.22 %	11.59 %
up to 25 % / *do 25 %*	11	33	25	12	7	10	98
Share in category *Udio po kategoriji*	11.22 %	33.67 %	25.51 %	12.24 %	7.14 %	10.20 %	100 %
Share in total *Udio u ukupnosti*	6.71 %	20.12 %	15.24 %	7.32 %	4.27 %	6.10 %	59.76 %
up to 50 % / *do 50 %*	2	7	4	6	2	2	23
Share in category *Udio po kategoriji*	8.70 %	30.43 %	17.39 %	26.09 %	8.70 %	8.70 %	100 %
Share in total *Udio u ukupnosti*	1.22 %	4.27 %	2.44 %	3.66 %	1.22 %	1.22 %	14.02 %
up to 75 % / *do 75 %*	1	1	3	3	1	3	12
Share in category *Udio po kategoriji*	8.33 %	8.33 %	25.00 %	25.00 %	8.33 %	25.00 %	100 %
Share in total *Udio u ukupnosti*	0.61 %	0.61 %	1.83 %	1.83 %	0.61 %	1.83 %	7.32 %
above 75 % *više od 75 %*	6	3	1	0	0	2	12
Share in category *Udio po kategoriji*	50.00 %	25.00 %	8.33 %	0.00 %	0.00 %	16.67 %	100 %
Share in total *Udio u ukupnosti*	3.66 %	1.83 %	0.61 %	0.00 %	0.00 %	1.22 %	7.32 %
Counts total *Ukupan broj*	25	47	35	26	12	19	164
Share total *Ukupan udio*	15.24 %	28.66 %	21.34 %	15.85 %	7.32 %	11.59 %	100 %

Table 3 Observed frequencies: Share of development investment – WPI companies
Tablica 3. Učestalost: Udio razvojnih investicija u drvoprerađivačkim poduzećima

Share of development investment *Udio razvojnih investicija*	**Group 0 ROE <0** *Skupina 0, točka povrata<0*	**Group 1 ROE: 0-2 %** *Skupina 1., točka povrata 0-2 %*	**Group 2 ROE: 2-4 %** *Skupina 2., točka povrata 2-4 %*	**Group 3 ROE: 4-7 %** *Skupina 3., točka povrata 4-7 %*	**Group 4 ROE: 7-10 %** *Skupina 4., točka povrata 7-10 %*	**Group 5 ROE>10 %** *Skupina 5., točka povrata >10 %*
0 %	1	0	1	0	0	2
Share in category *Udio po kategoriji*	50.00 %	0.00 %	50.00 %	0.00 %	0.00 %	100 %
Share in total / *Udio u ukupnosti*	2.94 %	0.00 %	2.94 %	0.00 %	0.00 %	5.88 %
up to 25 % / *do 25 %*	4	8	5	1	3	21
Share in category *Udio po kategoriji*	19.05 %	38.10 %	23.81 %	4.76 %	14.29 %	100 %
Share in total / *Udio u ukupnosti*	11.76 %	23.53 %	14.71 %	2.94 %	8.82 %	61.76 %
up to 50 % / *do 50 %*	2	2	2	0	1	7
Share in category *Udio po kategoriji*	28.57 %	28.57 %	28.57 %	0.00 %	14.29 %	100 %
Share in total / *Udio u ukupnosti*	5.88 %	5.88 %	5.88 %	0.00 %	2.94 %	20.59 %
up to 75 % / *do 75 %*	0	1	0	2	0	3
Share in category *Udio po kategoriji*	0.00 %	33.33 %	0.00 %	66.67 %	0.00 %	100 %
Share in total / *Udio u ukupnosti*	0.00 %	2.94 %	0.00 %	5.88 %	0.00 %	8.82 %
above 75 % / *vise od 75 %*	1	0	0	0	0	1
Share in category *Udio po kategoriji*	100.00 %	0.00 %	0.00 %	0.00 %	0.00 %	100 %
Share in total / *Udio u ukupnosti*	2.94 %	0.00 %	0.00 %	0.00 %	0.00 %	2.94 %
Counts total *Ukupan broj*	8	11	8	3	4	34
Share total / *Ukupan udio*	23.53 %	32.35 %	23.53 %	8.82 %	11.76 %	

Table 4 Average performance by categories: Share of development investment
Tablica 4. Prosječni poslovni rezultati prema kategorijama: Udio razvojnih investicija

Share of development investment/ Performance *Udio razvojnih investicija / poslovni rezultati*	**0 %**	**up to 25 %** *do 25 %*	**up to 50 %** *do 50 %*	**up to 75 %** *do 75 %*	**above 75 %** *više od 75 %*	**All categories** *Sve kategorije*
All tested companies *Sva promatrana poduzeća*	2.105263	2.010204	2.217391	2.916667	1.250000	2.060976
WPI companies *Drvoprerađivačka poduzeća*	1.000000	1.714286	1.571429	2.333333	0.000000	1.647059

3.2 Investing direction
3.2. Područje investiranja

In the analysis of investing direction, companies could choose any number of responses and identify one or more crucial approach to invest. For this reason, we did not analyze responses through cumulative values, but the relative frequencies via separate categories identified for major investment direction. All categories of investments in all tested companies (*N*=164) compared with WPI companies (*N*=34) are presented in Tab. 5, and categories with the largest relative abundance are presented in Figure 2.

In the sample of all tested companies, 128 firms (78 %) identified the category of manufacturing technology, machinery and equipment as crucial in directing of investments. The most mentioned category, however, does not mean statistically significant effect on the performance of enterprises. This result was probably affected by the participation of relatively large amounts of non-manufacturing companies with-

Table 5 Areas of investments
Tablica 5. Područja investiranja

Areas of investments *Područja investiranja*	**All tested companies** *Sva promatrana poduzeća*		**WPI companies** *Drvoprerađivačka poduzeća*	
	Number of companies *Broj poduzeća*	**Relative** *Relativne vrijednosti* %	**Number of companies** *Broj poduzeća*	**Relative** *Relativne vrijednosti* %
Technology, machinery, equipment *Tehnologija, postrojenja, oprema*	128	78	33	97
Intangibles /*Investicije u nematerijalno*	55	34	5	15
Construction investments / *Konstrukcijske investicije*	51	31	12	35
Training and staff development *Edukacija i razvoj kadrova*	46	28	9	26
Research and development / *Istraživanje i razvoj*	18	11	1	3
Financial investments / *Investicije u kapital*	17	10	4	12
Vehicles / *Vozni park*	2	1	0	0
Quality assurance / *Osiguranje kvalitete*	2	1	0	0
Marketing / *Marketing*	1	1	0	0
Without investment / *Bez investicija*	2	1	0	0
162 of 164 companies invest *investiraju 162 od 164 poduzeća*	162	99	34	100
Total number of answers / *Ukupan broj odgovora*	164	100	34	100

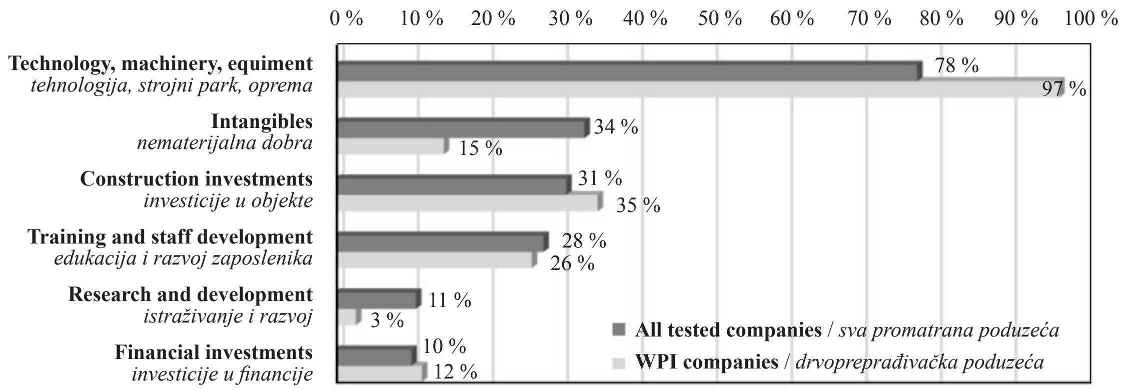


Figure 2 Investing direction – the most observed relative frequencies
Slika 2. Područje investiranja – najučestalija područja, relativne vrijednosti

Table 6 Contingency: Industry vs. Intangible investment – statistics
Tablica 6. Vjerojatnost: Industrija i investicije u nematerijalno – statistika

Statistics / *Statistika*	**Chi-square** χ^2	***df***	***p***
Pearson´s chi-square / *Pearsonov* χ^2	10.75800	*df*=3	*p* =0.01311
M-L chi-square / *M-L* χ^2	11.24314	*df*=3	*p* =0.01048
Contingency coefficient(CC) / *Koeficijent vjerojatnosti (CC)*	0.2481117		
Cramér V coefficient / *Cramerov V koeficijent*	0.2561202		
Adjusted CC / *Prilagođen CC*	0.32528		

Table 7 Contingency; Industry vs. Intangible investment – frequencies
Tablica 7. Vjerojatnost: Industrija i investicije u nematerijalno - učestalost

Industry / Intangible investment *Industrija / investicije u nematerijalno*	**Wood Processing** *Prerada drva*	**Automotive** *Auto industrija*	**Other** *Ostalo*	**Engineering** *Metaloprerađivačka industrija*	**Row Totals** *Ukupno*
Observed Frequencies / *Dobivena učestalost*					
Crucial investment *Nisu ključne investicije*	29	11	55	14	109
Crucial investment / *Ključne investicije*	5	5	29	16	55
Totals / *Ukupno*	34	16	84	30	164
Expected Frequencies / *Očekivana učestalost*					
Not crucial investment *Nisu ključne investicije*	22.59756	10.63415	55.82927	19.93902	109.0000
Crucial investment / *Ključne investicije*	11.40244	5.36585	28.17073	10.06098	55.0000
Totals / *Ukupno*	34.00000	16.00000	84.00000	30.00000	164.0000
Residual Frequencies / *Učestalost ostatka*					
Not crucial investment *Nisu ključne investicije*	6.40244	0.365854	-0.829268	-5.93902	0.00
Crucial investment / *Ključne investicije*	-6.40244	-0.365854	0.829268	5.93902	0.00
Totals / *Ukupno*	0.00000	0.000000	0.000000	0.00000	0.00

out technology investment but with higher business performance. The second most numerous category was intangible investment. Research was not interested in the volume of investments of a certain category.

Relatively more wood processing companies (97 % share compared with the sample of all tested companies with 78 % share, which also consisted of trade and service businesses without the need of technology) invest in production technology and machinery. However, a lot of companies realize only recovery, not development investment, so this category does not lead to higher performance.

We analyzed if an investing direction is more typical for some industry or specialization and whether the direction to intangible investment is statistically significant. As demonstrated in the last research (Rajnoha *et al*., 2013), just intangible investment (in foreign ownership companies) causes higher performance. Category of intangibles as crucial investment is mostly typical for engineering industry, and not at all for wood processing industry, as shown by statistical analysis presented in Tab. 6 and 7.

3.3 Investment project preparation
3.3. Priprema investicijskih projekata

Similarly as in the previous analysis, efforts were made to identify some differences in investment behavior, with the focus on the preparation of investment projects in specific industries.

From the statistical results (Tab. 8 and 9), it can be stated that the preparation of investment projects is characteristic for the category of engineering and automotive industries, while the WPI industry and other sectors do not consider the preparation of investment projects as principal.

In relation to the achieved performance in these sectors (see more in Rajnoha *et al*., 2013), which follows the relationship of industry and preparation of investment projects, this means higher performance in the engineering and automotive industries, but lower

Table 8 Contingency: Industry vs. Investment project preparation – statistics
Tablica 8. Vjerojatnost: Industrija i priprema investicijskih projekata – statistika

Statistics / *Statistika*	**Chi-square** χ^2	*df*	*p*
Pearson´s chi-square / *Pearsonov* χ^2	7.123180	*df*=3	*p* =0.06807
M-L chi-square / *M-L* χ^2	8.260908	*df*=3	*p* =0.04092
Contingency coefficient (CC) / *Koeficijent vjerojatnosti (CC)*	0.2040246		
Cramér V coefficient / *Cramerov V koeficijent*	0.2084083		
Adjusted CC / *Prilagođen CC*	0.26429		

Table 9 Contingency; Industry vs. Investment project preparation – frequencies
Tablica 9.Vjerojatnost: Industrija i priprema investicijskih projekata – učestalost

Industry / Investment project preparation *Industrija / priprema investicijskih projekata*	**Other** *Ostalo*	**Wood Processing** *Prerada drva*	**Automotive** *Autoindustrija*	**Engineering** *Metalo-prerađivačka industrija*	**Row Totals** *Ukupno*
Observed Frequencies / *Dobivena učestalost*					
Without investment projects *Bez investicijskih projekata*	24	8	2	2	36
With investment projects *S investicijskim projektima*	60	26	14	28	128
Totals / *Ukupno*	84	34	16	30	164
Expected Frequencies / *Očekivna učestalost*					
Without investment projects *Bez investicijskih projekata*	18.43902	7.46341	3.51220	6.58537	36.0000
With investment projects *S investicijskim projektima*	65.56098	26.53659	12.48780	23.41463	128.0000
Totals / *Ukupno*	84.00000	34.00000	16.00000	30.00000	164.0000
Residual Frequencies / *Učestalost ostatka*					
Without investment projects *Bez investicijskih projekata*	5.56098	0.536585	-1.51220	-4.58537	0.00
With investment projects *S investicijskim projektima*	-5.56098	-0.536585	1.51220	4.58537	0.00
Totals / *Ukupno*	0.00000	0.000000	0.00000	0.00000	0.00

performance in WPI and other industries. It can be said that preparation of investment projects affects the performance of enterprises. Unfortunately, direct evidence about the relationship between the preparation of investment projects and achieved business performance could not be statistically proven.

4. DISCUSSION AND CONCLUSIONS
4 DISKUSIJA I ZAKLJUČCI

Selected areas of investment management were analyzed in Slovak companies with the focus on companies of wood processing industry. The result of complex research shows lower performance in the mentioned industry compared with the average of all tested companies or some selected industries (automotive, engineering, etc.). In the present paper, efforts were made to identify crucial problems in investment behavior and trends in wood processing companies affecting low business performance. The main results in this part of research can be summarized as follows.

First, intangible investments, which are crucial for better performance, are not a typical investment activity of WPI companies. On the other hand, engineering industry, where intangibles are crucial investment, reached better performance than wood processing industry.

Second, preparation of investment projects is characteristic for the category of engineering and automotive industries, while the WPI industry and other sectors do not consider the preparation of investment projects as principal. The same trend is observed in achieved performance in separate categories of industry: Engineering and automotive with investment projects and higher performance, in contrast with absence of investment projects and lower performance in wood processing industry.

The wood processing industry in Slovakia is currently in a difficult situation, but there are still possibilities for better investment management and potential of positive impact on performance of companies.

5 REFERENCES
5. LITERATURA

1. Brealey, M. A.; Myers, S. C., 2003: Principles of Corporate Finance. New York: McBraw Hill.
2. Brealey, M. A.; Myers, S. C., 1999: Financial Theory and Corporate Policy. Praha: EAST Publishing, p. 971.
3. Damodaran, A., 2012: Investment valuation, tools and techniques for determining the value of any asset, 3rd ed. New Jersey: John Wiley & Sons.
4. Drábek, J.; Jelačić, D., 2007: Investment Projects. Zvolen: Nikara, p. 65.
5. Drábek, J.; Merková, M., 2010: Efektívnosť priamych zahraničných investícií v odvetví spracovania dreva. Vydavateľstvo TU Zvolen, p.103.
6. Drevospracujúci priemysel. Agentúra SARIO. [online]. http://www.sario.sk/?drevospracujuci-priemysel.
7. Kislingerová, E., 1999: Oceňovánípodniku. Praha: C. H. Beck, 304 p.
8. Kislingerová, E. *et al*., 2010: Manažerské finance, 3rd Ed. Praha: C. H. Beck, p. 826.
9. Knápkova, A.; Pavelková, D., 2010: Finančníanalýza: Komplexníprůvodce s příklady. Praha: Grada Publishing, p. 208.
10. Merková, M.; Drábek, J.; Polách, J., 2011: Impact of Investment on Labour Productivity Growth in Wood Processing Industry in Slovak Republic. Finance and the Performance of Firms in Science, Education and Practice. International Scientific Conference, 324-332.
11. Merková, M.; Drábek, J., 2011: Potential of Effects from Foreign Direct Investment. Development trends in economics and management in wood processing and furniture manufacturing. International Scientific Conference, 115-124.

12. Merková, M.; Drábek, J., 2013: Vybrané metódy merania a riadenia výkonnosti podnikov v investičnejoblasti. Ekonomika a manažmentpodnikov 2013, International Scientific Conference, 259-264.
13. Merková, M.; Drábek, J.; Jelačić, D., 2012: Determinants of Effects of Foreign Direct Investment in Terms of Slovak Republic and Wood-Processing Industry of Slovakia. Drvna industrija, 63(2): 129-142. http://dx.doi.org/10.5552/drind.2012.1136
14. Moravčík, M., 2007: Vypracovanie lesníckej časti prognózy a vízie vývoja slovenského poľnohospodárstva, potravinárstva, lesníctva a vidiek asprávy zaúlohy riešené v roku 2007 v rámcikontraktu, ktorý bol uzavretý medzi MP SR a NLC. http://www.nlcsk.sk/files/1231.pdf
15. Ojurović, R.; Moro, M.; Šegotić, K.; Grladinović, T.; Oblak, L., 2013: Analysis of the investment in wood processing and furniture manufacturing entities by key factors of competitiveness. Drvna industrija, 64(2): 131-137. http://dx.doi.org/10.5552/drind.2013.1235
16. Pearson, K., 1904: On the Theory of Contingency and its Relation to Association and Normal Correlation. London: Dulau& Company.
17. Polách, J.; Drábek, J.; Merková, M.; Polách, J. Jr., 2012: Real and Financial Investment. 1st ed. Praha: C. H. Beck. 264 p.
18. Questionnaire Surveyof the Grant Project of the Ministry of Education Nr. 1/0089/11 - Measurement and performance management of the wood industry companies in SR.
19. Rajnoha, R. *et al*., 2013: Meranie a riadenievýkonnostipodnikov. Zvolen: Vydavateľstvo TU Zvolen, 313 p.
20. Rajnoha, R.; Jankovský, M.; Merková, M., 2014: Economic comparison of automobiles with electric and with combustion engines: An analytical study. Procedia - social and behavioral sciences,109: 225-230. http://dx.doi.org/10.1016/j.sbspro.2013.12.449
21. Rimarčík, M., 2007: Statistics pre prax. Košice: Enigma, 200 p.
22. Sujová, A.; Rajnoha, R.; Merková, M., 2014: Business process performance management principles used in Slovak enterprises. Procedia - social and behavioral sciences 109: 276-280. http://dx.doi.org/10.1016/j.sbspro.2013.12.457

Corresponding address:

Prof. DENIS JELAČIĆ, Ph.D.

University of Zagreb
Faculty of Forestry
Svetošimunska 25
HR-10000 Zagreb, CROATIA
e-mail: djelacic@sumfak.hr

Ispravak / errata corrige

U radu „Some Physical and Mechanical Properties of Borate-Treated Oriental Beech Wood“ autora Hakana Simseka i Erguna Baysala, objavljenome u broju 2 /2015 časopisa Drvna industrija, pogreškom je ostala nepromjenjena mjerna jedinica u 4. koloni tablice 3, koja umjesto g/cm^3 treba biti N/mm^2.

Uredništvo se ispričava autorima zbog nenamjerne pogreške u pripremi rada za objavljivanje.

Correction / errata corrige

In the paper „Some Physical and Mechanical Properties of Borate-Treated Oriental Beech Wood“ by Hakan Simsek i Ergun Baysal published in Drvna industrija No.2 /2015, the measurement unit in table 3, column 4 should be N/mm^2 instead g/cm^3.

The Editorial Board would like to apologize to the authors for unintended errors occurred during the preparation of the paper for publishing.

Alexander Pfriem[1]

Thermally Modified Wood for Use in Musical Instruments

Toplinski modificirano drvo za izradu glazbenih instrumenata

Review paper • Pregledni rad
Received – prispjelo: 21. 8. 2014.
Accepted – prihvaćeno: 20. 5. 2015.
*UDK: 630*835.2; 630*842*
doi:10.5552/drind.2015.1426

ABSTRACT • *The unique mechanical and acoustical properties of wood and its aesthetic appeal still make it the material of choice for musical instruments. Here tropical hardwoods are typically used in musical instruments. This paper gives an overview of how the use of thermally modified wood can contribute to the use of raw materials for musical instruments. It is shown that a mild thermal treatment leads to clear changes of the measurable acoustic characteristics, such as Young's modulus, damping and sound velocity. In conclusion, thermally modified wood (mild treatment) is a material with favorable characteristics for making musical instruments.*

Key words: *acoustical wood properties, musical instruments, thermally modified wood*

SAŽETAK • *Zbog jedinstvenih mehaničkih i akustičnih svojstava te estetskih obilježja drvo se često rabi kao materijal za izradu glazbenih instrumenata. U radu se opisuje kako uporaba toplinski modificiranog drva može pridonijeti boljoj raspoloživosti sirovine za izradu glazbenih instrumenata. Pokazalo se da blaga toplinska obrada drva dovodi do jasnih promjena mjerljivih akustičnih veličina kao što su Yangov modul elastičnosti, prigušenje i brzina zvuka. Zaključno, drvo koje je umjereno toplinski modificirano ima poželjna obilježja za izradu glazbenih instrumenata.*

Ključne riječi: *akustična svojstva drva, glazbeni instrumenti, toplinski modificrano drvo*

1 INTRODUCTION
1. UVOD

The unique mechanical and acoustical properties of wood and its aesthetic appeal still make it the material of choice for musical instruments. Worldwide, several hundred wood species are available for making wind, string, or percussion instruments (Wegst, 2006). Here tropical hardwoods are typically used in musical instruments. Examples for tropical hardwoods in musical instruments are:

- Ebony (e.g. fretboards)
- Brazilian rosewood (e.g. bottom and ribs of guitars)
- Mahogany (e.g. in guitars and violins)
- Páu brasil (Pernambuco) (bows of stringed instruments)
- Grenadilla (e.g. flute and clarinets)

These wood species are often illegally cut down. Some species (e.g. Brazilian Rosewood, some Mahogany species, Pernambuco) are protected by CITES (Convention on International Trade in Endangered Species). Today, the demand increases to replace tropical wood in musical instruments. The search for alternative wood has to take into consideration anatomical features, physical, mechanical, acoustical, and chemical properties.

On the other hand, the desire of musical instrument manufactures to reduce negative characteristics

[1]Author is professor at Eberswalde University for Sustainable Development - University of Applied Sciences, Eberswalde, Germany.
[1]Autor je profesor Sveučilišta održivog razvoja u Eberswaldu – Sveučilište primijenjenih znanosti, Eberswalde, Germany.

of the raw material wood by special modification processes has existed for a century now. An overview of different historical modification processes can be found in the paper by Martius (1999). Many of these processes were not further pursued. Today, however, the question arises whether some of these historical procedures, with consideration of new, further developed methods, can help to satisfy the increasing demand of high-quality wood for musical instruments.

This paper gives an overview of how the use of thermally modified wood can contribute to the use of raw material for musical instruments.

2 OVERVIEW
2. PREGLED LITERATURE

In some scientific papers, the effect of heat treatment upon the acoustic properties of wood are described. Gadd and D'Arcy (1986) state that the heat treatment of spruce gives no statistically significant effect on characteristic values of wood. Such treatments, with temperatures between 110 °C and 115 °C, result only in slight changes in material properties.

A study with several producers of guitars from Finland, conducted between 1998 and 2002, shows the use of thermally modified wood, made by the finish VTT process, in musical instruments. It was clearly observed that the treatment temperature affects the achieved sound velocity of wood samples. The conclusion of this research is that when tonewoods are thermally treated in a specific manner, the changes in wood are the same as in naturally aged wood, whereas certain qualities of wood improve while the wood maintains its workability and strength. Further, the benefits of thermal-treatment seem more apparent when wood species of higher quality are treated (results published in Thompson, 2006).

Obataya *et al.* (2003, 2006a, 2006b) showed the influence of high temperature kiln drying on the practical performances of Japanese cedar wood. This heat treatment is sometimes regarded as an accelerated ageing. However, heat-treated wood and aged wood are qualitatively different with respect to their hygroscopicity and vibrational properties.

The aim of the work of Pfriem *et al.* (2005) and Wagenführ *et al.* (2006) was to compare thermally modified and unmodified twin samples of resonance spruce wood for sound boards. By a specific thermal treatment, physical-technical characteristics of wood can be changed in such a way that they correspond better to the requirements of wood used for sound boards than unmodified woods. More serious is the reduced moisture sorption, larger dimensional stability, better durability as well as acoustic characteristics. The effects of the relatively mild thermal treatment (180 °C) can be compared with an "artificial aging". Due to the thermal modification, objectively measurable parameters are improved, and hence it can be concluded that sound characteristics are improved, too.

Pfriem (2006) and Pfriem *et al.* (2007) built and tested musical instruments made with thermally modified wood. For the purpose of this study, guitars, violins, and harmonicas (partly) made from thermally modified wood were prepared and tested. The analysis of possible application areas in musical instruments was not only in the foreground of this investigation. Rather, the physical changes of material behavior caused by thermal modification were investigated with special reference to the general requirements for making instruments.

Mohebby *et al.* (2007) investigated the influence of hydrothermal modification on musical properties of mulberry wood. This wood is used traditionally for making instruments in Iran. Due to the improved hydrophobicity and dimensional stability, sound properties became better by hydrothermal modification.

Investigations focused on the use of thermally modified wood for statically and dynamically highly stressed components of musical instruments were carried out by Zauer and Pfriem (2010). The cross sections of thermally modified maple (*Acer pseudoplatanus* L.) were reinforced with carbon fibers reinforced epoxy resin in a single-stage process. The results clearly show that thermal treatment improves the sound quality of wood. Additionally, the reinforcement with carbon fiber increases the static and dynamical properties of thermally modified wood.

Zauer *et al.* (2014) modified European beech (*Fagus sylvatica* L.) to increase the acoustic and mechanical properties similar to Hard maple (*Acer saccharum*) to substitute the latter especially in highly stressed components of musical instruments. A relatively mild treatment, at temperatures ranging between 140 °C and 160 °C and a treatment time of 12 h, leads to an improvement of both mechanical and acoustical properties of beech wood. E.g. the average damping values of beech wood were improved to the level of hard maple wood by this mild treatment procedure. The materials may be used as substitution material in electric guitars.

3 CONCLUSIONS
3. ZAKLJUČAK

Apart from a change of the acoustically relevant characteristics, thermally modified wood exhibits advantages concerning the dimensional stability and sorption in regard to changing climatic conditions. On the other hand, the modification of wood at high temperatures results in a reduction in strength and toughness. Certainly, a mild thermal treatment (modifying at 160-180 °C in oxygen-poor atmosphere) leads to clear changes of the measurable acoustic characteristics, such as Young's modulus, damping and sound velocity. In conclusion, thermally modified wood (mild treatment) is a material with favorable characteristics for making musical instruments. A pre-selection of raw materials is, however, absolutely necessary. Inappropriate materials can hardly be improved by thermal modification. Due to these investigations, traditional production technologies for making musical instruments can be adapted to use thermally modified wood in musical instruments. For thermally modified wood (mild treatment), three application areas are possible:

- Use in instruments, where high dimensional stability and low moisture sorption and reduced reaction to climatic variability are required.
- Use in musical instruments, where specific sound characteristics are required, which otherwise can only be attained by use of wood stored for a very long time. A reduction of storage time and in that way a significant saving on storage costs can be obtained. Thermally modified wood will not replace wood used so far, but it can be a successful supplement. Through the use of thermally modified wood, the assortment of musical instrument manufacturers can be widened or extended.
- Since the thermally improved wood shows similar sound characteristics to naturally aged wood, it is suited for the restoration and reconstruction of old musical instruments.

In addition, based on the results obtained, it can be concluded that thermally modified timber can also be used for other applications. As musical instruments represent the "upper class" in the wood processing industry, such statements regarding the workability and usability can also be applied to other areas.

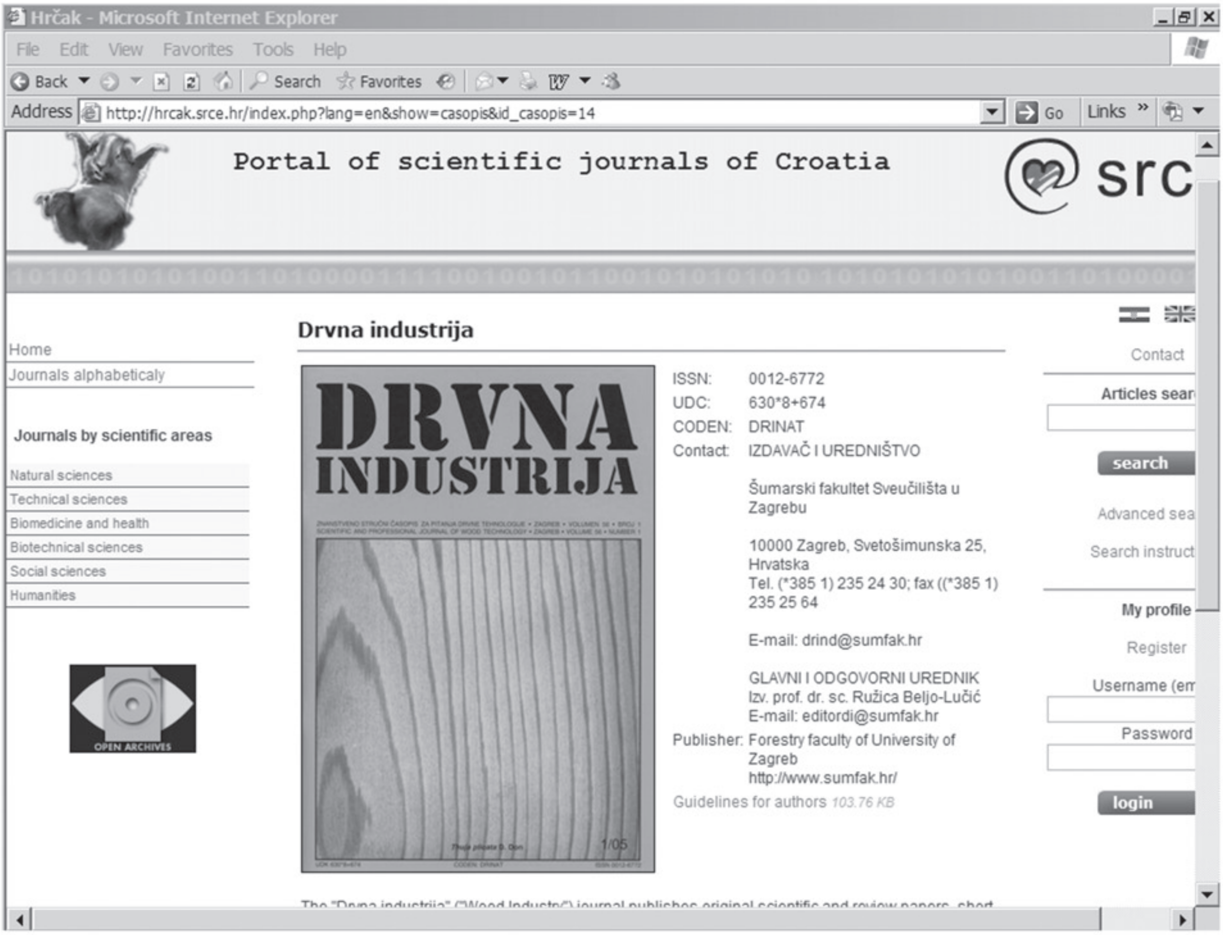
4 REFERENCES
4. LITERATURA

1. Gadd, C.; D'Arcy, J., 1986: On the effect of heat treatment upon acoustic properties of spruce. Journal of the Violin Society of America, 7 (4): 157-166.
2. Martius, K., 1999: Herkunft, Lagerung und Präparation von Tonhölzern im Spiegel historischer Quellen. Scripta Artium 1: 23-34.
3. Mohebby, B.; Yaghoubi, K.; Roohnia, M., 2007: Acoustic Properties of Hydrothermally Modified Mulberry (*Morus alba* L.) Wood. Proceedings of the third European Conference on Wood Modification, Cardiff, 283-286.
4. Obataya, E.; Higashihara, T.; Gril, J., 2003: Effects of heat treatment on the hygroscopicity of wood. Proceeding of the Second International Conference of the European Society for Wood Mechanics, Stockholm, 33-37.
5. Obataya, E.; Shibutani, S.; Hanata, K.; Doi, S., 2006a: Effects of high temperature kiln drying on the practical performances of Japanese cedar wood (*Cryptomeria japonica* D. Don) I: changes in hygroscopicity due to heating. Journal of Wood Science, 52(1): 33-38. http://dx.doi.org/10.1007/s10086-005-0716-9
6. Obataya, E.; Shibutani, S.; Hanata, K.; Doi, S., 2006b: Effects of high temperature kiln drying on the practical performances of Japanese cedar wood (*Cryptomeria japonica* D. Don) II: changes in mechanical properties due to heating. Journal of Wood Science, 52(2): 111-114. http://dx.doi.org/10.1007/s10086-005-0748-1
7. Pfriem, A.; Wagenführ, A.; Ziegenhals, G.; Eichelberger, K., 2005: Use of wood performed by heat-treatment for musical instruments. Proceedings of the Second European Conference on Wood Modification, Göttingen, 390-397.
8. Pfriem, A., 2006: Untersuchungen zum Materialverhalten thermisch modifizierter Hölzer für deren Verwendung im Musikinstrumentenbau. Ph.D. thesis TU Dresden.
9. Wagenführ, A.; Pfriem, A.; Grothe, T.; Eichelberger, K., 2006: Untersuchungen zur vergleichenden Charakterisierung von thermisch modifizierter Fichte für Resonanzdecken von Gitarren. Holz als Roh- und Werkstoff, 64: 313-316. http://dx.doi.org/10.1007/s00107-005-0057-9
10. Pfriem, A.; Eichelberger, K.; Wagenführ, A., 2007: Acoustic properties of thermally modified spruce for use for violins. Journal of the Violin Society of America: VSA-Paper 21(1): 102-111.
11. Thomson, H. S., 2006: Thermo-treated Wood... Vintage Tone or Voodoo from Finland? The ToneQuest, 7(3): 11-16.
12. Wegst, U., 2006: Wood for Sound. American Journal of Botany, 93(10): 1439-1448. http://dx.doi.org/10.3732/ajb.93.10.1439
13. Zauer, M.; Pfriem, A., 2010: Reinforcement of Thermally Modified Wood for Use in Highly Stressed Components of Musical Instruments. Proceedings of the fifth European Conference on Wood Modification ECWM5, Riga, 31-38.
14. Zauer, M.; Sproßmann, R.; Wagenführ, A., 2014: Improvement of the acoustic properties of European beech to substitute hard maple for the use in musical instruments. Proceedings of the Seventh European Conference on Wood Modification ECWM7, Lisboa, Portugal.

Corresponding address:

Prof. Dr.-Ing. ALEXANDER PFRIEM

Eberswalde University for Sustainable Development - University of Applied Sciences
Professorship Wood Chemistry, Wood Physics and Chemical Engineering
Schicklerstraße 5
16225 Eberswalde, GERMANY
e-mail: alexander.pfriem@hnee.de



Portal of scientific journals of Croatia

http://hrcak.srce.hr/

Na Šumarskom fakultetu održana 13. Generalna skupština InnovaWooda

Od 9. do 11. lipnja 2015. Šumarski fakultet Sveučilišta u Zagrebu bio je domaćin 13. Generalne skupštine InnovaWooda (InnovaWood General Assembly and Board meetings 2015), međunarodne organizacije sa sjedištem u Bruxellesu. Na skupštini je sudjelovao više od trideset gostiju iz dvadesetak zemalja (sl. 1.).

InnovaWood krovna je organizacija koja objedinjuje četiri europske mreže u šumarskome i drvnom sektoru, proizvodnji namještaja i potpori inovacijama u tim sektorima. Ima više od 50 članova iz 26 zemalja i vodeća je organizacija u šumarstvu i drvnoj tehnologiji. Usto, InnovaWood nudi niz različitih proizvoda i usluga na području obrazovanja, istraživanja, inovacija i transfera tehnologije. Posebno podržava primjenu i uvođenje inovacija, istraživanja, obuku i obrazovanje kao alate za povećanje konkurentnosti europske industrije, u skladu s općom politikom Europske unije.

Tijekom tri dana održane su brojne tematske radionice, ali i mnoge druge aktivnosti. Dana 9. lipnja 2015. održana je sjednica Izvršnog odbora i sve nazočne službeno je pozdravio i primio prodekan za međunarodnu suradnju Šumarskog fakulteta prof. dr. sc. Danko Diminić.

Generalna skupština počela je raditi 10. lipnja 2015., a uvodne riječi s pozdravnim govorima održali su predsjednik InnovaWooda prof. Joris Van Acker i dekan Šumarskog fakulteta prof. dr. sc. Vladimir Jambreković. Oba su sugovornika istaknula važnost međusobne suradnje na vrlo zahtjevnome globalnom svjetskom tržištu. Nakon pozdravnih riječi rad InnovaWooda nastavljen je u Vijećnici Šumarskog fakulteta. Predstavljen je vrlo bogat plan rada te su održane brojne radionice utemeljene na novim projektima, konkurentnosti i transferu znanja. U sklopu rada Generalne skupštine prof. dr. sc. D. Diminić održao je predavanje o Fakultetu i o 250 godina hrvatskoga šumarstva te su predstavljena dva IPA projekta. Članovi InnovaWooda obišli su prostore i laboratorije Šumarskog fakulteta, koji su im detaljno pokazani.

Također valja istaknuti kako je s uglednim španjolskim institutom AIDIMA Furniture, wood and packaging Technology Institute, E-46980 Paterna (Valencia), Spain, potpisan Ugovor o suradnji (sl. 2.). Tim ugovorom Laboratorij za ispitivanje namještaja i dijelova za namještaj Šumarskog fakulteta u Zagrebu postigao je dogovor o dugogodišnjoj suradnji u ispitivanju namještaja i razvoju novih metoda ispitivanja.

Svakako treba istaknuti da je prof. dr. sc. Ivica Grbac, jedan od osnivača InnovaWooda, kao član Izvršnog odbora zapravo najzaslužniji što je taj iznimno važan skup održan na Šumarskom fakultetu u Zagrebu te je zbog svojih dosadašnjih aktivnosti unutar te ugledne organizacije ponovno jednoglasno izabran za člana Izvršnog odbora.

Ovogodišnja Generalna skupština InnovaWooda bila je vrlo važan događaj za Šumarski fakultet, koji se

Slika 1. Članovi InnovaWooda s dekanom Šumarskog fakulteta u Zagrebu prof. dr. sc. Vladimirom Jambrekovićem

Slika 2. Potpisivanje ugovora o suradnji između Šumarskog fakulteta i AIDIMA instituta

Slika 3. Dekan predaje priznanje u povodu 25. obljetnice održavanja znanstvenoga međunarodnog savjetovanja *Ambienta* predsjedniku InnovaWooda prof. Jorisu Van Ackeru

još jedanput pokazao kao dobar domaćin u organizaciji značajnih međunarodnih skupova. Također, Šumarski je fakultet tim skupom učvrstio dugogodišnju dobru suradnju s InnovaWoodom, koji je pratio i prati Fakultet u organiziranju međunarodnih savjetovanja *Drvo u graditeljstvu* i *Ambienta*. Tijekom dugogodišnje suradnje u organiziranju međunarodnog savjetovanja *Ambienta* InnovaWood svojim aktivnostima na područjima istraživanja, edukacije i transfera tehnologije uspješno pridonosi ostvarenju ciljeva savjetovanja (sl. 3.).

Više informacija o spomenutom događaju te detaljan program rada možete naći na web stranici http://www.innovawood.com/.

doc. dr. sc. Ivica Župčić

Miljenko Klarić obranio doktorski rad

Miljenko Klarić, mag. ing. techn. lign., obranio je 3. srpnja 2015. na Šumarskom fakultetu Sveučilišta u Zagrebu doktorski rad s naslovom *Identifikacija i karakterizacija činitelja promjene boje drva crne johe* (*Alnus glutinosa* (L.) Gaertn.) *tijekom hidrotermičkih procesa*. Povjerenstvo za obranu doktorskog rada činili su prof. dr. sc. Vladimir Jambreković (Šumarski fakultet, Sveučilište u Zagrebu), prof. dr. sc. Željko Gorišek (Biotehniška fakulteta, Univerza v Ljubljani) i prof. dr. sc. Primož Oven (Biotehniška fakulteta, Univerza v Ljubljani). Javnom obranom doktorskog rada Miljenko Klarić stekao je akademski stupanj doktora znanosti s područja biotehničkih znanosti, znanstvenog polja drvna tehnologija. Mentor rada bio je prof. dr. sc. Stjepan Pervan.

ŽIVOTOPIS

Miljenko Klarić rođen je u Zagrebu 4. siječnja 1982. kao drugi sin majke Magdalene Klarić (rođ. Sessan) i oca Stjepana Klarića. Oženjen je Kristinom Klarić (rođ. Bičanić). Osnovnu školu Stjepana Radića završio je u Božjakovini, potom je pohađao Prvu ekonomsku školu u Zagrebu. Diplomirao je na Šumarskom fakultetu, na Drvnotehnološkom odsjeku, smjer proizvodne tehnologije. Stekao je i zvanje web dizajnera te specijalista odnosno stručnjaka zaštite na radu s općim i posebnim dijelom državnoga stručnog ispita. Od 1. veljače 2005. do 30. studenoga 2008. radi kao samostalni obrtnik. Od 1. prosinca 2008. do 30. lipnja 2011. zaposlen je u Drvnoj industriji Novoselec, gdje obavlja poslove tehnologa I, voditelja Službe zaštite na radu i glavnog inženjera. Od 1. srpnja 2011. zaposlen je na Šumarskom fakultetu Sveučilišta u Zagrebu kao znanstveni novak u suradničkom zvanju asistenta na Drvnotehnološkom odsjeku, Zavodu za tehnologije materijala predstojnika prof. dr. sc. Vladimira Jambrekovića. Redoviti je član Hrvatskog zavoda za norme (HZN), u sklopu kojega aktivno sudjeluje u radu odbora HZN/TO 218: Drvo, HZN/TO 513: Mjerne jedinice i mjerila, HZN/TO E106: Elektromagnetska polja u ljudskome okolišu te HZN/TO 135: Nerazorna ispitivanja. U Hrvatskom zavodu za norme obnaša dužnost predsjednika tehničkog odbora HZN/TO 218: Drvo. Član je međunarodnih organizacija Forest Products Society (FPS) i Society of Wood Science and Technology (SWST).

PRIKAZ DOKTORSKOG RADA

Doktorski rad Miljenka Klarića sastoji se od 178 stranica (I – VIII + 170) teksta, u koji je uključeno 125 slika, 64 tablice i 169 naslova literature. Rad je podijeljen na sedam osnovnih dijelova:

1. *Uvod*, 27 str.
2. *Problematika istraživanja*, 2 str.
3. *Hipoteze i ciljevi istraživanja*, 1 str.
4. *Materijali i metode*, 28 str.
5. *Rezultati, analiza i rasprava,* 84 str.
6. *Zaključna razmatranja*, 6 str.
7. *Zaključci*, 2 str.

U doktorskom radu dan je uvodni prikaz anatomske strukture i kemijskog sastava drva te problematika njegova sušenja i parenja u kontekstu obrađivane tematike. Predstavljena je i problematika pojave neželjene promjene boje drva crne johe (*Alnus glutinosa* (L.) Gaertn.) u industrijskoj praksi, pri čemu je istaknut nedostatak znanstvenih i praktičnih spoznaja vezanih za promjenu boje drva te je obrazložen znanstveni doprinos provedenog istraživanja. S obzirom na predstavljenu problematiku istraživanja, a s ciljem da se znanstveno unaprijedi razumijevanje mehanizama promjene boje drva crne johe, postavljene su hipoteze i ciljevi istraživanja. Kako bi se ostvarili zadani ciljevi, primijenjene su znanstvene metode ekstrakcije, gravimetrije, spektrofotometrije, tekućinske kromatografije visoke djelotvornosti te su provedeni hidrotermički postupci – sušenje i parenje drva. Eksperimentalni dio doktorskog rada proveden je na Šumarskom fakultetu, Fakultetu kemijskog inženjerstva i tehnologije te na Agronomskom fakultetu Sveučilišta u Zagrebu, kao i na Biotehničkom fakultetu Sveučilišta u Ljubljani. Istraživanje je provedeno na uzorcima devet reprezentativnih stabala crne johe, pri čemu su razvijene i implementirane poboljšane metode pripreme i sprečavanja degradacije uzoraka. Tijekom provođenja istraživanja utvrđeno je najpovoljnije neutralno organsko otapalo za ekstrakciju i odabrana metoda ekstrakcije oregonina ((5*S*)-1,7-bis(3,4-dihidroksifenil)-5-(β-D-ksilopiranosiloksi)-heptan-3-on), ukupnih fenolnih spojeva i ekstraktiva iz drva crne johe te je razvijena optimalna metoda tekućinske kromatografije visoke djelotvornosti za kvalitativnu i kvantitativnu analizu oregonina. Istraživanjem je utvrđeno postojanje i raspodjela oregonina, ukupnih fenolnih spojeva i ekstraktiva u radijalnome anatomskom smjeru drva crne johe, uz što je istražena i njihova zastupljenost u zoni zdrave neprave srži. Određena je raspodjela sadržaja vode u radijalnome anatomskom smjeru nakon obaranja stabala crne johe, što je iznimno važno za optimizaciju i rezultate procesa sušenja i parenja drva. Vezano za provedbu hidrotermičkih procesa, najprije je ispitan utjecaj vremena trajanja parenja i radijalne pozicije uzorka drva na promjenu boje te je analizirana povezanost promjene boje s raspodjelom oregonina i ukupnih fenolnih spojeva. Izrađeni su predikcijski modeli odnosa promjene svjetline i komponenti kromatičnosti s obzirom na trajanje parenja i radijalnu anatomsku poziciju. Provedena je i gravimetrijska analiza sadržaja vode u drvu nakon procesa parenja u ovisnosti o radijalnoj anatomskoj poziciji i trajanju parenja, što su iznimno važni podatci za uspješno provođenje postupka sušenja drva nakon parenja. Tijekom istraživanja provedeno je sušenje uzoraka drva crne johe pri izotermnim uvjetima, ali uz različitu relativnu vlažnost zraka, kako bi se utvrdio utjecaj radijalne pozicije uzorka i relativne vlažnosti zraka na promjenu boje, pri čemu je analiziran utjecaj raspodjele oregonina i ukupnih fenolnih spojeva na promjenu boje. Izrađeni su i predikcijski modeli odnosa promjene svjetline i komponenti kromatičnosti u ovisnosti o relativnoj vlažnosti zraka i radijalnoj anatomskoj poziciji. Tijekom sušenja drva provedena je i gravimetrijska analiza sadržaja vode s obzirom na radijalnu anatomsku poziciju. Nadalje, ispitan je utjecaj topline na postojanost oregonina, pri čemu je odabrana temperatura koja je bila identična temperaturi tijekom provedenog parenja drva, te temperature koje su uobičajene pri klasičnome komornom sušenju. Utvrđen je i utjecaj ultraljubičastog zračenja na postojanost oregonina. Provedenim istraživanjima ostvareni su svi zadani ciljevi, a njihovom analizom potvrđene su i hipoteze istraživanja. Osim zadanih ciljeva, provedena su istraživanja proširena te su dobivene nove spoznaje koje će biti korisne pri obradi i preradi drva crne johe te će poslužiti kao polazište za daljnja znanstvena istraživanja, a metodologija razvijena u ovom istraživanju može se primijeniti i u znanstvenim istraživanjima ostalih vrsta drva.

OCJENA DOKTORSKOG RADA

Doktorski rad Miljenka Klarića, mag. ing. techn. lign., samostalno je izrađeni izvorni znanstveni rad u kojemu je pristupnik znanstveno istražio i obrazložio problematiku formacije narančastocrvene promjene boje drva crne johe (*Alnus glutinosa* (L.) Gaertn.) tijekom provedbe hidrotermičkih procesa. U istraživanju su jasno postavljene znanstvene hipoteze i ciljevi te su primijenjene adekvatne znanstvene metode. Postavljenim hipotezama i ciljevima kvalitetno je obuhvaćena istraživana problematika, zbog čega su rezultati dali novi cjeloviti uvid u mehanizme i činitelje koji utječu na promjenu boje drva crne johe tijekom hidrotermičkih procesa. Istraživanja su dobro planirana i postavljena, uz opsežan laboratorijski rad, a dobiveni su rezultati razumljivo i dobro protumačeni te samostalno kritički raspravljeni. Svi navedeni rezultati nove su, dosad neobjavljene znanstvene spoznaje, te su pri njihovoj analizi provedene adekvatne statističke metode kojima su potvrđena sva tumačenja rezultata. Sve su navedene cjeline same po sebi doprinos znanosti, no njihova međusobna ovisnost iznimno je važna za istraživanu tematiku, što je u doktorskom radu prikazano i obrazloženo unutar diskusije i zaključaka. Nove znanstvene spoznaje pridonijele su boljem i potpunijem razumijevanju procesa promjene boje sekundarnog ksilema crne johe tijekom hidrotermičkih procesa. Nadalje, postavljeni su kvalitetni temelji za daljnja znanstvena istraživanja. Ovaj doktorski rad vrlo je vrijedan doprinos drvnotehnološkoj znanosti, osobito području istraživanja i razvoja hidrotermičke obrade drva.

prof. dr. sc. Stjepan Pervan

MICROBERLINIA BRAZZAVILLENSIS A. CHEV.

UDK: 674.031.937.32

NAZIVI

Microberlinia brazzavillensis A. Chev. naziv je botaničke vrste iz porodice *Leguminosae/Caesalpinioideae.*

Trgovački naziv drva te vrste jest zingana (Njemačka, Francuska, Kamerun), zebrano (Njemačka, Velika Britanija), african zebra-wood (Velika Britanija), izingana (Gabon), amouk (Kamerun), enuk-enug (Gvineja).

NALAZIŠTE

Stabla *Microberlinia brazzavillensis* nalazimo u tropskim kišnim šumama, na pjeskovitim tlima zapadne Afrike: u Kamerunu, Gabonu, Kongu i Gvineji.

STABLO

U svojoj domovini *Microberlinia brazzavillensis* naraste do 40 metara, dužina debla mu je od 15 do 20 metara, a prsni promjer od 0,5 do 1,0 metar. Kora drva je raspucana, ljuskasta, sivkaste boje. Debljina kore iznosi od 0,5 do 1,0 centimetar.

DRVO

Makroskopska obilježja

Srž je obojena, svjetlosmeđa, izrazito siva do tamnosmeđa, pa čak i maslinasto smeđa. Prošarana je prugama smeđe do gotovo crne boje, koje nalikuju zebrinim prugama. Ovisno o presjeku drva, pruge mogu biti valovite do ravne. Tekstura drva je gruba, a žica je blago do vrlo usukana.

Drvo je rastresito porozno. Granica goda vidljiva je zbog marginalnog parenhima. Pore drva dobro su vidljive golim okom. Drvni traci i aksijalni parenhim vidljivi su pod povećalom.

Mikroskopska obilježja

Traheje su raspoređene pojedinačno, u parovima i u kratkim radijalnim nizovima. Promjer traheja iznosi 110...180...230 mikrometara, a gustoća im je 1...4...11 na 1 mm^2 poprečnog presjeka. Volumni je udio traheja oko 14,0 %.

Aksijalni je parenhim apotrahealno marginalan, paratrahealno vazicentričan i konfluentan, katnog rasporeda. Volumni udio aksijalnog parenhima iznosi oko 17 %.

Drvni su traci homogeni, katnog rasporeda, visine 90...205...325 mikrometara, odnosno 2 do 20 stanica, širine 12...17...25 mikrometara, odnosno širine jedne stanice. Gustoća drvnih trakova je 10...13...14 na 1 mm poprečnog presjeka. Volumni udio drvnih trakova iznosi oko 15 %. U drvnim tracima i aksijalnom parenhimu ima kristala. Drvna su vlakanca libriformska, odnosno vlaknaste traheide. Dugačka su 1120...1440 ...1680 mikrometara. Debljina staničnih stijenki vlakanaca jest 1,75...2,2...2,65 mikrometara, a promjer lumena 2,4...7,0...11,1 mikrometar. Volumni udio vlakanaca iznosi oko 54 %.

Fizička svojstva

Gustoća standardno suhog drva, ρ_o	650...730 kg/m^3
Gustoća prosušenog drva, ρ_{12-15}	690...780...850 kg/m^3
Gustoća sirovog drva, ρ_s	900...1050 kg/m^3
Poroznost	52,0...57,0 %
Radijalno utezanje, β_r	4,8...5,5 %
Tangentno utezanje, β_t	7,3...9,1 %
Volumno utezanje, β_v	12,3...14,8 %

Mehanička svojstva

Čvrstoća na tlak	35...50...65 MPa
Čvrstoća na vlak, okomito na vlakanca	2,8...4,3 MPa
Čvrstoća na savijanje	(50) 84···120 MPa
Tvrdoća (prema Brinellu), paralelno s vlakancima	oko 5,1 MPa
Tvrdoća (prema Brinellu), okomito na vlakanca	oko 2,7 MPa

TEHNOLOŠKA SVOJSTVA

Obradivost

Drvo se ručno i strojno dobro obrađuje. Rezanje i ljuštenje može biti otežano zbog usukane žice. Dobro se lijepi, brusi i politira. Ipak, velike je pore prije brušenja potrebno ispuniti transparentnim sredstvom.

Drvo dobro drži vijke i čavle, no potrebno ga je prethodno predbušiti. Toksične reakcije pri obradi drva nisu česte, no ako se pojave, obično su to samo iritacije očiju i kože. Dok se obrađuje, drvo ima karakterističan i neugodan miris.

Sušenje

Drvo treba sušiti polako, da se ne bi izvitoperilo, iskrivilo i da se ne pojavi kolaps.

Trajnost i zaštita

Prema normi HRN 350-2, 2005, srž drva srednje je otporna na gljive uzročnice truleži (razred otpornosti 3) i srednje otporna na termite (razred otpornosti M). Srž je slabo permeabilna (razred 3). Prema normama, namjene drva odgovaraju razredu otpornosti 2, tj. drvo se može upotrebljavati u unutrašnjim prostorima ili u vanjskim natkrivenim prostorima.

Uporaba

Drvo *Microberlinia brazzavillensis* najčešće se upotrebljava za izradu dekorativnih furnira, kao i za izradu namještaja, stolarije, intarzija, sportskih rekvizita, kundaka, gitara, dijelova u automobilskoj industriji, a služi i kao konstrukcijsko drvo te kao drvo za rezbarenje i tokarenje.

Sirovina

Drvo *Microberlinia brazzavillensis* na tržište dolazi u obliku trupaca i piljenica.

Napomena

Drvo nije na popisu ugroženih vrsta međunarodne organizacije CITES. Ipak ga je međunarodna organizacija IUCN Red list uvrstila na svoj popis ugroženih vrsta jer je populacija tog drveća zbog odumiranja i pretjerane eksploatacije u posljednje tri generacije smanjena za oko 20 %.

Drvo sličnih svojstava imaju vrste *Microberlinia bisulcata* A. Chev. i *Marmaroxylon racemosum* Kilip.

Literatura

1. Richter, H. G.; Dallwitz, M. J. (2000 onwards): „Commercial timbers: descriptions, illustrations, identification, and information retrieval“. In English, French, German, and Spanish. Version: 4th May 2000. http://biodiversity.uno.edu/delta/
2. Wagenführ, R.; Scheiber, C., 1974: HOLZATLAS, VEB Fachbuchverlag, Leipzig, 399-400.
3. ***1964: Wood dictionary, Elsevier publishing company, Amsterdam.
4. ***http://tropix.cirad.fr/FichiersComplementaires/EN/Africa/ZINGANA.pdf

(preuzeto 25. kolovoza 2015.).

prof. dr. sc. Jelena Trajković

doc. dr. sc. Bogoslav Šefc

Upute autorima

Opće odredbe

Časopis *Drvna industrija* objavljuje znanstvene radove (izvorne znanstvene radove, pregledne radove, prethodna priopćenja), stručne radove, izlaganja sa savjetovanja, stručne obavijesti, bibliografske radove, preglede te ostale priloge s područja biologije, kemije, fizike i tehnologije drva, pulpe i papira te drvnih proizvoda, uključujući i proizvodnu, upravljačku i tržišnu problematiku u drvnoj industriji.
Predaja rukopisa podrazumijeva uvjet da rad nije već predan negdje drugdje radi objavljivanja ili da nije već objavljen (osim sažetka, dijelova objavljenih predavanja ili magistarskih radova odnosno disertacija, što mora biti navedeno u napomeni) te da su objavljivanje odobrili svi suautori (ako rad ima više autora) i ovlaštene osobe ustanove u kojoj je istraživanje provedeno. Kad je rad prihvaćen za objavljivanje, autori pristaju na automatsko prenošenje izdavačkih prava na izdavača te na zabranu da rad bude objavljen bilo gdje drugdje ili na drugom jeziku bez odobrenja nositelja izdavačkih prava.
Znanstveni i stručni radovi objavljuju se na hrvatskome, uz sažetak na engleskome, ili se pak rad objavljuje na engleskome, sa sažetkom na hrvatskom jeziku. Naslov, podnaslovi i svi važni rezultati trebaju biti napisani dvojezično. Ostali se članci uglavnom objavljuju na hrvatskome. Uredništvo osigurava inozemnim autorima prijevod na hrvatski. Znanstveni i stručni radovi podliježu temeljitoj recenziji najmanje dvaju recenzenata. Izbor recenzenata i odluku o klasifikaciji i prihvaćanju članka (prema preporukama recenzenata) donosi Urednički odbor.
Svi prilozi podvrgavaju se jezičnoj obradi. Urednici će od autora zahtijevati da tekst prilagode preporukama recenzenata i lektora, te zadržavaju i pravo da predlože skraćivanje ili poboljšanje teksta. Autori su potpuno odgovorni za svoje priloge. Podrazumijeva se da je autor pribavio dozvolu za objavljivanje dijelova teksta što su već negdje objavljeni te da objavljivanje članka ne ugrožava prava pojedinca ili pravne osobe. Radovi moraju izvještavati o istinitim znanstvenim ili tehničkim postignućima. Autori su odgovorni za terminološku i metrološku usklađenost svojih priloga. Radovi se šalju elektroničkom poštom na adresu:
drind@sumfak.hr ili techdi@sumfak.hr

Upute

Predani radovi smiju sadržavati najviše 15 jednostrano pisanih A4 listova s dvostrukim proredom (30 redaka na stranici), uključujući i tablice, slike te popis literature, dodatke i ostale priloge. Dulje je članke preporučljivo podijeliti na dva ili više nastavaka. Tekst treba biti u *doc formatu*, u potpunosti napisan fontom *Times New Roman* (tekst, grafikoni i slike), normalnim stilom, bez dodatnog uređenja teksta.
Prva stranica poslanog rada treba sadržavati puni naslov, ime(na) i prezime(na) autora, podatke o zaposlenju autora (ustanova, grad i država) te sažetak s ključnim riječima (duljina sažetka približno 1/2 stranice A4).
Posljednja stranica treba sadržavati titule, zanimanje, zvanje i adresu (svakog) autora, s naznakom osobe s kojom će Uredništvo biti u vezi.
Znanstveni i stručni radovi moraju biti sažeti i precizni. Osnovna poglavlja trebaju biti označena odgovarajućim podnaslovima. Napomene se ispisuju na dnu pripadajuće stranice, a obrojčavaju se susljedno. One koje se odnose na naslov označuju se zvjezdicom, a ostale uzdignutim arapskim brojkama. Napomene koje se odnose na tablice pišu se ispod tablica, a označavaju se uzdignutim malim pisanim slovima, abecednim redom.
Latinska imena trebaju biti pisana kosim slovima (italicom), a ako je cijeli tekst pisan kosim slovima, latinska imena 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 ciljeva rada.
Materijal i metode trebaju biti što preciznije opisane da omoguće drugim znanstvenicima ponavljanje pokusa. Glavni eksperimentalni podaci trebaju biti dvojezično navedeni.
Rezultati trebaju obuhvatiti samo materijal koji se izravno odnosi na predmet. Obvezatna je primjena metričkog sustava. Preporučuje se upotreba SI jedinica. Rjeđe rabljene fizikalne vrijednosti, simboli i jedinice trebaju biti objašnjeni pri njihovu prvom spominjanju u tekstu. Za pisanje formula valja se koristiti Equation Editorom (programom za pisanje formula u MS Wordu). Jedinice se pišu normalnim (uspravnim) slovima, a fizikalni simboli i faktori kosima (italicom). Formule se susljedno obrojčavaju arapskim brojkama u zagradama, npr. (1) na kraju retka.
Broj slika mora biti ograničen samo na one koje su prijeko potrebne za objašnjenje teksta. Isti podaci ne smiju biti navedeni i u tablici i na slici. Slike i tablice trebaju biti zasebno obrojčane, arapskim brojkama, a u tekstu se na njih upućuje jasnim naznakama ("tablica 1" ili "slika 1"). Naslovi, zaglavlja, legende i sav ostali tekst u slikama i tablicama treba biti napisan hrvatskim i engleskim jezikom.
Slike je potrebno rasporediti na odgovarajuća mjesta u tekstu, trebaju biti izrađene u rezoluciji 600 dpi, crno-bijele (objavljivanje slika u koloru moguće je na zahtjev autora i uz posebno plaćanje), formata jpg ili tiff, potpune i jasno razumljive bez pozivanja na tekst priloga.
Svi grafikoni i tablice izrađuju se kao crno-bijeli prilozi (osim na zahtjev, uz plaćanje). Tablice i grafikoni trebaju biti na svojim mjestima u tekstu te originalnog formata u kojemu su izrađeni radi naknadnog ubacivanja hrvatskog prijevoda. Ako ne postoji mogućnost za to, potrebno je poslati originalne dokumente u formatu u kojemu su napravljeni (*excel* ili *statistica* format).
Naslovi slika i crteža ne pišu se velikim tiskanim slovima. Crteži i grafikoni trebaju odgovarati stilu časopisa (fontovima i izgledu). Slova i brojke moraju biti dovoljno veliki da budu lako čitljivi nakon smanjenja širine slike ili tablice. Fotomikrografije moraju imati naznaku uvećanja, poželjno u mikrometrima. Uvećanje može biti dodatno naznačeno na kraju naslova slike, npr. "uvećanje 7500 : l".
Diskusija i zaključak mogu, ako autori žele, biti spojeni u jedan odjeljak. U tom tekstu treba objasniti rezultate s obzirom na problem postavljen u uvodu i u odnosu prema odgovarajućim zapažanjima autora ili drugih istraživača. Valja izbjegavati ponavljanje podataka već iznesenih u odjeljku *Rezultati*. Mogu se razmotriti naznake za daljnja istraživanja ili primjenu. Ako su rezultati i diskusija spojeni u isti odjeljak, zaključke je nužno napisati izdvojeno. Zahvale se navode na kraju rukopisa. Odgovarajuću literaturu treba citirati u tekstu, i to prema harvardskom sustavu (*ime – godina*), npr. (Bađun, 1965). Nadalje, bibliografija mora biti navedena na kraju teksta, i to abecednim redom prezimena autora, s naslovima i potpunim navodima bibliografskih referenci. Popis literature mora biti selektivan, a svaka referenca na kraju mora imati naveden DOI broj, ako ga posjeduje (http://www.doi.org) (provjeriti na http://www.crossref.org).

Primjeri navođenja literature

Članci u časopisima: Prezime autora, inicijal(i) osobnog imena, godina: Naslov. Naziv časopisa, godište (ev. broj): stranice (od – do). Doi broj.

Primjer

Kärki, T., 2001: Variation of wood density and shrinkage in European aspen (*Populus tremula*). Holz als Roh- und Werkstoff, 59: 79-84. http://dx.doi.org/10.1007/s001070050479.

Knjige: Prezime autora, inicijal(i) osobnog imena, godina: Naslov. (ev. izdavač/editor): izdanje (ev. svezak). Mjesto izdanja, izdavač (ev. stranice od – do).

Primjeri

Krpan, J., 1970: Tehnologija furnira i ploča. Drugo izdanje. Zagreb, Tehnička knjiga.
Wilson, J. W.; Wellwood, R. W., 1965: Intra-increment chemical properties of certain western Canadian coniferous species. U: W. A. Cote, Jr. (Ed.): Cellular Ultrastructure of Woody Plants. Syracuse, N.Y., Syracuse Univ. Press, pp. 551- 559.
Ostale publikacije (brošure, studije itd.)
Müller, D., 1977: Beitrag zür Klassifizierung asiatischer Baumarten. Mitteilung der Bundesforschungsanstalt für Forstund Holzvvirt schaft Hamburg, Nr. 98. Hamburg: M. Wiederbusch.

Web stranice
***1997: "Guide to Punctuation" (online), University of Sussex, www.informatics.sussex.ac.uk/department/docs/punctuation/node00.html. First published 1997 (pristupljeno 27. siječnja 2010).

Autoru se prije konačnog tiska šalje pdf rada. Rad je potrebno pažljivo pročitati, ispraviti te vratiti Uredništvu s listom ispravaka te s formularom za prijenos autorskih prava na izdavača. Ispravci su ograničeni samo na tiskarske pogreške: dodaci ili znatnije promjene u radu naplaćuju se. Autori znanstvenih i stručnih radova besplatno dobivaju po jedan primjerak časopisa. Autoru svakog priloga također se dostavlja besplatan primjerak časopisa.

Dodatne informacije o načinu pisanja znanstvenih radova mogu se naći na web adresi:
www.ease.org.uk/publications/author-guidelines

Instructions for authors

General terms

The “Drvna industrija” (“Wood Industry”) journal publishes scientific papers (original scientific papers, review papers, previous notes), professional papers, conference papers, professional information, bibliographical and survey articles and other contributions related to biology, chemistry, physics and technology of wood, pulp and paper and wood products, including production, management and marketing issues in the wood industry.

Submission of a paper implies that the work has not been submitted for publication elsewhere or published before (except in the form of an abstract or as part of a published lecture, review or thesis, in which case it must be stated in a footnote); that the publication is approved by all co-authors (if any) and by the authorities of the institution where the research has been carried out. When the paper is accepted for publication, the authors agree to the transfer of the copyright to the publisher and that the paper will not be published elsewhere in any language without prior consent of the copyright holders.

The scientific and professional papers shall be published either in Croatian, with an extended summary in English, or in English with an extended summary in Croatian. The titles, headings and all the relevant results shall be presented bilingually. Other articles are generally published in Croatian. The Editor’s Office shall provide the translation into Croatian for foreign authors. The scientific and professional papers will be subject to a thorough review by at least two selected referees. The Editorial Board shall make the choice of reviewers, as well as the decision about the classification of the paper and its acceptance (based on reviewers’ recommendations).

All contributions are subject to proofreading. The editors will require authors to modify the text in the light of the recommendations made by reviewers and language advisers, and they reserve the right to suggest abbreviations and text improvements. Authors are fully responsible for the contents of their contributions. It shall be assumed that the author has obtained the permission for the reproduction of portions of text published elsewhere, and that the publication of the paper in question does not infringe upon any individual or corporate rights. Papers shall report on true scientific or technical achievement. Authors are responsible for the terminological and metrological consistency of their contributions. The contributions are to be submitted by e-mail to the following address:

E-mail: drind@sumfak.hr

Details

Papers submitted shall consist of no more than 15 single-sided DIN A-4 sheets of 30 double-spaced lines, including tables, figures and references, appendices and other supplements. Longer papers should be divided into two or more continuing series. The text should be written in doc format, fully written using Times New Roman font (text, graphs and figures), in normal style without additional text editing.

The first page of the paper submitted should contain full title, name(s) of author(s) with professional affiliation (institution, city and state), abstract with keywords (approx. 1/2 sheet DIN A4).

The last page should provide the full titles, posts and address(es) of each author with indication of the contact person for the Editor’s Office.

Scientific and professional papers shall be precise and concise. The main chapters should be characterized by appropriate headings. Footnotes shall be placed at the bottom of the same page and consecutively numbered. Those relating to the title should be marked by an asterix, others by superscript Arabic numerals. Footnotes relating to the tables shall be printed under the table and marked by small letters in alphabetical order.

Latin names shall be printed in italics and underlined.

Introduction should define the problem and if possible the framework of existing knowledge, to ensure that readers not working in that particular field are able to understand author’s intentions.

Materials and methods should be as precise as possible to enable other scientists to repeat the experiment. The main experimental data should be presented bilingually.

The results should involve only material pertinent to the subject. The metric system shall be used. SI units are recommended. Rarely used physical values, symbols and units should be explained at their first appearance in the text. Formulas should be written by using Equation Editor (program for writing formulas in MS Word). Units shall be written in normal (upright) letters, physical symbols and factors in italics. Formulas shall be consecutively numbered with Arabic numerals in parenthesis (e.g. (1)) at the end of the line.

The number of figures shall be limited to those absolutely necessary for clarification of the text. The same information must not be presented in both a table and a figure. Figures and tables should be numbered separately with Arabic numerals, and should be referred to in the text with clear remarks (“Table 1” or “Figure 1”). Titles, headings, legends and all the other text in figures and tables should be written in both Croatian and English.

Figures should be inserted into the text. They should be of 600 dpi resolution, black and white (color photographs only on request and extra charged), in jpg or tiff format, completely clear and understandable without reference to the text of the contribution.

All graphs and tables shall be black and white (unless requested otherwise with additional payment). Tables and graphs should be inserted into the text in their original format in order to insert them subsequently into the Croatian version. If this is not possible, original document should be sent in the format in which it was made (excel or statistica format).

The captions to figures and drawings shall not be written in block letters. Line drawings and graphs should conform to the style of the journal (font size and appearance). Letters and numbers shall be sufficiently large to be readily legible after reduction of the width of a figure or table. Photomicrographs should have a mark indicating magnification, preferably in micrometers. Magnification can be additionally indicated at the end of the figure title, e.g. “Mag. 7500:1”.

Discussion and conclusion may, if desired by authors, be combined into one chapter. This text should interpret the results relating to the problem outlined in the introduction and to related observations by the author(s) or other researchers. Repeating the data already presented in the “Results” chapter should be avoided. Implications for further studies or application may be discussed. A conclusion shall be expressed separately if results and discussion are combined in the same chapter. Acknowledgements are presented at the end of the paper. Relevant literature shall be cited in the text according to the Harvard system (“name – year”), e.g. (Bađun, 1965). In addition, the bibliography shall be listed at the end of the text in alphabetical order of the author’s names, together with the title and full quotation of the bibliographical reference. The list of references shall be selective, and each reference shall have its DOI number (http://www.doi.org) (check at http://www.crossref.org).:

Example of references

Journal articles: Author’s second name, initial(s) of the first name, year: Title. Journal name, volume (ev. issue): pages (from - to). DOI number.

Example:
Kärki, T., 2001: Variation of wood density and shrinkage in European aspen (*Populus tremula*). Holz als Roh- und Werkstoff, 59: 79-84. http://dx.doi.org/10.1007/s001070050479.

Books:
Author’s second name, initial(s) of the first name, year: Title. (ev. Publisher/editor): edition, (ev. volume). Place of publishing, publisher (ev. pages from - to).

Examples:
Krpan, J. 1970: Tehnologija furnira i ploča. Drugo izdanje. Zagreb: Tehnička knjiga.
Wilson, J.W.; Wellwood, R.W. 1965: Intra-increment chemical properties of certain western Canadian coniferous species. U: W. A. Cote, Jr. (Ed.): Cellular Ultrastructure of Woody Plants. Syracuse, N.Y., Syracuse Univ. Press, pp. 551-559.

Other publications (brochures, studies, etc.):
Müller, D. 1977: Beitrag zur Klassifizierung asiatischer Baumarten. Mitteilung der Bundesforschungsanslalt für Forst- und Holzwirtschaft Hamburg, Nr. 98. Hamburg: M. Wiederbusch.

Websites:
***1997: “Guide to Punctuation” (online), University of Sussex, www.informatics.sussex.ac.uk/department/docs/punctuation/node00.html. First published 1997 (Accessed Jan. 27, 2010).

The paper will be sent to the author in pdf format before printing. The paper should be carefully corrected and sent back to the Editor’s Office with the list of corrections made and the form for the transfer of copyrights from the author to the publisher. Corrections should be limited to printing errors; amendments to or changes in the text will be charged. Each contributor will receive 1 copy of the journal.

Further information on the way of writing scientific papers can be found on the following website:

www.ease.org.uk/publications/author-guidelines