ECO-EFFICIENT RESOURCE WOOD WITH SPECIAL FOCUS ON HARDWOODS

in conjunction with the

“Conference of Climate protection through forestry, renewable materials, smart technologies and environmental education”

and with the

COST Action FP1407 Workshop

Sopron, 8–9th September 2016

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ALFRED TEISCHINGER & RÓBERT NÉMETH & PETER RADEMACHER & MIKLÓS BAK & FANNI FODOR

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Proceedings of the "ECO-EFFICIENT RESOURCE WOOD WITH SPECIAL FOCUS ON HARDWOODS" in conjunction with the "Conference of Climate protection through forestry,renewable materials, smart technologies and environmental education" and with the "COST Action FP1407 Workshop"
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COST is a unique means for European researchers, engineers and scholars to jointly develop their own ideas and new initiatives across all fields of science and technology through trans-European networking of nationally funded research activities

It anticipates and complements the activities of the EU Framework Programmes. It also increases the mobility of researchers across Europe and fosters the establishment of scientific excellence in nine key domains, with Forestry, their Products and Services (FPS) being one of these. At any given time, there are between 20 and 30 COST Actions running within the FPS Domain, each one running for 3-4 years.

Now, the 7th Hardwood Conference has the pleasure to be linked with one of the current COST Actions, **FP1407**: Understanding wood modification through an integrated scientific and environmental impact approach (ModWoodLife)

As part of the interaction between this Action and Hardwood Conference, the following presenters have been provided with financial assistance for their involvement at this conference:

Jakub Dömény (Czech Republic), Milan Gaff (Czech Republic), Željko Gorišek (Slovenia), Andreja Kutnar (Slovenia), Tillmann Meints (Austria), Julia Mihajlova (Bulgaria), Primoz Oven (Slovenia), Radim Rousek (Czech Republic), Dick Sandberg (Sweden), Matthew Schwarzkopf (Slovenia), Nasko Terziev (Sweden), Luigi Todaro (Italy), Gus Verhaeghe (Belgium), Kerstin Wagner (Austria), Mario Zauer (Germany), Aleš Zeidler (Czech Republic)

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COST
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

FP1407
ModWoodLife

Contents

Plenary session

COST Action FP1407 - Understanding wood modification through an integrated scientific and environmental impact approach

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Keywords: Modification, processing, LCA, EPD, cascading

ABSTRACT

Cooperation in Science and Technology, COST is the longest-running European framework supporting transnational cooperation among researchers, engineers and scholars across Europe. Based on a European intergovernmental framework for cooperation in science and technology, COST has been contributing since its creation in 1971 to closing the gap between science, policy makers and society throughout Europe and beyond. COST funds pan-European, bottom-up networks of scientists and researchers across all science and technology fields. These networks, called COST Actions, promote international coordination of nationally-funded research.

The COST Action FP1407 "Understanding wood modification through an integrated scientific and environmental impact approach" started in March 2015 and will last until April 2019. The main aim of the Action is to characterize the relationship between modification processing, product properties, and the associated environmental impacts. This includes the development and optimization of modified processing and quantification of the impacts of emerging treatment technologies compared to traditional processing and alternative materials to maximize sustainability and minimize environmental impacts. The Action provides the critical mass of Europe-wide knowledge needed to achieve the future developments in the wood modification processing with integrating assessment of process parameters, developed product properties, and environmental impacts.

Forest-based industries are continually developing advanced processes, materials and wood-based solutions to meet evolving demands and increase competitiveness. Several emerging environmental-friendly processes of wood modification (chemical, thermal and impregnation/polymerization) have been developed, which can improve the intrinsic properties of wood, and provide desired form and functionality. However, a more detailed consideration reveals several issues which lead to the question: Is the global environmental impact of wood modification processing and further uses of the resulting products comparable with the impact of native, untreated wood? To address this question the COST Action FP1407 will apply the cradle to cradle (C2C) concept to the development of products based on wood modification processes. This paradigm values new advanced wood-based materials with improved intrinsic properties that promote efficient product reuse, recycling and end-of-life use, and pave the way to a low-carbon economy (Figure 1).

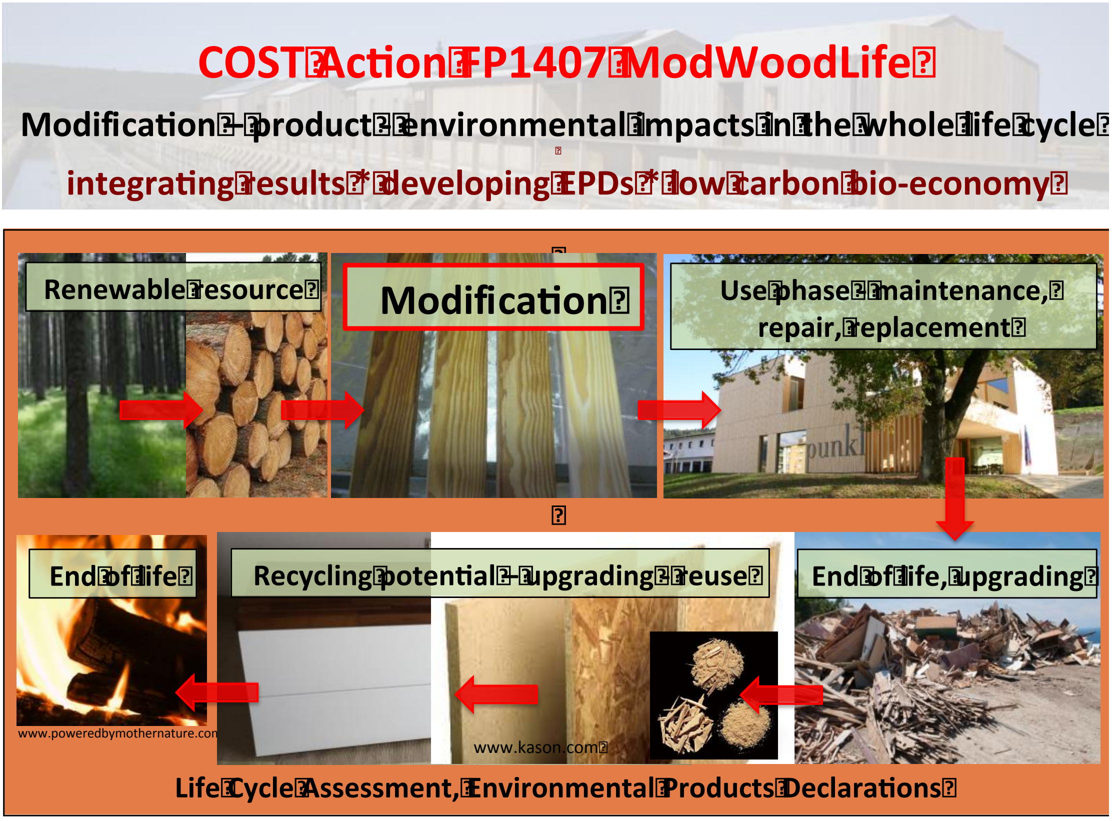

Figure 1: COST Action FP1407

The networking, multi-disciplinary collaboration, exchange of knowledge, and scientific excellence, as well as the expertise of industrial members, address the following issues through open access dissemination and promotion: Societal (Creating innovation encouraging and engaging environment that would result in value-added products, processes and systems, which enable sustainable building for the next generation of improved and renewable building materials and increased resource efficiency); Scientific (Fundamental research targets increased resource efficiency, extended product life, while the applied part contributes to improvements in product performance and functionality and minimizes the overall negative environmental and human health impacts); Economy (Innovative transformation of the forest products industry to a competitive knowledge-based industry that fosters the extended and improved use of local natural resources, development of innovative products, including new and currently underused products).

More information: http://costfp1407.iam.upr.si/en/

European Hardwoods Innovation Alliance – E-HIA

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Keywords: Innovation and Research Alliance, European Hardwoods; Multi-actor approach

ABSTRACT

Objective of the new "European Hardwoods Innovation Alliance - EHIA":

A new initiative for the creation of a focused, thematic innovation, research and training alliance, has been launched, by the European umbrella organisation InnovaWood in an integrative close collaboration with the European Forest Institute (EFI). This initiative is called "European Hardwoods Innovation Alliance – EHIA". The European Commission Services accepted EHIA as a commitment under the European Innovation Partnership for Raw Materials (ID 669).

Key objective of EHIA is to produce a detailed innovation and research program (IRP) with an accompanying implementation action plan (IAP). For this purpose, sixteen Innovation and Research themes have been pre-defined:

[1]Smart buildings and timber construction; [2]facades and exterior applications; [3]interior design; [4]furniture and well-being; [5]wood-based composites, new materials and fibers; [6]green chemistry (food and non-food); [7]life-style goods; [8]mobility (humans, animals and products); [9]clever keen injection (transfer of existing know-how into the forest-based sector); [10]harvesting, transportation and logistics; [11]forest ownership and resource availability; [12]hardwoods resource location and potential; [13]mobilization; [14]forest management strategies; [15]tree breeding; trade and markets; [16]societal attitudes and expectations.

The E-HIA IRP will generate excellent knowledge and provide new products, processes and services. It will emphasize the value added use of HARDWOODS within Europe and contribute to tackle the grand societal challenges.

This Alliance will coordinate the know-how and the critical mass leading to breakthroughs in innovation, research and it will create new qualified employment in smart rural regions within Europe.

The Timeframe is considered to facilitate collaboration with a long-term perspective (2025 and beyond). It is important to underline that the E-HIA will not replace evolutions and innovations in existing forest-based value chains that are built upon softwood species. It is focussing on new potentials and new applications by using hardwood species in an innovative way.

Background:

Europe is covered by 41% with forest. Historically hardwoods were used in the construction sector, furniture, cladding, flooring etc. Today the forest-based industries within Europe are predominately based on softwood use. Coniferous tree species account for 57% of the European growing stock in forests, that corresponds to 20.0 billion m3. The growing stock of broadleaved tree species amounts to 15.0 billion m3. But, the stem volume of living trees in European forests is evenly distributed between broadleaved and coniferous tree species in almost all regions with the exception of the North Europe region where around 75% of growing stock is coniferous [Forest Europe, 2015].

The European Hardwoods Innovation Alliance runs under the umbrella of InnovaWood in a close collaboration with the European Forest Institute (EFI).

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European Commission Services, DG for Internal Market, Industry, Entrepreneurship and SMEs; 2nd Call for Commitments, 2016. **EHIA (ID 669):** https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/european-hardwoods-innovation-alliance-0

InnovaWood is a European network of research organisations dealing with research, education & training and technology transfer in the wood and furniture sector. The network comprises over 50 organisations in 27 countries and has the overall aim to provide a forum for its member organisations to stimulate new innovations and developments. http://www.innovawood.com/

European Forest Institute (EFI) is an international organisation, established by European States and comprising c.115 Associate and Affiliate Member organisations in 36 countries, five Regional Offices and three Project Centres. EFI conducts research and provided policy support on issues related to forests. http://www.efi.int

Forest Europe: State of European Forests 2015
http://www.foresteurope.org/docs/fullsoef2015.pdf

Session I/1.
Material Properties I. - Native wood

Agricultural and forestry biomass sidestream valorization development - a new international initiative - AgriForValor

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Keywords: agriculture, forestry, biomass sidestream, valorization, innovation

ABSTRACT

The scantiness of raw material sources is observable on several areas, which draws the attention on the one hand to the need of expansion of these sources and on the other hand to the conscious use of them. This statement could be correct related to the biomass based product manufacturing and the biomass based energy production as well. The biomass valorization development should be based on the newest research results and should be realized using the tools of innovation. The AgriForValor project which is leaded by the Steinbeis Innovation gGmbH and will be realized in the cooperation of 16 European institutes would achieve significant results in this field.

Table 1: The current and expected rate of the different renewable energy sources used in electricity and cooling-heating sector in Hungary in 2010 and 2020 (Ministry of National Development, 2011)

Renewable energy sources	2010		2020	
	%	PJ/year	%	PJ/year
Biomass	83	40,74	62	60,97
Biogas	1	0,32	5	4,63
Geothermal energy	9	4,23	17	16,43
Heat pump	0	0,25	6	5,99
Wind power	5	2,49	5	5,56
Hydropower	1	0,7	1	0,86
Solar energy	1	0,25	4	3,73

The main goal of the AgriForValor project is to develop the agricultural and forestry waste, by-product and residue utilization, turning the primary and secondary biomass into a valorized biomass sidestream, involving the main players of biomass value chain (Agro/Forest, RTD and Bio-industry sector). Research results and current used techniques related to biomass valorization will be reviewed and evaluated with the aim to choose the best practices for biomass valorization by regions, to redound to the formation of new market stable product chains, and to search for new types of use of primary and secondary biomass. The project, which is founded by the European Union, started in 1st March 2016.

Figure 1: Wood chips are the one of the most important primary forestry biomass; it is widely used for heat and electricity production in Europe

The project intends to integrate the biomass producers, biomass users and the actors of RTD and Bio-industry sectors into innovation partnership networks, which can contribute to improve the competitiveness of agricultural and forestry sector. These networks will be managed by 3 Biomass Innovation Design Hubs located in Spain, Ireland and Hungary. The workshops will be organized by the Hubs with the aim to facilitate new connections between stakeholders, to share knowledge and experiences, to formulate grass root ideas, and for promoting new business models.

Figure 2: The logo of the AgriForValor project; the leaves with different colour symbolize the cooperation of the representatives of biomass producers, RTD and Industrial sector

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"*Prosopis alba* Gris." Plantation Wood

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Keywords: White mesquite, Prosopis alba, plantations, wood physical and mechanical properties.

ABSTRACT

Prosopis spp. "mesquites" wood has been used mainly for the making of parquet flooring, wood carving items, barrels, sliced veneers and high quality solid wood furniture in Argentina since the '80s which brought about a remarkable decrease of their timber stock. Among them, the White mesquite tree is the most widely used in the country due to its overall dimensions and characteristics along with a healthy state which altogether makes it a higher quality timber. This wood stock might be recovered by applying silvicultural management methods on identical individuals obtained by clonning and an enhanced wood processing in the forest product industry. Thus, this paper was aimed at determining the industrial feasibility of the White mesquite Prosopis alba Gris. wood from final felling trees performed on a experimental stand. Test material consisted of logs obtained from a plantation at the Forest Nursery in Fernandez, Santiago del Estero dated year 2000 whose DBHs (diameter at breast height) ranged from 30 to 40 cm. The analyses implied determining 1) macroscopic sapwood/heartwood rate and wood colour. 2) Physical properties: 12% MC (moisture content) and oven-dry density; 3) Mechanical properties tests: Bending Stiffness MOE and Bending Strength MOR values, Dynamic Bending Strength values, Crushing Strength value. Results, showed that wood from final felling trees is harder and much better than that obtained from mature trees from natural woods which would make it a first class raw material suitable for industrial applications.

Tables

*1).**Table 1: Results Wood physical and mechanical properties***

Prosopis alba Gris. Plantation Wood Wood physical and mechanical properties.		Final felling wood ẋ	 σ	 CV%
Weight (barking wet logs) MC 50% Kg/m³		987,5	144,1	14,6
Weight (barking wet logs) MC 12% Kg/m³		715,6	104,4	14,6
Oven dry weight (Norma DIN 52182) Kg/m³		660,0	40,0	6,0
Weight 12% (acc. Kolman) Kg/m³		740,0	40,0	5,4
Tension	Bending Strength value (MOR) N/mm²	121,7	39,7	32,6
	Bending Stiffness value (MOE) N/mm²	16661,9	36,8	0,2
Dynamic Bending Strength value (J/mm²)		23,3	11,3	48,6
Crushing Strength value (N/mm²)		52,4	10,2	19,5

Figures

Figure 1: Prosopis alba trees plantation for timber production purposes.

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Shrubs – a forgotten resource of wood

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Keywords: hardwood, shrubs, wood quality, mechanical strength, natural resources, wood

ABSTRACT

Wood was the most frequently used raw-material in former times. It was handled with great wisdom which was gathered over centuries. Selection of a wood species for each application was well considered.

BLAU (1917), an ethnographer in Bohemia, mentioned that at a farmhouse in Carinthia 12 different wood species were found. Studying a farmhouse in Bohemia, he was able to find 27 different species. These findings underline the high variability of wood utilization in former times.

Out of all woody plants growing in the surrounding nature just several species are used for wood processing nowadays. But in old literature we can find interesting comments about utilization of many more wood species than we are using nowadays.

It was possible to determine in total 48 different wood species in different museums in Austria (KLEIN ET AL. 2016). The most frequently identified species was spruce (*Picea abies*) followed by beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*) and birch (*Betula pendula*). Within these 48 wooden species, 17 species can be classified as shrub. The most frequently used shrubs were hazelnut (*Corylus avellana*), cornelian cherry (*Cornus mas*) and barberry (*Berberis vulgaris*). Furthermore there are ten different fruit-bearing trees included, such as pear (*Pyrus communis*) or apple (*Malus domestica*), cherry (*Prunus avium*), plum (*Prunus domestica*), rocky cherry (*Prunus mahaleb*) walnut (*Juglans regia*) and four different species of genus *Sorbus*.

In Austria, 2.5 % of the utilized woodland area is covered with shrubs which is more than by fir (2.3 %) or oak (2 %) (PREM 2008). Nevertheless, the wood of shrubs is not commercially used today, although the wood properties of many shrubs would be worth utilizing. If all shrubs are grouped together, they rank in the eighth position of the most utilized species in former times; more than 5 % of all objects were made of wood coming from shrubs.

It is noticeable that many shrubs have high density values between 0.8 and 1 g/cm3. This can be compared with hornbeam (*Carpinus betulus*), being the commercially used species with the highest density value of 0.74 g/cm^3 and oak (*Quercus spp.*), having 0.64 g/cm^3.
The high density is one of the properties that make shrubs valuable, but with wood density other properties such as strength follow. An overview of various properties (like strength, abrasion resistance etc.) will be presented.

Three shrubs were chosen to be described in detail. These are cornelian cherry, barberry and hazelnut: Cornelian cherry (*Cornus mas*) is one of the wood species having the highest density. It was selected, if high impact strength, good vibration damping and good dimensional stability were required. It was used for tool handles, for rungs of ladders, for objects in textile industry, e.g., as weavers shuttle or for striking tools such as mallet or threshing flail. In the analysed folkloristic literature it is mentioned only once for the wooden tooth of a harrow. In old literature dealing with wood species it was highly praised (e.g., MOELLER, 1883). It is described to be hardly fissile, hard and fibrillar. To the above mentioned range of application, teeth of combs and clock mechanisms can be added from the literature.
Barberry (*Berberis vulgaris*) was used for its high resistance against abrasion and good vibration damping. Most rake teeth were made of barberry and also folklorist literature mentions the wood to be best suitable for this application (MOSER, 1980). Interestingly, the literature describing wood properties does not mention rake teeth made of barberry at all, but recommends using it for inlays, due to its nice yellow colour.
Hazelnut (*Corylus avellana*) sticks out of the group of shrubs. It was the most utilized shrub, ranking on its own in eighth place of the most utilized species. In contrast to most other shrubs, hazelnut was not used because of its high density. It was used because of its high flexibility and good fissility. Therefore, it was used for barrel hoops and for all basket-works (more than 50 % of all wattle was made of hazelnut). Furthermore it was utilized for tool handles, walking sticks and skiing sticks. The literature also mentions hazel for the same field of application (GAYER 1939).

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Wood Formation Dynamics in Some Selected Hardwood Trees

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Keywords: Birch, beech, pinning-technique, cambium dynamics, wood formation

ABSTRACT

During its active period, the vascular cambium of trees delivers phloem cells to the outside and xylem cells to the inside through cell divisions leading to the secondary growth of stems. The cambium of trees is a very powerful tissue producing an enormous amount of biomass. An estimate by FAO (2016) for the global above-ground woody biomass is 422 billion m^3. Also in Germany, the production of woody biomass, being around 11 m^3 per ha and year, is impressive (POLLEY ET AL. 2009). Throughout the year, the vascular cambium undergoes structural changes which are related to the various activity stages within the season (e.g. PRISLAN ET AL. 2013, SCHMITT ET AL. 2016).

Wood formation dynamics in boreal and temperate climates result in a mostly S-shaped curve with a slow begin after dormancy, followed by a stage of high activity and a slow decrease at the end of the vegetation period. To follow these seasonal intra-annual rhythms of wood formation, we used the pinning-technique. Briefly, a pin of 1.2mm in diameter was inserted through the bark and the cambium into the outer xylem. Due to this wounding, the cambium was stimulated to produce wound reaction tissue around the pinning canal, whereby the transition between regularly formed xylem and wound tissue in most cases clearly indicates the location of the cambium at the time of wounding. At the end of the growing season, the study trees were felled and small samples containing one pinning canal were embedded and sectioned for light microscopy. For further details see SEO ET AL. (2007).

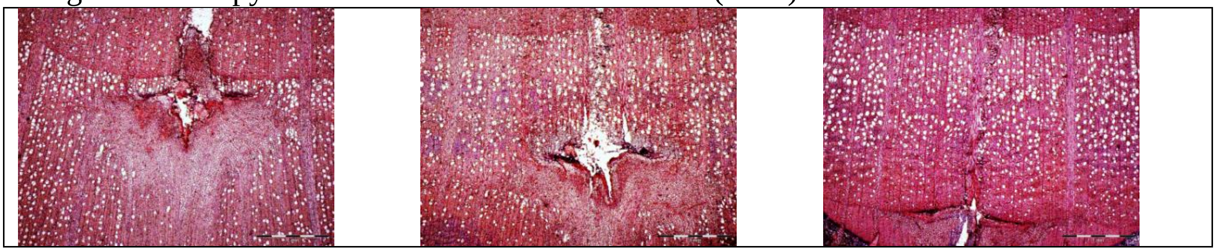

Fig. 1: Light micrographs showing cross sections of xylem portions in beech trees along a pinning canal with varying amounts of wood formed until date of pinning: left/pinning 23 May, middle/pinning 19 June, right/pinning 29 August.

For birch trees (*Betula* spp.) growing in Abisko/North-Sweden under extremely cold climate conditions it was recorded that the trees had a wood formation period of only 4-5 weeks. These trees regularly started wood formation in the first half of July and stopped it already in the first half of August. Entire tree ring-widths were about 1mm only. Defoliation of the birch trees just

before the onset of wood formation caused an end of wood formation about two weeks later reducing tree ring-widths by about 50%.

Wood formation dynamics were also determined for six different provenances of European beech (*Fagus sylvatica* L.) growing at a site close to Kiel/North-Germany. Wood formation in all trees typically followed an S-curve with a short and slowly starting early stage, a middle stage with distinctly increased wood formation and a slowly decreasing stage at the end of the vegetation period. In contrast to the situation in northern Europe the beech trees formed wood over a period of up to four months with a beginning in the second half of May and an end at around middle of September. Provenance-specific characteristics of duration and course of wood formation were not recorded, although a certain tendency of a slightly delayed onset of wood formation for those provenances with warmer yearly average temperatures was observed (SCHMITT ET AL. 2012).

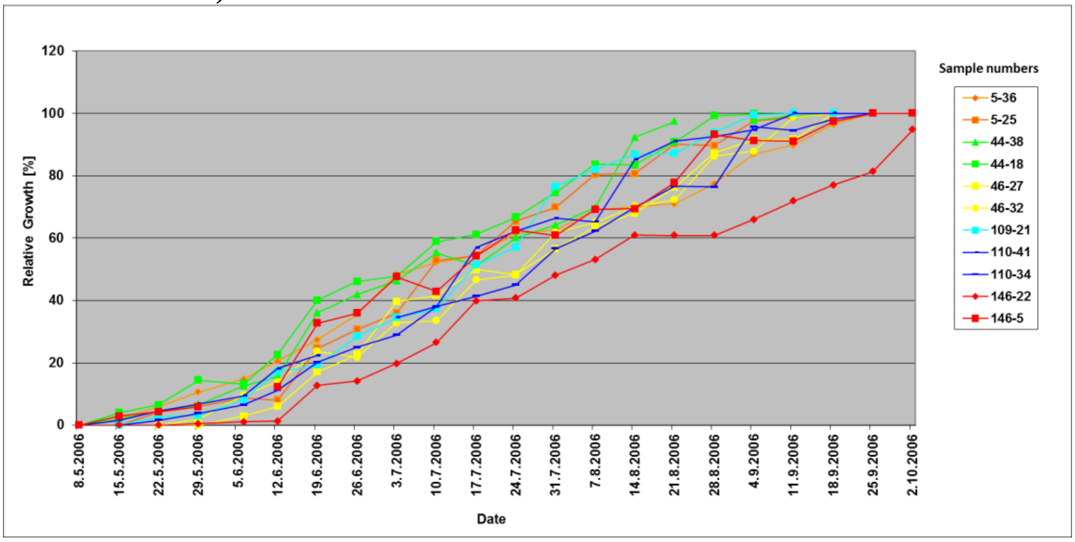

Fig. 2: Diagram of seasonal course of wood formation for 2006 in beech trees as relative growth in percent of the total tree ring-width. Different provenances are presented in different colours.

The obtained results were analyzed for effects due to specific intra-annual climate conditions, especially to the influence of temperature.

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Relationship between ultrasonic velocity and spiral grain in standing hybrid aspen trees

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Keywords: non-destructive testing, ultrasonic velocity, spiral grain angle, standing trees, *Populus tremula* L. *x P. tremuloides* Michx.

ABSTRACT

Aspen (*Populus tremula* L.) accounts for about 9% of the total hardwood volume in Sweden and comes second after the dominant birch. Aspen is the classic timber used for sauna benches in Scandinavia while its main use is less valuable biomass for pulp, paper and matches (Christersson 2010). Since there are no Swedish grading rules and design values for aspen timber almost no timber is used for structural purposes. Despite an increase in the growing stock of hardwood trees and aspen in particular, the demand from the Swedish market exceeds the supply and considerable amounts of roundwood and sawn wood are imported each year. Today a great proportion of high quality aspen does not reach the timber industry. One reason is that aspen trees often grow interspersed within the coniferous forests which make their extraction and delivery costly. At the same time, wood industries using aspen have to cope with variable, non-consistent sources of raw material with usually inferior quality as compared to well managed conifers. Hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx) offers a well growing and thus economically interesting supplementary resource since it is grown in plantations and is managed well (Rytter and Stener 2014). While private forest owners increasingly plant hybrid aspen, it is needed to create appropriate grading systems of stems and logs for a value added wood conversion. Non-destructive testing of standing trees could provide useful information is this respect.

Materials and methods

Six even-aged (19 years) plots of 14 × 14 hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx) trees with a planting distance of 2.5 × 2.5 m were selected for the study. The plots were established on well drained, former agricultural fields with gentle slopes to the south close to Ingelstad, Sweden (Latitude: 56º74´ N, Longitude: 14º88´ E, altitude: 145 m). A thinning was performed ten years after the establishment of the plots resulting to 754 trees per ha from the initial 1,410 trees per ha. The total height, diameter at breast height, spiral grain and ultrasonic wave velocity of 8 randomly selected standing trees per plot (48 trees in total) were measured. Velocity of ultrasonic waves was measured by using a commercial ultrasonic tester (Sylvatest Trio, CBS-CBT Technologies, Switzerland) of 22 kHz pulsed longitudinal waves (Sandoz et al. 2000). Two exponential piezoelectric conical transducers were imbedded in the tree trunk (deep enough to go through the bark) for transmitting and receiving the pulses at a distance of 150 cm above breast height. Spiral grain under the bark was assessed by the scribe test method (Säll 2000). A positive number was given for both left and right handed angles. Increment cores were collected from the sapwood of each tree at the middle of the 150 cm portion and transferred to the laboratory in sealed plastic bags to determine moisture content and wood density.

Results

The diameter at breast height of sampled trees ranged from 166 to 294 mm and tree heights varied from 16.3 to 23.0 m. The average moisture content was 102.6% for sapwood. The average basic density of the same wood zone was determined as 0.342 g/cm^3. For tree stems, the high anisotropy and inhomogeneity of wood make the wave propagation more complex than in homogeneous, isotropic materials. Variations in stiffness, density, and moisture content within a tree can affect the acoustic velocity. However, a change in acoustic wave velocity due to a change in density has been not always confirmed (Baar et al. 2012). In our case, with increasing density the ultrasonic velocity significantly decreased ($r = 0.691$, $P<0.05$). Also, variations in grain angle, including knots, branches and spiral grain, can reduce the measured velocity (Jones and Emms 2010). A statistically significant negative correlation ($P<0.05$) was found between the ultrasonic wave velocity and spiral grain angle (Fig. 1). Trees with high spiral grain angles from 4^o to 7^o had a statistically significant (t-test, $P<0.05$) lower mean ultrasonic velocity (3,781 m/s) than trees with low angles from 0^o to 3^o (3,937 m/s). It is therefore evident that non-destructive measurements of the ultrasonic wave velocity in standing hybrid aspen trees could provide quite reliable estimations of spiral grain under bark. The results are useful for future studies to understand the combined effect of ultrasonic properties and spiral grain of aspen trees on the stiffness of derived sawn products.

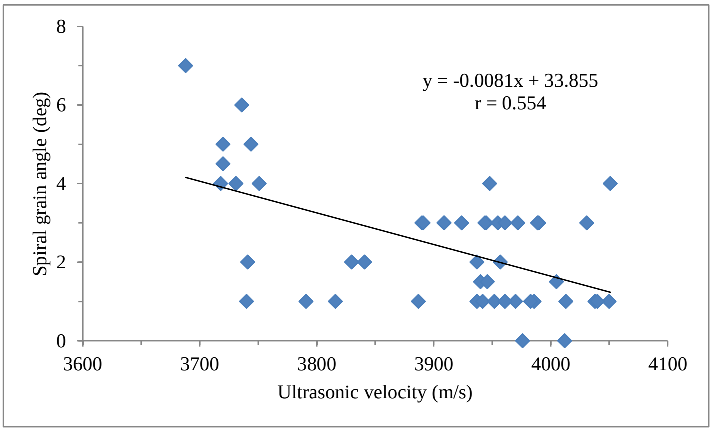

Figure 1: Relationship between ultrasonic wave velocity and spiral grain angle

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Anatomical and chemical characteristics of wound-associated wood in beech

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Keywords: Beech, wounding, discoloration, wound-wood, reaction zone, chromatography, extractives

ABSTRACT

Common beech (*Fagus sylvatica* L.) is one of the economically most important deciduous tree species in Europe (VEK ET AL. 2015). Beech wood is generally known as the appreciated and applicable material widely used in a forest-based industrial sector. Beech is characterized by the formation of discoloration in the central part of a stem, also called the red heart, which has negative impact on the industrial processes and technological properties of beech wood. Wounding of the tree is the first event in a series of complex tissue changes leading to wood discoloration. Hence, the aim of present contribution is to review the anatomical and chemical characteristics of wound associated and discolored wood in beech.

Wound-wood, discolored wood and the reaction zones were the most conspicuous features of wounded stems in beech. Wound-wood surrounding the injury was composed of cells with irregular anatomy (Fig. 1a). Reaction zones were 3-7 mm thick darker layers separating dicolored wood and sound sapwood. Vessels were occluded with tyloses in the reaction zones (Fig. 1b). Suberin linings were found in tyloses and parenchyma cells (Fig. 1c). Insoluble deposits filled lumina of ray and axial parenchyma, fiber tracheids and all pit apertures in the reaction zones. Reaction zones have been reported to exhibit the altered physical properties in comparison to sapwood (OVEN ET AL. 2008).

It was found by GC/MS analysis that the lipophilic extracts of wound-associated beech wood contain mainly saturated and unsaturated fatty acids, fatty alcohols and sterols while the hydrophilic extracts consist of monosaccharides and oligosaccharides, sugar alcohols and sugar acids, as well as of simple phenols and flavonoids (VEK ET AL. 2014). Quantitative chemical analyses showed a high content of low-molecular extractives and proanthocyanidins in wound-wood and sapwood, whereas reaction zones contained less of these compounds as sapwood. Samples of discolored wood were characterized by the lowest amounts of phenolic compounds.

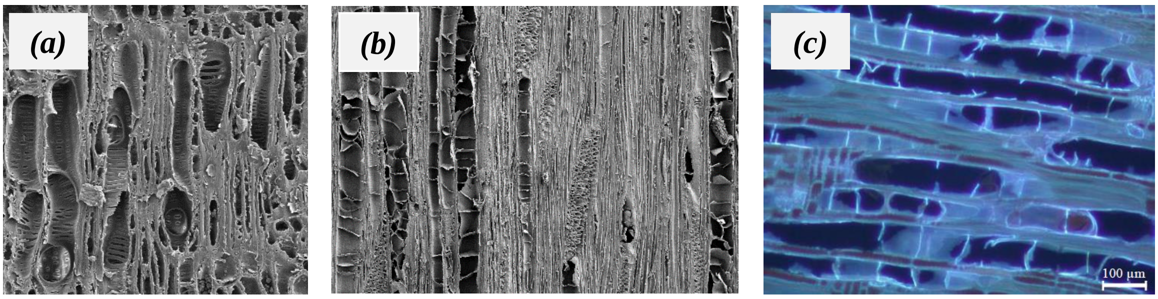

***Figure 1:** Scanning electron micrograph of (a) wound-wood and (b) reaction zone (FEI Quanta SEM, mag. of 1000 x and 353 x). (c) Autoflourescence of tyloses in the vessels of reaction zone (OVEN ET AL. 2010).*

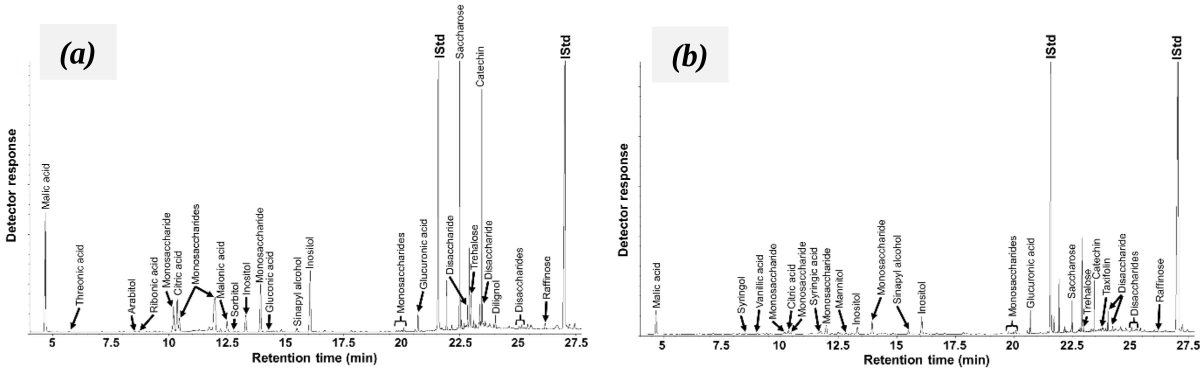

Figure 1: GC chromatograms of extractives in (a) intact sapwood and (b) reaction zone of discolored beech. IStd - internal standard.

Formation of wound-wood as well as anatomical and chemical changes occurring in reaction zones are interpreted as a part of active response in wood of beech. Extractives in wound-wood and sapwood function either as an existing protection or as a pool for polymerization to oligomeric compounds during the reaction zone formation. However, high contents of phenolic extractives in wound-wood can be also understood as a kind of protection for the repair processes. It was found that the reaction zones in beech function more as physical barriers (VEK ET AL. 2013).

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How wood-decay fungi may influence the durability of hardwood - exploring the potential impact of pathogenic *Armillaria* species

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Keywords: Wood durability, wood-decay fungi, *Armillaria*, hardwood species, oak

ABSTRACT

We are interested to investigate the possible role of wood-decay fungi in the decline of the wood durability of oak species. Our current research is focused on the Armillaria (Basidiomycota, Agaricales) genus, which belongs to the group of white-rot fungi and represents primary decay drivers in forest ecosystem processes. We have recently sequenced genomes and generated high quality annotated databases for two Armillaria species. Comparative genomic and transcriptomic analyses revealed that Armillaria species have distinctive genetic potentials in degrading pectins and aromatic compounds. Our findings confirmed the adaptive invasive character of Armillaria as a white-rot fungus with a facultative necrotrophic lifestyle.

The benefits of naturally durable woods, growing in balanced natural ecosystems, have long been recognized. Although supplies of high-quality natural wood resources have declined, interests in these species and in the possible recovery of their ecosystems still continue.

Based on our recent observations and data from the literature, we hypothesize that specialized wood decay-fungi may contribute to the decline of wood durability of several hardwood species, especially oak. The decline of ecosystems is indeed the consequence of various environmental stress factors where the impact of climate changes and interfering human activities is expected to pose a significant threat to forest ecosystems by weakening host resistance and increasing parasitic infection rates (La Porta *et al.* 2008), and possibly changing the surrounding microbial environment in the soil.

Wood durability, designating decay resistance, reflects both the genetic potential of a tree and the manifesting resistance of its wood to deteriorating environmental factors. The wide variation in durability among and within species depends mostly on the degree and specificity of lignification, the extractive content of heartwood representing mostly toxic antifungal compounds (Taylor *et al.* 2002), and on the plant immune system, which provides defence against microbial invaders in live tissues.

Wood-decay fungi, invading live woody tissues, need to be well adapted to overcome several major constraints: the innate immune system of the living plant tissues, the presence of potentially toxic antifungal compounds, the low nitrogen and phosphorous content in the woody environment, and the complexity of the organic substrates. Lignin is a complex aromatic heteropolymer, which provides stiffness to stem tissues facilitating stem aerial development and protection against destruction by microorganisms. Lignin encrusts the other cell wall components and forms chemical complexes with them, and prevents cell wall structures from being easily degraded.

White-rot fungi, including *Armillaria* species, are crucial soil components in carbon recycling as they are capable of degrading all major wood components and responsible for the mineralization of lignin. White-rot fungi have the ability to invade live tissues and overcome the major constraints.

Our current research interest is focused on the *Armillaria* (*Basidiomycota, Agaricales*) genus. The genus includes approximately 40 morphological species. Their vegetative diploids are long-lived regular white-rot associates and decay drivers of the native forest ecosystems worldwide and are among the largest known organisms on Earth. The majority of *Armillaria* species are wood-inhabiting facultative necrotrophic fungi that can cause devastating epidemics in forest ecosystems and most of them exhibit either conifer or hardwood specific interactions (Baumgartner *et al.* 2011). The facultative necrotrophic *Armillaria* species, like the hardwood (mostly oak) specific *A. mellea* and the conifer specific *A. ostoyae*, are amongst the most effective host invading fungal species.

Recently, using the latest „PacBio" technology, we have sequenced and generated high quality annotated genomes and databases for two *Armillaria* species (*A. ostoyae* and *A. cepistipes*). Further comparative genomics and transcriptomic analyses revealed that *Armillaria* species, besides having an extended genetic potential to degrade lignocellulose (Figure 1/A) and pectin, have distinctive sets of genes, belonging to the β-ketoadipate pathway (Figure 1/B), which may enable the fungus to degrade all forms of aromatics including also the highly diverse breakdown products of lignin. Our results highlight the importance of secreted fungal enzymes involved in degrading the extracellular polyphenols and aromatics (Sipos *et al. in prep*).

We have recently identified forest sites (Keszthely Mountains, Hungary) exhibiting a severe oak decline associated with *Armillaria* infections. We plan running DNA/RNA analyses and modern molecular biology applications (metagenomics and metatranscriptomics) to monitor the presence and functional activities of *Armillaria* and other associated microbial partners, from cross sections of the roots and stems of various oak species from the region.

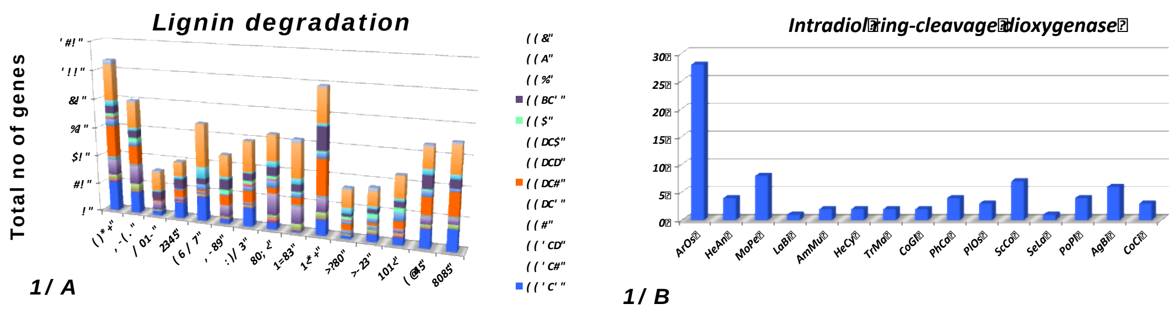

Figure 1: Comparative genomics of gene families involved in the degradation of aromatics

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Investigation of artificial aged beech wood surfaces with FTIR spectroscopy

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Keywords: artificial ageing, xenon bulb, beech wood, FTIR spectroscopy

ABSTRACT

In this study artificial aged beech (*Fagus sylvatica* L.) wood sample were investigated with Fourier Transformation Infrared Spectroscopy. The wood surfaces were sanded (grit size: P150) before ageing. To simulate natural sunlight in indoor environment xenon lamp was used. Wood sample with radial cut surface was exposed for 240 hours. During ageing the wood surface becomes darker, detected by eye. Results show significant differences in spectra, at the wood-specific wavenumbers, detected on wood surface by using FTIR spectroscopy.

Introduction

Photodegradation is the most intensive degradation type of wood surfaces in indoor environment. In order to understand the chemical changes on wood surfaces during ageing, FTIR measurements can be performed.

Materials and Methods

Measurements were performed on sample of 5mm * 15mm * 30mm. Sample surface were sanded with sandpaper (grit size: P150). Xenon bulb equipped Original Hanau Suntest was used for artificial ageing, since the xenon radiation is the most useable radiation type to simulate sunlight (TOLVAJ AND PERSZE 2011). FTIR measurements were made during ageing 6 times (1h, 8h, 20h, 60h, 132h and 240h). The spectral range was between 4000cm^{-1} and 400cm^{-1}. Each spectrum was calculated as an average value of 50 measurements. To evaluate results of the FTIR measurements MS Office Excel was used.

Results and discussion

Execution of the measurements was similar to previous researches (STACHOWIAK-WENCEK ET AL. 2015; COLOM ET AL. 2003). The FTIR spectra clearly show the signs of ageing on wood surface. At the specific wavenumbers significant differences were found in spectra (Fig.1.). At 1745 cm^{-1} – 1734 cm^{-1} the CO stretching in unconjugated ketone, acetyl and carboxyl groups (TOLVAJ AND FAIX 1995), acetyl or carboxyl acid (COLOM ET AL. 2003), at wavenumbers 1655 cm^{-1} – 1643 cm^{-1} CO stretching in conjugated systems, at 1508 cm^{-1} 1505 cm^{-1} changes in aromatic skeletal (C=C, lignin (COLOM 2003)), at 1230 cm^{-1} OH i.p. bending, acetyl in xylans, 1173 cm^{-1} 1170 cm^{-1} C-O-C stretching (asymmetric (cellulose (COLOM 2003) and at wavenumber 1128 cm^{-1} -1120 cm^{-1} C-O-C stretching (symmetric) (TOLVAJ AND FAIX 1995) was identified.

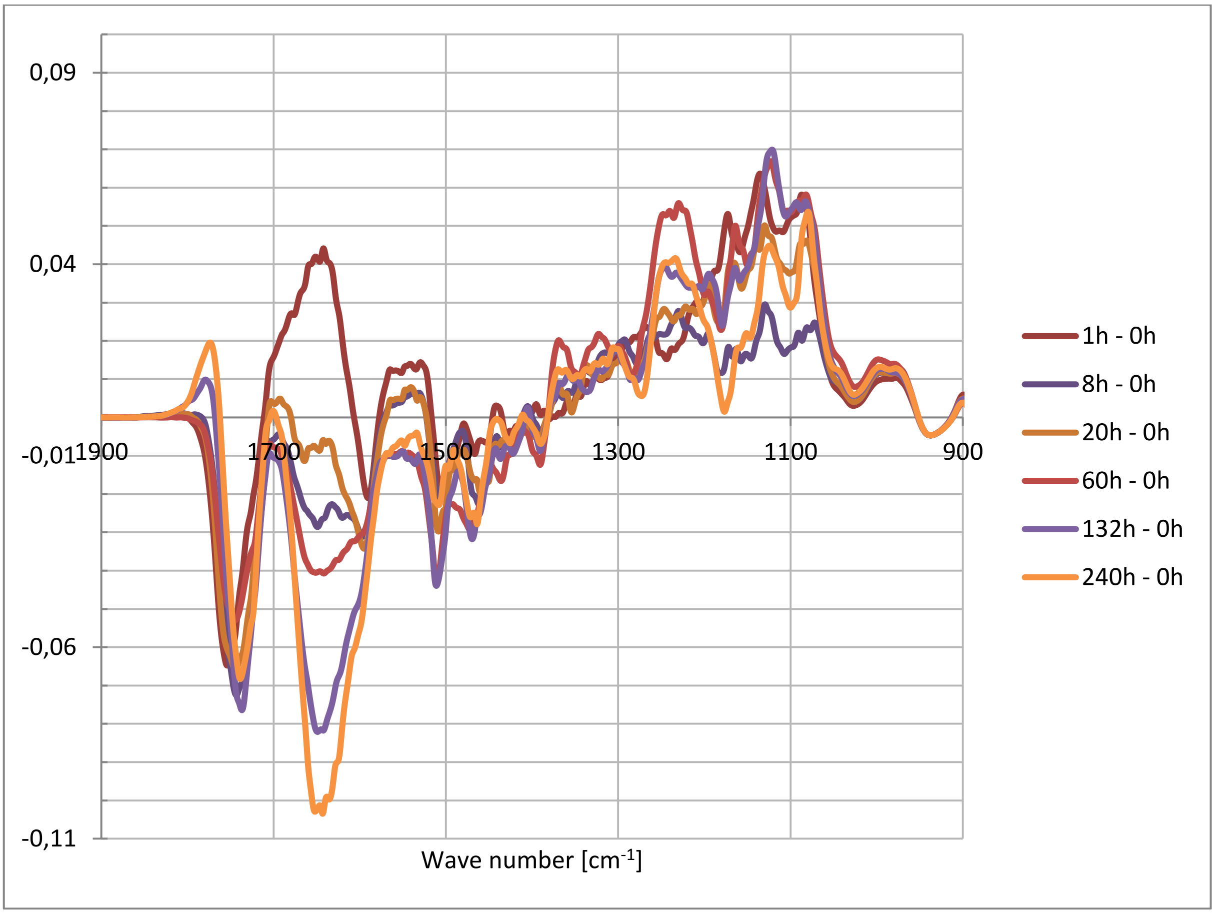

Figure 1: Differential FTIR spectra of artificial aged beech wood surface

Conclusions

As the results shows, the FTIR spectra measurements are suitable to monitoring the wood surface changes during ageing. Based on the measurements, the specific wavenumbers can be identified from spectra. Further investigations were started to identify the relationship between the surface free energy of aged wood surfaces, comparing with the FTIR results.

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Session I/2.
Material Properties II. - Modified Wood

Robinia Wood Research – new innovations for a traditional material

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Keywords: Robinia heartwood, Robinia juvenile wood, durability class, robinetin-derivative extractives, wood impregnation with native extracts, branch wood, chain added value

ABSTRACT

Due to its high amount of extracts, Robinia wood counted among the European wood species to those with the highest decay resistance against wood decaying microorganisms. Although the subsequent high ranking as regards quality and related chemical composition have been used and known for long, leading to a lot of ambitious applications, the scientific background of the responsible processes and continuative bio-engineered utilization of this have not been deeply developed (ECKSTEIN ET AL. 2000). Therefore, additional efforts and innovative applications of this interesting material are requested to increase the availability and usage of this unique wood species (RADEMACHER AND FODOR 2016).

Investigation at the lab level have shown that single phenolic compounds, mainly belonging to the robinetin-derivative, can be extracted with technical solvents out of Robinia wood, isolated in the separation process using columns filled with exchanger resin, and applied as a native, renewable component in the impregnation process to improve the durability, also of normally non-durable wood species like beech or poplar (Fig. 1; SABLIK ET AL. 2016). Not only Robinia wood residues from harvest or sawmill process, but also bark or twigs of Robinia and other durable wood species have been used for this application.

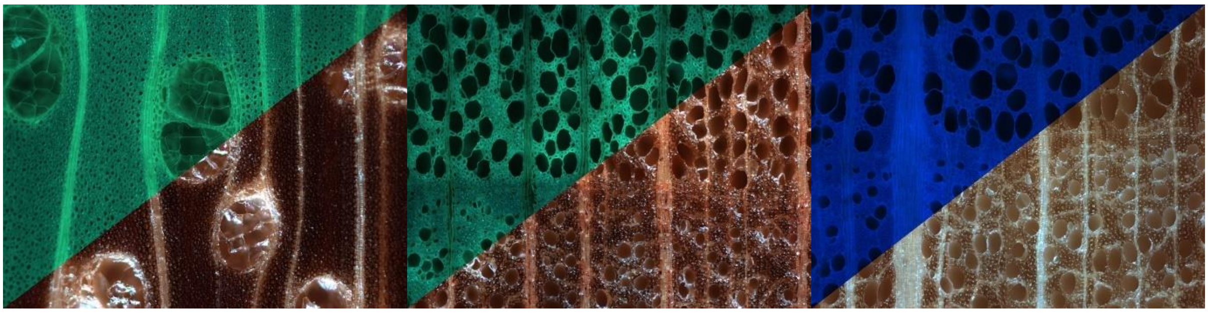

Figure 1: UV-detection of robinetin-derivative (indicated by green colour) in 70yr-old Robinia (left) and robinetin-impregnated beech wood (middle) compared to robinetin free beech wood (right; indicated by blue colour) in upper-left halves of microscopic photos; lower-right halves: without UV-detection in normal light

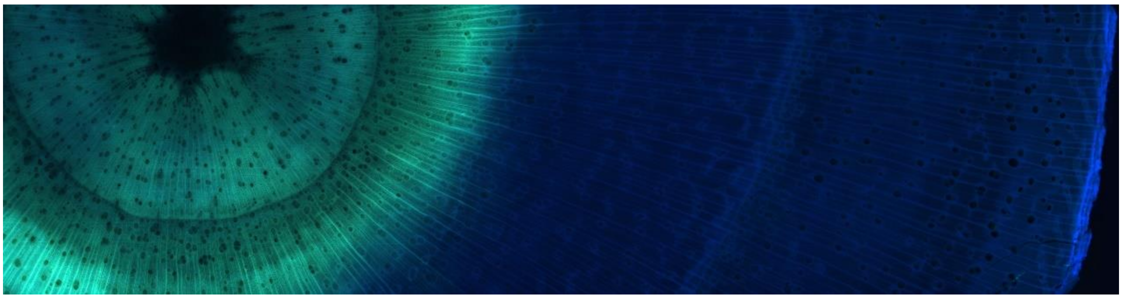

Figure 2: UV-detection of robinetin-derivative (indicated by green colour) in 2-3-year-old Robinia fast growing plantation wood compared to robinetin free wood (indicated by blue colour) in 1-2yr-old wood

Chemical analysis and durability tests have proved the dependency of extract quantity and effectiveness on the age of Robinia trees, leading to an increase in older trees, resulting at age of 15-20 in more durable wood of durability class 1-2. But already 2-3-year-old Robinia wood showed first amounts of robinetin derivative (Fig. 2), leading to decreased fungi-decay two times compared to sapwood or non-durable wood species. The technical utilization of the leached extract components from wood chips of fast growing plantations, often disturbing the aimed final process of burning in energy plants or gluing for particleboards, can lead to a higher added value in the process chain.

With respect to the limited raw materials of fossil origin, global warming and low amount of high quality wood assortments in Central Europe, the effective utilization of bio-material, producible in a sustainable and renewable way, especially that with high native properties like Robinia or Castanea wood, is urgently required. In this respect, innovative applications of additional Robinia wood assortments, like juvenile wood for furniture or chemical sources, fast growing plantation material, branches or Robinia process residues, are not only aimed at increasing the amount, but also the quality of the used wood. For instance, Robinia branch wood shows even higher density compared to traditionally used stem wood, corresponding with a higher strength for most of mechanical strains.

Possible additional applications of further Robinia wood assortments and new research topics:

- Application of robinetin-derivative from extracted Robinia wood process residues
- Utilization of robinetin extracts for native wood impregnation of non-durable wood
- Utilization of separated juvenile Robinia wood assortments for decorative usage
- Thermal treatment of juvenile wood in order to gain wood with higher durability
- Impregnability of juvenile wood with native components (→ liquefied juvenile wood)
- Application of Robinia branch wood for extreme strength requirements

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Mechanical properties and spatial fiber angle in veneers and plywood materials

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Keywords: Tensile strength, veneer, fiber angle,

ABSTRACT

It is well known that wood has, compared with other materials, a very good density : strength ratio (specific strength). This property is given by the specific wood structure and the strength of the individual components, primarily by the strength of the individual fibers. For all fiber-reinforced composite materials the strength of the interphase and the fiber orientation is important for the mechanical properties.

The fiber orientation can be influenced only insofar as the interphase adhesion between the fibers and the binder substance, which is formed in wood by the lignin, enable this. Finally the fiber orientation is a not or only very limited modifiable structure property. If there are no specific growth characteristics, the fibers are unidirectional oriented in growth direction (longitudinal). However, almost all trees or stems have specific growing characteristics as reaction wood, spiral grain and intergrown knots. This has, additional to the directional dependency of properties (tangential, radial), effects on the mechanical properties. The strong dependency of the direction of the mechanical properties is one of the decisive reasons for the development of different wood-based materials or composites.

Already in the 20's of the last century, as wood was still indispensable for the aircraft industry, the influence of the direction of the fibers in the individual layers of the plywood has been extensively studied. Many investigations focus on the detection of the fiber direction in the wood elements, as well as on the fiber direction in the individual layers of the plywood.

Very thin veneers (0.1 mm to 0.3 mm) succeeded in this way to produce multi directional composite materials. These results have a contemporary relevance even today. For many building materials (beams, columns, and boards) materials with multidirectional properties are not required. If the induced stresses are considered, the fiber orientation of the wood can be used in a proper manner. For example, the bending properties of beams are mainly determined by the mechanical properties of the strength of the surface layer. Therefore, the fibers of the surface layers should be aligned in the longitudinal direction of the beam. Also for plywood and LVL the veneers with the optimum fiber orientation should therefore be arranged in the surface layers.

If the mechanical properties of the components of a plywood or LVL are known, a specific layering can influence the properties of the boards selectively. If the strength of a component for plywood or LVL should be determined, the angle between the fibers in the wood and the direction of the force must be considered. In tensile test specimens the fiber direction angle in tangential and radial direction can differ in each direction and each layer from the ideal angle of 90 ° (Fig. 1). The more realistic strength indication requires the indication of the spatial orientation of the fiber. For this reason, in preliminary investigations special specimens for

tensile testing were prepared and tested. It was shown, that not only the well-known influence of tangential fiber angle affects the mechanical properties greatly, but also the radial fiber angle is very important.
Both angles, the tangential and in the radial fiber angle, affect the tensile strength in the same strong manner. The effects are already visible at angle deviations of less than 10 °. An increasing of fiber angle creates more shear fractures.
In the case of unfavorable fiber angles in the surface layers of LVL or plywood, also shear fractures occur during the bending test. Consequently, the bending strengths are lower than in the case of an optimum fiber angle.

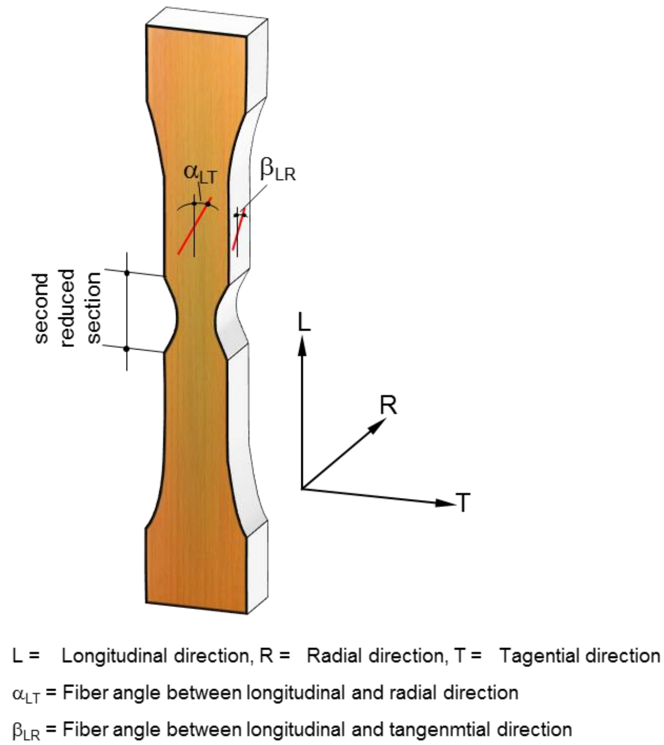

Figure 1: Test specimens for tensile tests with indicated fiber angles

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Colour stability of chemically modified oak wood – nanoiron and ammonia treatment

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Keywords: Quercus sp., colour change, artificial sunlight, nanoiron, ammonia gas

ABSTRACT

Wood colour and its stability are very important aesthetic aspects of interior-used wood products such as furniture or flooring. Most temperate wood species are characterized by pale inconspicuous colour patterns. These, however can be modified by processes like steaming, heating or ammonia treatment to mimic appearance of tropical wood species (MIKLEČIĆ *et al*. 2012, TOLVAJ *et al.* 2012, FEHÉR *et al.* 2014).
Particularly disposed to discolouration in contact with iron and moisture are wood species rich in tannin-like compounds. In these conditions, strongly coloured tannin-iron complexes are produced. Same extractives cause wood darkening if this is exposed to ammonia (FARMER 1967). The current demanded dark surfaces typical for subfossil oak obtaining its colour by contamination with soil iron can be met by targeted impregnation of oak wood with water solutions containing iron particles.
The tests were carried out on three test sets, each containing ten specimens, prepared from oak wood. The first consisted of native specimens, the specimens of the second one were treated by ammonia gas (AT) for 3 days, and the specimens of the last were vacuum impregnated with nano-iron (NIT) water solution (4 g/l) for one hour. After the conditioning (20 °C, 65%). the specimens were exposed to a 500-hour treatment with a xenon-arc lamp light (Q-SUN XE-3) simulating outdoor sunlight. The colour changes in particular parameters, caused by individual treatments and the following light exposure were monitored by means of a spectrophotometer (BYK-Gardner spectre-guide 45/0 gloss) working in the CIEL*a*b* colour system. The colour of the samples surface was measured at 0, 25, 50, 100, 200, 300 and 500 hours from the beginning.
Both treatments tested induced darker colouring of oak wood, more intensive darkening was observed in case of the nano-iron treatment (Figure 1, Table 1).

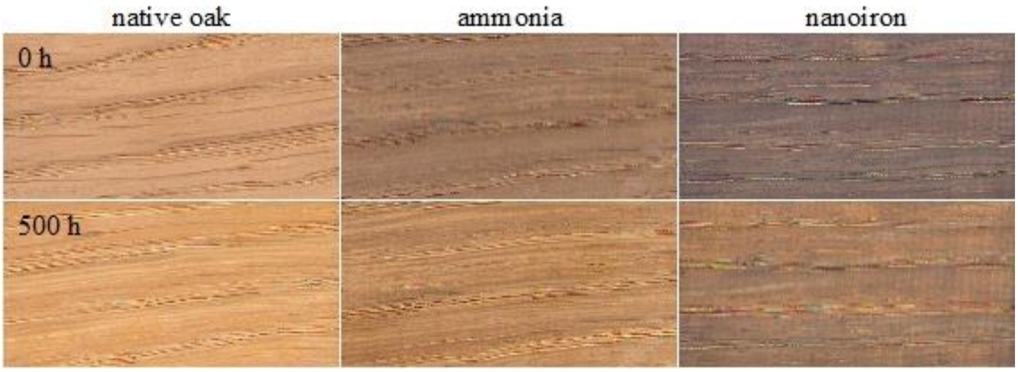

Figure 1: The colour of native and treated oak wood before and after artificial sunlight exposure for 500 hours.

Table 1: The colour parameters of native and treated oak wood before and after artificial sunlight exposure

	native oak			ammonia			nano-iron		
	L*	a*	b*	L*	a*	b*	L*	a*	b*
0 h	62.8	8.0	22.0	41.0	4.9	12.7	36.2	2.9	6.0
500 h	60.5	10.1	27.4	47.0	7.0	18.8	43.7	6.9	17.3

The native oak showed a steep drop in lightness ca 25–50 hours of exposure followed by gradual re-increase during further exposure to the artificial sunlight (Figure 2). The darker surfaces generated by tannin reacting chemically with iron and ammonia evidently faded in the course of light exposure. In case of chromatic parameters a* and b*, the AT oak more or less copied the colour change progress of native oak. On the contrary, the NIT wood showed a double increase in both parameters. The colour of NIT wood after light exposure was more or less equivalent to the original colour of the ammonium-treated oak (Figure 1). Distinct reddening (Figures 1, 2) of NIT oak may be caused by oxidation of non-precipitated iron particles.

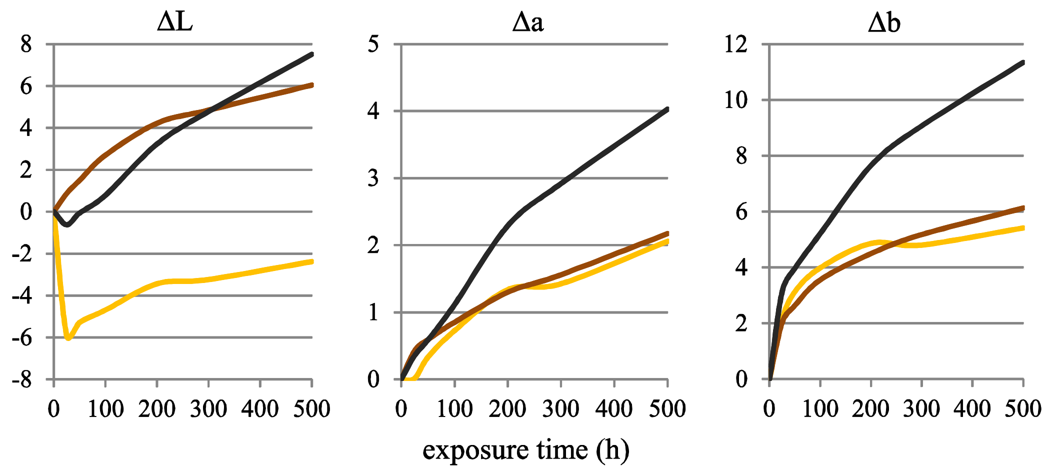

Figure 2: Colour parameters variation during exposure to artificial sunlight (yellow – native oak, brown – ammonia treatment, black – nano-iron treatment).

Acknowledgement
This study was financially supported by the Internal Grant Agency (IGA), the Faculty of Forestry and Wood Technology, Mendel University in Brno, (LDF_PSV_2016015).

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Impact of false heartwood and thermal modification on impact bending strength of beech wood

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Keywords: Beech (*Fagus sylvatica* L.), wood properties, false heartwood, thermal modification, impact bending strength.

ABSTRACT

Beech is one of the most economically important and most common deciduous trees in Czech Republic. Its share in overall species composition is around 8.0 % nowadays (Report on the state of forest and forestry in the Czech Republic 2014). With expecting decline of spruce forests in the future, beech share will increase together with its importance for the wood processing industry. One of the wood defects that influence the usability of beech is false heartwood. It is one of the most common defects which affects wood quality and its usability (RAČKO AND ČUNDERLÍK 2006). Another important limiting factor of beech wood utilization is its low resistance to weather conditions and biotic factors. One of the ways to reduce this negative property is heat treatment.

This research is a part of a large project focused on wood properties, colour and chemical changes and durability of thermally modified beech wood with false heartwood. This paper deals with influence of thermal treatment and false heartwood on impact bending strength, wood density and equilibrium moisture content of beech wood.

Testing samples (20 mm × 20 mm × 300 mm) with false heartwood and reference samples were cut from beech boards. Afterwards, one third of testing samples was subjected to the first degree of heat treatment, in an air atmosphere at 165 °C, and the second third of samples was heat-treated at 210 °C, in accordance with the Finnish technology for the wood heat treatment. Prior to testing all the samples were conditioned to equlibrium moisture content (EMC) in order to assess the influence of heat treatment on this property. Impact bending strength, wood density and EMC were tested according to the Czech national standards (ČSN 490117, ČSN 490108 and ČSN 490103 respectively).

The resulting values of impact bending strength for the individual degrees of heat treatment are shown in the table 1. Table 2 shows the percentage decrease of wood density and EMC in comparison with reference samples depending on heat treatment and presence of false heartwood.

Table 1: Impact bending strength of beech wood in relation to degree of thermal treatment and false heartwood occurrence

Treatment			Mean [J/cm^2]	Coefficient of variation [%]
False Heartwood	Present	Reference	9,9	39,6
		165°C	5,9	48,8
		210°C	1,5	83,9
	Without	Reference	8,7	39,4
		165°C	6,9	25,5
		210°C	2,3	39,0

Table 2: Proportional decrease in wood density and equilibrium moisture content in relation to degree of thermal treatment and false heartwood occurrence

Treatment			Density	Moisture content
False Heartwood	Present	165°C/reference	1,5 %	38,8 %
		210°C/reference	8,2 %	60,7 %
	Without	165°C/reference	1,0 %	33,6 %
		210°C/reference	8,5 %	55,9 %

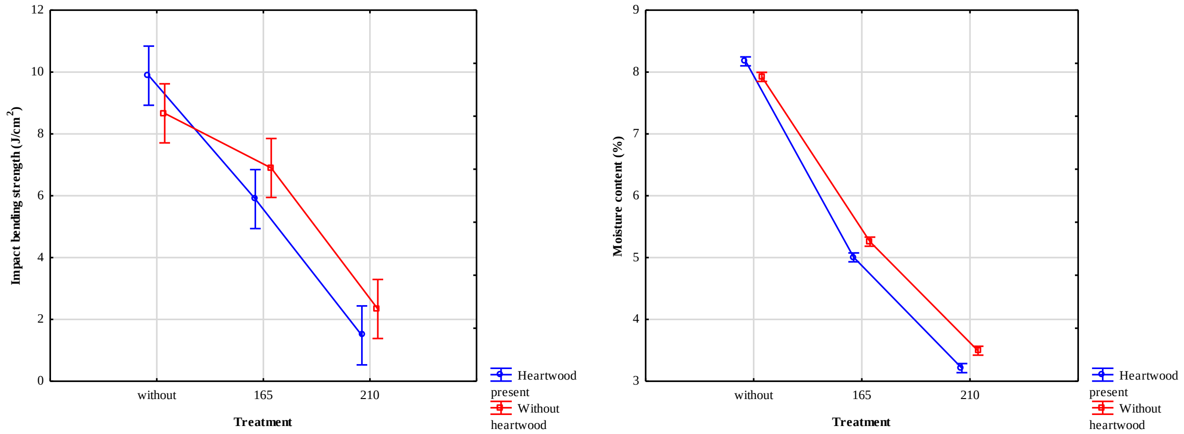

Figure 1: The effect of heartwood and heat treatment temperature on impact bending strength (left) and moisture content (right)

Statistically significant impact of heat treatment on impact bending strength was shown (Fig. 1 left). The decrease of impact bending strength of thermally modified wood was also confirmed by Esteves and Pereira (2008) or ITA (2003). In contrast to Molnár et al. (2001) the influence of heartwood was not shown, despite the fact that the density of the heartwood is significantly lower. Heartwood however, in comparison to the trees without heartwood, contains probably only compounds, which doesn't have impact on impact bending strength, only on density. Statistically significant difference in moisture content between trees with heartwood and without it was found (Fig. 1 right). Although the difference in numbers itself is not striking, it is still statistically significant at all heat treatment degrees.

ACKNOWLEDGMENT

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Session I/3.
Material Properties III. - Modified Wood

Colour stability of thermally modified black locust and poplar wood during short-term photodegradation

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Keywords: black locust, poplar, thermal treatment, UV radiation, colour change

ABSTRACT

Thermal treatment of wood has a long history, and different methods have been continuously modified and developed not only in Europe but worldwide. Main advantages of thermal treatment of wood material include reduced hygroscopicity, improved dimensional stability, and better resistance to degradation due to insects and micro-organisms. Improved properties facilitate outdoor application of thermally modified wood. Despite the extensive researches, behaviour of thermally modified wood during UV light exposure is still not clearly understood. In this study, black locust (*Robinia pseudoacacia* L.) and Pannonia poplar (*Populus* × *euramericana cv.* Pannónia) wood samples were subjected to dry thermal treatment in a laboratory scale drying chamber at 160°C and 200°C in the presence of air. The effective treatment duration was 2, 4, and 6 hours. To induce fast photodegradation, heat treated samples along with untreated control samples were then irradiated with a strong UV light emitter mercury vapour lamp. The total irradiation time was 36 hours. To monitor the colour stability, colour measurements were carried out with a Konica-Minolta 2600d type colorimeter.

Objective colour measurements revealed considerable colour change of the samples due to thermal treatments (Fig. 1). The first section of the lines (continuous lines) represents the effect of thermal treatment while the second part (dotted lines) shows the effect of UV treatment. The red colour increased for all species during thermal treatment, and the order of change followed the intensity of the treatment. The poplar proved to be highly sensitive to the temperature of the thermal treatment, but not sensitive to the treatment time. The yellow colour of poplar increased following the tendency of red colour change. The colour of black locust was less sensitive to the temperature than that of poplar. Its originally strongly yellowish colour decreased due to the thermal treatment following the same tendency as the lightness change produced. The lightness decreased for both species. The magnitude of the change depends on the intensity of the thermal treatment. The selected thermal treatment parameters resulted in a large variety of lightness.

The UV light induced photodegradation caused the most detailed differences in the redness change (Fig. 1). Trend lines of this colour coordinate were convergent for the poplar having low extractive content, but they were first rapidly convergent and later divergent for the black locust having high extractive content. After 7 hours of irradiation, the trend lines became straight, showing a slow increase. The thermally treated samples showed different changing behaviour depending on the treatment temperature. Samples treated at 160°C followed the altering tendency of the natural wood (thermally untreated) samples in all cases. This means that the heat treatment at 160°C did not affect the redness change behaviour of wood.

Samples treated at 200°C, however, changed their red colour in a different way compared to untreated wood. After a moderate decrease in redness during the first 7 hours of light irradiation,

these samples kept closely constant redness value during the examined time period. Samples treated at 200°C for 2 hours showed the most stable redness values during photodegradation. The redness change is mainly determined by the chemical changes of extractives and by the chromophore products of the thermally degraded hemicelluloses. It can be concluded that at 200°C thermally modified extractives and the chromophore products of hemicelluloses are fairly stable during light irradiation.

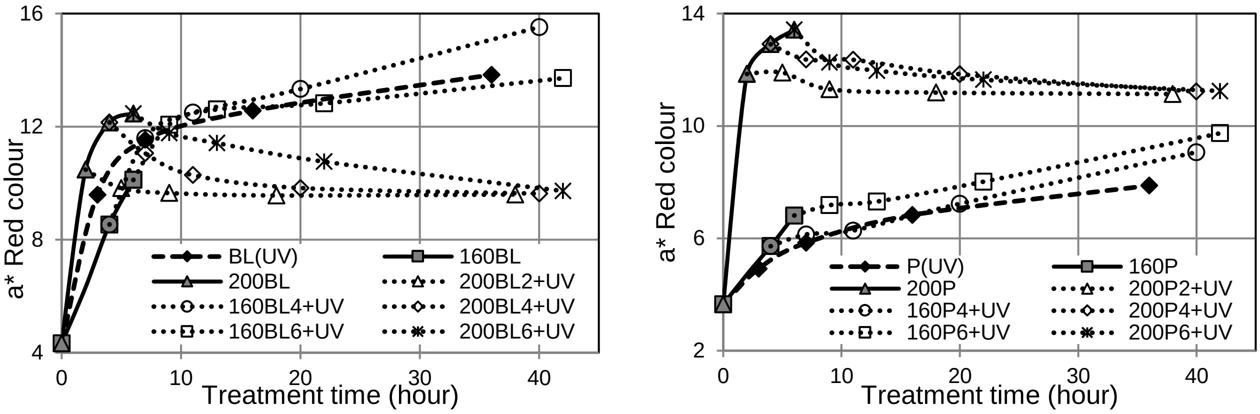

Fig. 1 *Redness change of black locust (BL) and poplar (P) caused by thermal treatment and light irradiation (UV). Abbreviation: thermal treatment temperature/sample name/ thermal treatment time in hour.*

The yellow colour of black locust is naturally different compared to the other European species. This deviation is caused by its high robinetin content. A previous study demonstrated that the high extractive content of black locust partly protects its lignin content during light irradiation. The same finding is partly demonstrated here as well. Some of the extractives for black locust underwent thermal degradation, represented by the increasing values of a^* and b^* coordinates. The extractives modified at 160°C thermal treatment were not able to protect the lignin of black locust. The yellow colour increase in the black locust samples was much greater than the yellowing of the natural black locust samples. However, treated black locust samples at 200°C did not produce remarkable yellowness changes during light irradiation. The yellow colour alteration in the samples treated at 200°C for 2 hours seemed to be the most stable, similarly as it was found for red colour. The yellow colour change of the investigated samples showed that the lignin of thermally modified wood undergoes a similar photodegradation as that of the untreated natural wood.

The lightness of the investigated samples decreased a lot during the thermal treatment. This decrease was 83 and 62% for black locust and poplar, respectively. There were only minor differences among the species during the light irradiation. The natural wood samples suffered rapid lightness decrease during the first 10 hours of light irradiation, followed by a moderate decrease. The originally dark thermally treated samples exhibited slow but continuous changes. The values of these changes were considerably less than those of the untreated samples. The direction of the alteration was determined by the initial lightness value. Samples having initial lightness values greater than 40 units showed decreasing lightness, while those with initial lightness values less than 40 units showed lightening during irradiation. These results suggest that thermal treatment slightly reduced the lightness change effect of photodegradation. Samples thermally treated at 160°C were more stable than the others treated at 200°C from the point of view of lightness change.

Densification of beech wood and fixation of compressive deformation by steaming at lower temperatures

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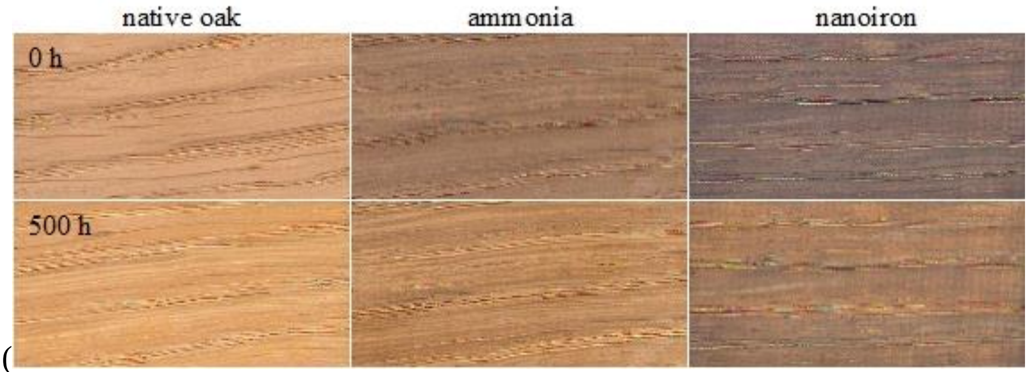
Keywords: wood densification, plasticization, thermo-hydro-mechanical treatment, fixation of deformation, compression set recovery, shape memory effect

ABSTRACT

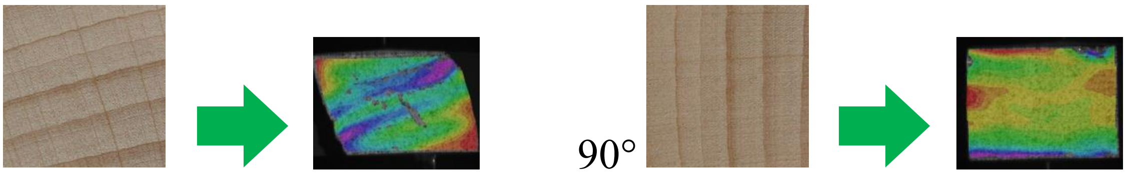
The process of wood plasticization and densification that improves mechanical properties has been known for decades, but the utilization in wet conditions is limited due to the problems with dimensional stability. The deformation produced during the process is not stable and recovers almost totally when re-moistened and heated. This phenomenon is known as compression set recovery (KUTNAR, KAMKE 2012) or shape memory (NAVI, SANDBERG 2012). Treatment in high temperatures can decrease the compression set recovery, but mechanical properties are negatively affected (HILL 2006). Process with saturated steam is more efficient (KUTNAR, KAMKE 2012), so that complete fixation can be reached for example in 20 min at 180°C or 4 min at 200°C (NAVI, SANDBERG 2012). The process with lower temperatures takes more time; however, the mechanical properties are less decreased (HEGER 2004).

This research is focused on European beech wood (*Fagus sylvatica*). At first, the influence of growth ring angle on the densification process was investigated using digital image correlation method (DIC) and distribution of vertical strain ε_{yy} (Lagrange)



(Figure 1).

15°



90°

Figure 3 Two examples of transversal compression test of beech wood evaluated by digital image correlation (DIC). Colors show vertical strain ε_{yy} (Lagrange) where blue and violet represent maximal strain and red indicates minimum.

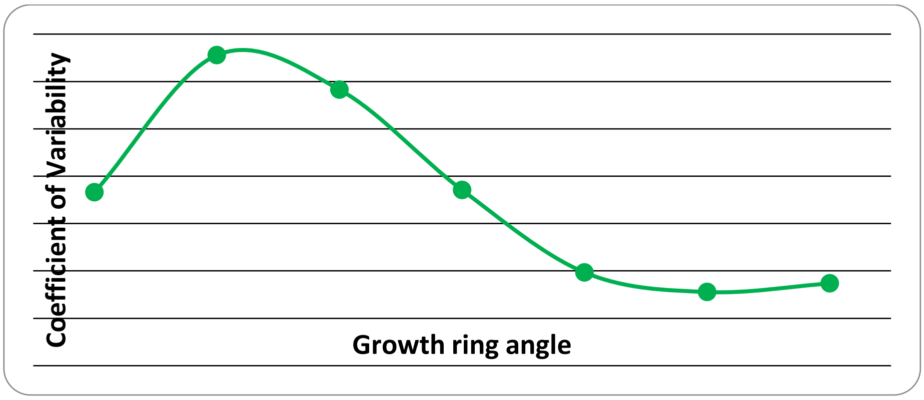
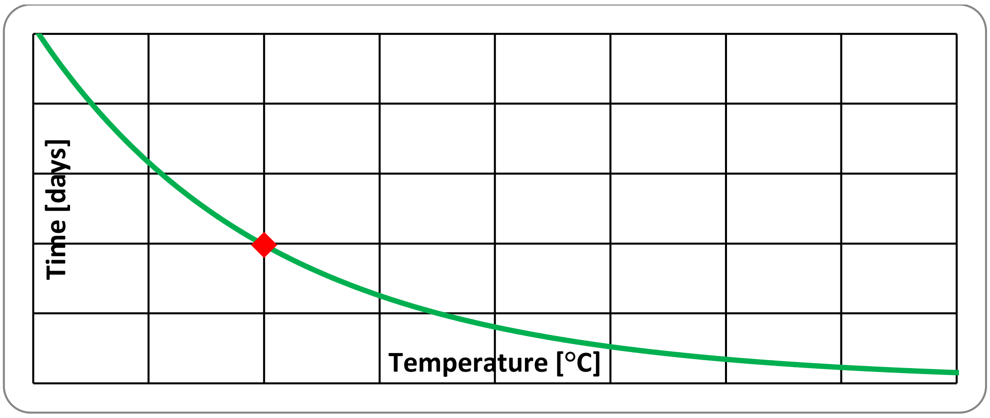


Figure 4 Comparison of strain variability based on DIC results. The highest strain variability showed a specimen compressed in almost radial direction (15°). The most uniform strain is in nearly tangential direction (75°).

A specimen with the lowest vertical strain variability was considered to be the most uniformly densified (Figure 2) and the growth ring angle of the specimen was considered to be the best for the densification process (tangential or nearly tangential direction of compression). Analysis of stress-strain diagrams showed that pressure of 10 MPa reduces the thickness of steamed specimens by 40%. Further compression could result in damage of the specimens.

The main part of this research focuses on complete elimination of the memory effect by treatment in saturated steam at a temperature of 90°C. It is based on experimental data of compressed spruce specimens that were published by Navi and Sandberg (2012). A model of steaming times for temperatures 80–200°C was created using the published equation (NAVI, SANDBERG 2012) and the time for the selected temperature was obtained (Figuere 5).



Figuere 5 Influence of the steaming temperature on the time necessary to achieve complete fixation. The dot highlights the time of treatment of 10 days for a selected temperature - 90°C

The model data show that steaming at 90°C can result in complete fixation of compressive deformation. This hypothesis will be verified by an experiment with beech (*Fagus sylvatica*) and spruce wood (*Picea excelsa*). Results can help us better understand the issue of the memory effect. Further research is needed to define the chemical reactions that are responsible for the stabilization.

ACKNOWLEDGEMENT

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Effects of thermo-vacuum treatment on antioxidant activity of the poplar wood extractives obtained by different techniques

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Keywords: poplar, thermo-vacuum, antioxidant activity, wood extractives

ABSTRACT

Heat treatment has increased significantly in the last few years and is still growing as an industrial process to improve some wood properties. Nowadays, there is a renewed interest in producing of thermo-treated wood extractives and their potential application in chemical, pharmaceutical and food industries.

Poplar (*Populus spp.*) is a deciduous tree belonging to the family of *Salicaceae*. It is one of the less expensive hardwoods. It's also fairly soft which makes it easy to work with. Poplar wood is quite white with some green or brown streaks in the heartwood and it's rarely used in the fine furniture.

The aim of this study was to verify the influence of the heat treatment on the polyphenolic and flavonoid content and on the antioxidant activity.

Poplar wood was treated at three different temperature, 180°C, 200°C and 220°C in a thermo-vacuum system for 3 hours. Heat-treated and untreated boards samples (control) were reduced to small size and then particles with similar size were subjected to three different solid-liquid extraction techniques: maceration, ultrasound and accelerated solvent extraction (ASE). For each extractive technique, after the pre-treatment with n-hexane to remove the lipophilic components, the solid phase was extracted with an ethanol: water (70:30 v/v) mixture. All extracts were filtered and the solvent was removed by rotary evaporator at 37°C. Dried extracts were kept at room temperature until the use. Total polyphenol, flavonoid and tannin content were evaluated by *in vitro* assays (Milella et al. 2011; Armentano et al. 2015). Antioxidant activity was evaluated by different assays, including DPPH (2,2-diphenyl-1-picrylhydrazyl) radical-scavenging method, FRAP (Ferric Reducing Ability Power) test and BCB (beta-Carotene Bleaching) assay (Russo et al. 2015).

Results in Figure (exemplified for ASE 100) reported the presence of polyphenol and flavonoid compounds. Tannins were detected in traces. The heat treatment influenced the content of these class of compounds and the highest content was observed in wood treated at 220°C and 200°C. The untreated wood, instead, showed higher amount of compounds than wood treated at 180°C. Extractives obtained from the wood treated at the highest temperature (200°C and 220°C) reported also the highest antioxidant activity. According to the results of phenolic content, the antioxidant activity of poplar treated at 180°C was less than the control. Extractive procedures showed slight differences in phenolic content and antioxidant activity, but poplar wood treated at 180°C was less active in each of them.

This study demonstrated the positive effect of high temperature on the antioxidant activity and phenolic content in poplar wood. Further investigations will be performed to identify the secondary metabolites in treated and untreated wood samples and to deepen the biological activity.

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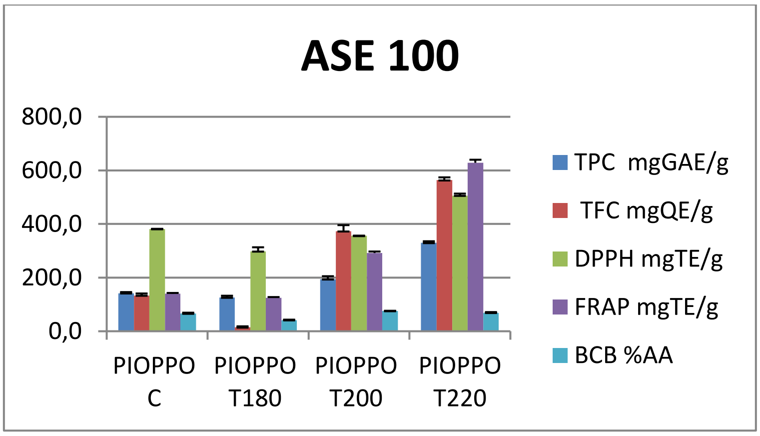

Chemical analysis of acetylated hornbeam (*Carpinus betulus* L.) wood

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Keywords: acetylation, hornbeam, IR spectroscopy, chemical components

ABSTRACT

Introduction: In this report hornbeam (*Carpinus betulus* L.) wood was acetylated with Accoya® method as a result of a cooperation between the University of West Hungary (Sopron, HU) and Accsys Technologies (Arnhem, NE). Hornbeam is mostly used as firewood because of its natural defects, low dimensional stability and low durability. On the other hand its incredible strength, hardness and wear-resistance (Molnár 2004) makes it a potential base material for acetylation which was not researched before. In the related master thesis (Fodor 2015) it was concluded that hornbeam gained 15.3% Weight Percentage Gain (WPG) which lead to higher dimensional stability, lower moisture content, better strength and hardness properties as well as high (Class 1) durability. Aims of the present research were the assessment of chemical properties of acetylated hornbeam wood compared to untreated wood.

Materials and methods: [*WOOD*-OH + $CH_3C(=O)$-O-$C(=O)$-CH_3 → *WOOD*-O-$C(=O)$-CH_3 + $CH_3C(=O)$-OH] For the tests untreated and acetylated hornbeam samples were used. Before the chemical analysis the control and acetylated hornbeam pieces were knife milled with 2 mm screen then fractioned. For the analysis particles with the size of 0.2-0.63 mm were used. The chemical composition was measured according the methods listed in Table 1. The hemicellulose content was given by subtracting the chemical components (cellulose, lignin, extracts, ash) from 100%. The samples were also analyzed by Fourier Transform Infrared spectroscopy (FTIR).

Results and discussion: The results are discussed according to the chemical analysis (Table 1) and the FTIR spectrum. (Figure 1). The peaks are referred as numbers in brackets (1-13). The **cellulose** content was slightly reduced probably due to acidic hydrolysis. This is observed by the peaks of C-H deformation (8) and asymmetric C-O-C stretching (10) in cellulose. On the other hand in some cases this change is not significant like the symmetrical C-H deformation (7), C-O stretching (12), and C-H deformation (13) in cellulose is close to zero. The **hemicellulose** content increased which is due to the fact that after acetylation the bound acetyl groups increased the weight of the polymer, and that the absorption of the C=O (carbonyl) groups (3) and C-O stretching (9) in xylan is higher. The amount of **lignin** is reduced after acetylation which is not due to the temperature (the other cell wall polymers degrade by heat much before the lignin) but rather due to the acidic medium which dissolved some part of it (Rowell 2005). The degradation of lignin is also confirmed by the IR spectrum as the aromatic skeletal vibration in syringyl (4) and guaiacyl lignin (5), the asymmetric C-H deformation in lignin (6), and the aromatic C-H skeletal vibration (11) decreased. Due to acetylation the color of hornbeam changed from pale yellow to a greyish brown (walnut-like) color. This is explainable by the increase of **extract content**, but these extracts are not polyphenols as the **TPC** decreased.

The reduction of TPC could have occurred due to the transformation of polyphenols or a leaching during the acetylation process. The **sugar** (soluble carbohydrate) content decreased because it was probably leached from the wood during the acidic process. In case of thermal modification this happens in a different way as the hemicellulose degrade to sugars so the sugar content can increase markedly. The **ash** content seemingly decreased but the lower value is just due to the higher weight of the acetylated sample before incineration (WPG). The reduction of **pH** is not the result of the acetyl groups, rather the residual acid content in the wood after acetylation. This could be a problem because of the corrosion of the metal joints. The pH and **buffer capacity** play an important role in the glueability and the surface treatability of the wood material. The higher buffer capacity indicates higher need of added base in order to adjust the pH to achieve the best bonding strength. The **moisture content** decreased significantly as a result of the bulking of the cell wall OH groups (Rowell 2005). The number of OH groups changed and rearranged in the system which explains the positive and negative peaks in the spectrum (1). The increase of methyl, methylene, and methane groups is due to the acetyl groups which switched places with some of the OH groups (2). The degree of moisture sorption decreased which led to lower moisture content values. This ensures the higher dimensional stability, lower swelling and shrinking rate and better strength properties in saturated state.

Table 1: Methods and test results of untreated (Un.) and acetylated (Ac.) hornbeam

Property	Unit	Method	Un.	Ac.	Diff.	Change
Cellulose Content	%	Kürschner-Hoffer	51.57	43.02	- 8.55	- 17 pp
Hemicellulose Content	%	-	27.40	38.49	+ 11.10	+ 41 pp
Lignin content	%	Klason (König-Komarov)	19.09	16.23	- 2.86	- 15 pp
Extract Content	%	Soxhlet extraction (1:1 cyclohexane:ethanol)	1.51	1.91	+ 0.40	+ 27 pp
Ash Content	%	EN 15403:2011	0.44	0.34	- 0.09	- 22 pp
Soluble Carbohydrate Content	mg/g	Dubois	14.63	3.49	- 11.14	- 76%
Total Phenolic Content (TPC)	mg/g	Folin-Ciocâlteu	2.65	1.39	- 1.26	- 48%
pH	-	pH meter	5.11	4.73		
Buffering capacity	mg/g	titration (0.02M NaOH)	1.11	2.15	+ 1.04	+ 94%
Moisture content	%	moisture analyzer	6.50	2.50	- 4.00	- 62 pp

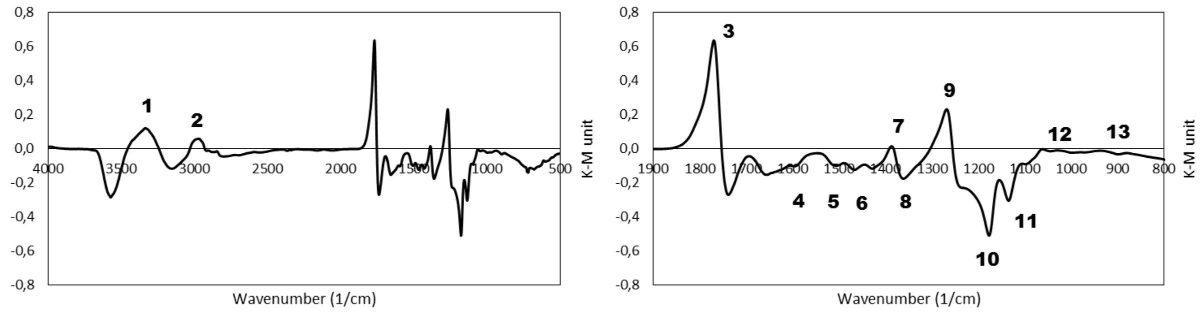

Figure 1: FTIR difference spectrum of hornbeam caused by acetylation

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Isolation, drying, acetylation and application of nanofibrillated cellulose

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Keywords: nanocellulose, isolation, drying, acetylation, nanocomposites

ABSTRACT

Wood is a chemical product of trees composed of three main macromolecules, cellulose, hemicelluloses and lignin. Development of methods and techniques nowadays enable isolation of individual polymer. One of the products derived from them is referred to as nanocellulose, which is available in the form of cellulose nanocrystals and cellulose nanofibrils. Nanocellulose has unique properties having practically unlimited possibilities of applications. The aim of this presentation is to discuss results obtained in the field of nanocellulose by the Department of wood science and technology of University of Ljubljana with the focus on isolation of nanofibrillated cellulose (NFC), effect of drying techniques on its properties, susceptibility of dry NFC to acetylation and finally, the application of NFC in nano-composites.
Our research showed that successful isolation of nanofibrillated cellulose (NFC) from stone groundwood pulp was achieved with combination of high shear and ultrasound treatment, which can be enhanced by treating raw material with TEMPO reagent.
The effects of air, oven, freeze and spray drying, on the morphological, thermal and structural behaviour of NFC were investigated (ŽEPIČ et al. 2014). FE-SEM observations indicated an interlaced network formation of predominantly in-plane fibrillar orientation for air and oven dried samples, while freeze and spray drying resulted in the formation of coarse and fine powder fractions (Fig. 1). Re-dispersed freeze and spray dried powders indicated that aggregation by a strong hydrogen bonding effect could be significantly reduced only in freeze drying pre-treatment.

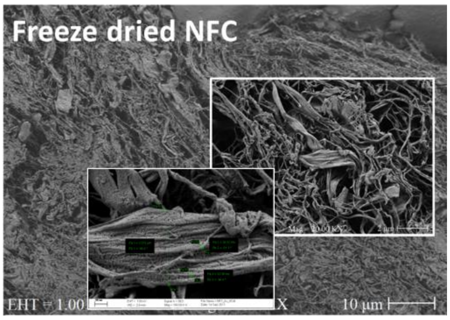

Figure 1: Scanning electron micrograph of freeze dried NFC (Žepič et al. 2014)

Acetylation reaction was employed for modification of NFC surface (ŽEPIČ et al. 2015). Our results revealed that all investigated properties of acetylated NFC depended on the morphology of the material obtained after different drying techniques (Fig. 2). It was found out that freeze dried NFC was the most appropriate starting type of dry material for acetylation, because drying did not change the morphology or the crystallinity of NFC.

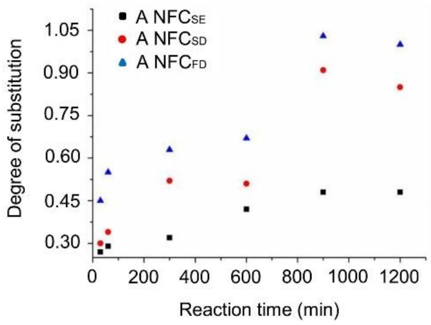

Figure 2: The degree of substitution as a function of reaction time for the acetylated NFC_{SE}, NFC_{SD} and NFC_{FD} at 1 vol.% of pyridine (Žepič et al. 2015)

PLA films containing different amounts of unmodified and acetylated NFC were prepared by solution casting resulting in improved mechanical properties (tensile strength and elongation at break) of nanocomposites films when acetylated NFC was added to basic PLA. Other successful fields of NFC application will be briefly discussed.

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Black Locust (*Robinia pseudoacacia* L.) Breeding and Recent Results

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Keywords: black locust, breeding methods, clonal variety, clonal seed orchard, mass production, quality timber

ABSTRACT

Black locust *Robinia pseudoacacia* L. is one of the most important tree species in Hungary, and occupies approximately 24% of all Hungarian forests. It is extremely fast growing but still produces high quality hardwood. It grows best on mesic, porous soils, but still survives among poor circumstances – it was originally planted for controlling sandy soil drifts. Due to the nitrogen-fixing bacteriums on the roots it improves the quality of the poor sandy soils. The wood quality is outstanding, as it endures extreme outdoor weather conditions and the industrial applications are versatile. It is an excellent firewood, even directly after cutting, as it does not need to be dried. Furthermore, Black Locust has a great nectar production, its honey is world-famous. There are numerous Black Locust stands growing under bad conditions with low industrial wood production. The objective of breeding Black Locust is to improve quality industrial wood production yields.
There are different methodologies in breeding Black Locust. The positive mass selection selected seed stands produce the least genetic progression.

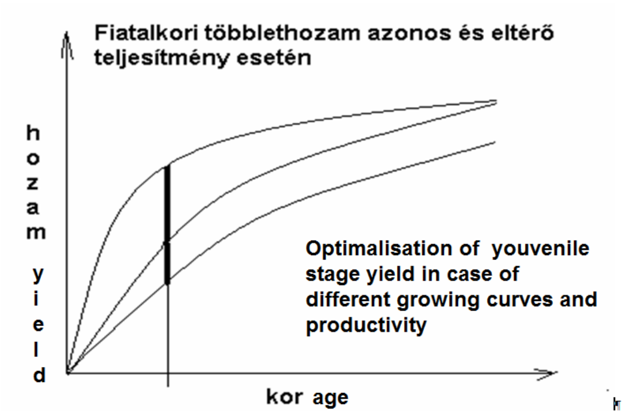

Figure 1: Theoretical basics of the juvenal age selection started in the nursery

Figure 2: Progeny test of the component clones of TURBO clonal seed orchard

Individual selection - based on selected plus trees - is a widely used intensive breeding method. Plus tree selection is an individual selection, which utilizes the diversity of the species' numerous individuals in order to select the most suitable genotypes given the breeder's objectives. Plus trees can be selected from forest stands or from tree nurseries. If end yield is the same, it is possible to take advantage of the rapid growth in early years and a plus can be demonstrated, eliminating the time factor. If end yields are different, profit can be much higher (Figure 1.).

Plus trees	Heihgt m	Diameter at D1,3 cm	Volume m3	Yield at 500 tree/ha m3/ha	Average annual increment m3/ha/year	Scored (bonited) stem qualty			
						Stem form	Forking	Upper part, crown	Average
OBE02	18	25	0,495	248	13,8	2	2	1	1,7
OBE05	18	23	0,415	208	11,5	2	1	1	1,3
OBE13	20	23	0,440	220	12,2	3	2	1	2,0
OBE14	20	19	0,290	145	8,1	1	2	3	2,0
OBE22	20	29	0,720	360	20,0	3	2,5	1	2,2
OBE25	21	24	0,490	245	13,6	2	2	1	1,7
OBE26	20	22	0,400	200	11,1	1	2	1	1,3
OBE32	21	24	0,490	245	13,6	3	3	3	3,0
OBE33	20	22	0,400	200	11,1	2	2	1	1,7
OBE35	22	25	0,555	278	15,4	3	2	1	2,0
OBE43	18	23	0,415	208	11,5	2	1	1	1,3
OBE45	18	23	0,415	208	11,5	2	3	2	2,3
OBE52	20	25	0,425	213	11,8	2	2	1	1,7
OBE53	21	26	0,580	290	16,1	1,5	2	3	2,2
OBE54	18	25	0,495	248	13,8	2,5	3	1	2,2
OBE59	22	26	0,600	300	16,7	1	2,5	1	1,5
OBE65	18	24	0,450	225	12,5	3,5	3,5	2	3,0
OBE69	20	25	0,525	263	14,6	2	2	1	1,7
OBE01	25	31	0,930	465	27,4	1	1	2	1,3
Average	**20**	**24**	**0,502**	**251,0**	**14,0**	**2,1**	**2,1**	**1,5**	**1,9**

Figure 3: Basic data of TURBO OBELISK variety group's ortet plus trees at age 18 years (except OBE01 which is 17 years old.

For the sake of completeness, artificial crossing and inducated poliploids also have to be mentioned, however these processes haven't produced any results for the practice beyond the theoretical basics.
There are several practical results in quality wood production: selected adult plus trees [that means all the shipmast Black Locust (Árbocakác) varieties selected and bred by Forest Research Institute (ERTI)] and clone varieties selected from the second generation plus trees of the progeny test stands. These are the 'TURBO OBELISK' clone varieties of SILVANUS CSOPORT KFT.
The 'TURBO' clonal seed orchard from 8 clones bred by SILVANUS CSOPORT KFT. is also a groundbreaking practical result, based on the method of early selection started in the nursery. The 'TURBO' variety for mass production is suitable primarily for energy plantations with ultra-short (2-3-5 years) and short rotation period.

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Session II/1.
Processing Technologies I.

Application of Microwave Heating for Acetylation of Beech (*Fagus sylvatica* L.) and Poplar (*Populus hybrids*) Wood

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Keywords: Acetic anhydride, Chemical reactions, Dimensional stability, Wood modification, Microwave treatment; Wood impregnation

ABSTRACT

Wood is a natural heterogeneous composite and is considered to be dimensionally unstable when exposed to wet conditions. Hydroxyl (-OH) groups of hemicellulose and cellulose chains are mainly responsible for the highly hygroscopic behaviour of wood (STAMM 1964). Chemical modification can, for instance, be used as an efficient way to transform hydrophilic OH groups into larger hydrophobic groups (KOLLMANN 1951). Acetylation of wood is one of the most commonly used chemical treatments to improve the dimensional stability and biological durability of wood. Acetylation effectively changes free hydroxyls within the wood into acetyl groups (ROWELL ET AL. 2013). The standard acetylation process includes impregnation of oven-dried wood with acetic anhydride (Ac_2O), followed by conventional heating to initiate the chemical reactions with wood polymers. Time consumption is an important issue for the proposed acetylation method. In order to reduce the reaction time and make the process more effective, an innovative wood acetylation process that uses microwave (MW) energy has been recently studied (LARSSON AND SIMONSON 1999; LI ET AL. 2009).

Unfortunately, published studies related to the acetylation process conducted using MW heating are still limited. Therefore, the present study aims to (1) analyze the acetylation process using MW heating, (2) evaluate the efficacy of MW heating on the chemical reactions during the process and its similarities with conventional methods, and (3) evaluate material properties (uptake of substances, equilibrium moisture content, wood swelling, and anti-swelling efficiency).

Microwave and conventional acetylation of wood was carried out to determine its efficacy on the material properties. Beech (*Fagus sylvatica* L.) and poplar (*Populus* hybrids) samples with dimensions 14 mm × 14 mm × 14 mm were pressure impregnated using Ac_2O (Sigma Aldrich, analytical grade ≥ 99%), and chemical reactions were initiated by microwave and conventional heating. The microwave acetylation process was carried out using laboratory equipment at a frequency of 2.45 GHz in several testing modes (1kW, 0.1 $m \cdot min^{-1}$; 2kW, 0.1 $m \cdot min^{-1}$; and 2kW, 0.025 $m \cdot min^{-1}$) to reduce time of the reaction. Conventional heating was carried out in a standard laboratory drying oven (Sanyo MOV 112) at 100°C.

The uptake of substance, equilibrium moisture content, wood swelling, and dimensional stability were determined in order to evaluate the efficacy and degree of acetylation.

Both microwave and conventional heating positively affected the selected material properties. The results showed that no significant differences were found between microwave and conventional heating; therefore, microwave heating can be used as a valid replacement in the acetylation process. The radial and tangential swelling of wood (S_R and S_T) at different relative

humidity levels are presented in Fig. 1. Microwave power of 2 kW and 0.1 m·min^{-1} conveyor speed were the optimum conditions for microwave acetylation. These process parameters resulted in 39.4% ASE $_T$ and 35.2% ASE $_R$ for beech and 38.0% ASE $_T$ and 16.3% ASE $_R$ for poplar samples. This work provides insight into the details of wood acetylation using microwave heating.

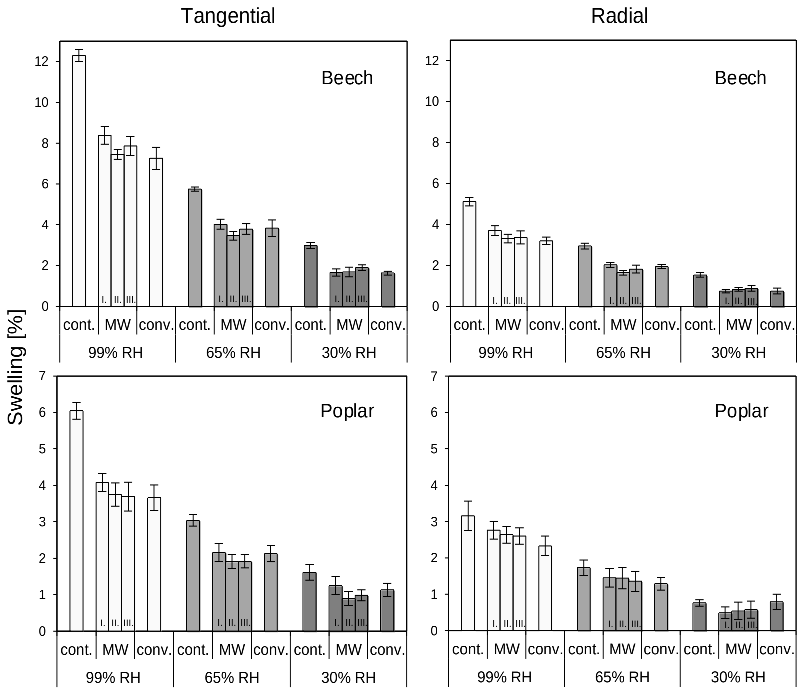

Fig 1 Swelling of beech and poplar in the tangential and radial directions

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Darkening of oak wood during different drying processes

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Keywords: Oak wood, colour change, darkening, drying

ABSTRACT

The inhomogeneous colour change of oak wood during drying processes is a major issue in the hardwood processing industry. This quality lowering effect concerns the whole time span of drying, from logging to in-service moisture content. The issue is well known in the classical sawnwood industry, as well as in veneer production. In both processing lines, it affects major losses by lower quality, caused by colour inhomogeneity, namely darkening from the edges, also known as "white clouds" (Figure1) (WASSIPAUL AND FELLNER, 1992; FORTUIN, ET AL. 1988).

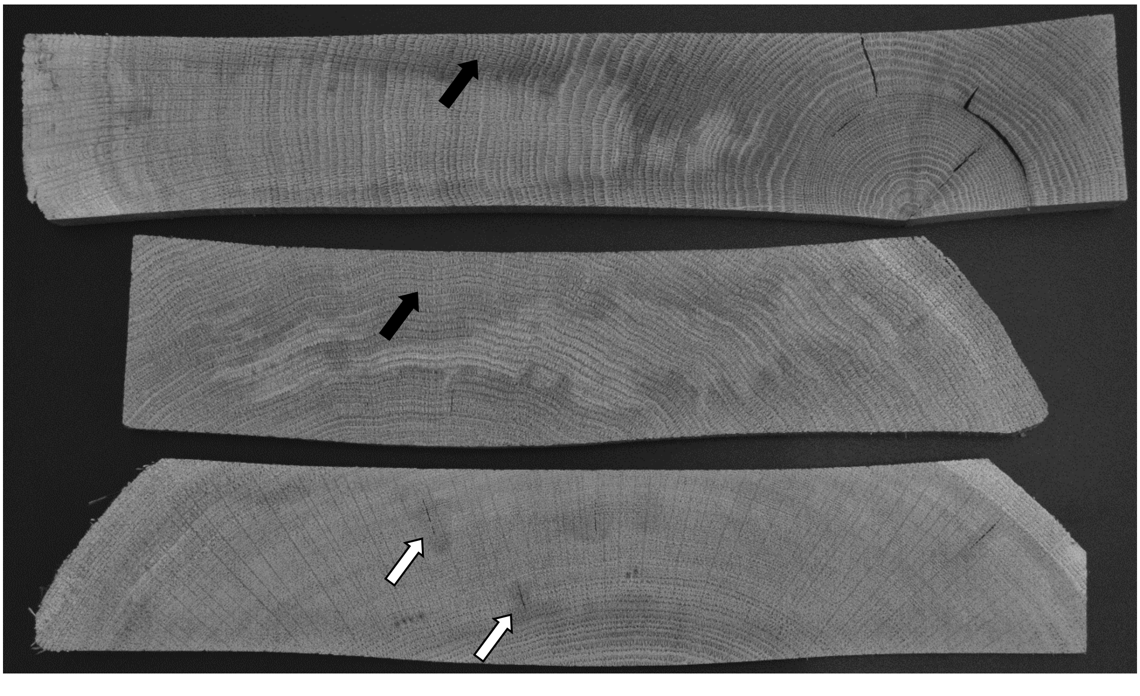

Figure1: Typical darker colour at the edges of the cross-section (black arrow) and around the inner cracks (white arrow)

Although the phenomenon is well known, the reasons and conditions how and when the colour change occurs is not completely revealed. In literature manly recommendations are given, how to reduce the colour inhomogeneity (FORTUIN, ET AL. 1988; STENUDD 2005). Different studies describe the darkening at the edges as a result of irregular accommodation of substances. The assumed mechanism is water transport along the diffusion direction to the outer regions

(KISSELOFF 1993; WASSIPAUL AND FELLNER, 1992; WEGENER AND FENGEL 1988). Additionally oxidative and enzymatic processes are in discussion (KOLLMANN ET AL. 1951; STENUDD 2005; WEGENER AND FENGEL 1988). The actual reasons for the darkening and the resulting recommendations to avoid them are partly described controversial in the different studies.
In a series of different oak drying processes – air drying, kiln drying and vacuum drying – the colour changes were investigated on the cross-sections of the timber, using colour measurement and scanning technology. Complementary the moisture content of specific regions in the cross-section were measured and correlated to the colour of the specific region (Figure2).

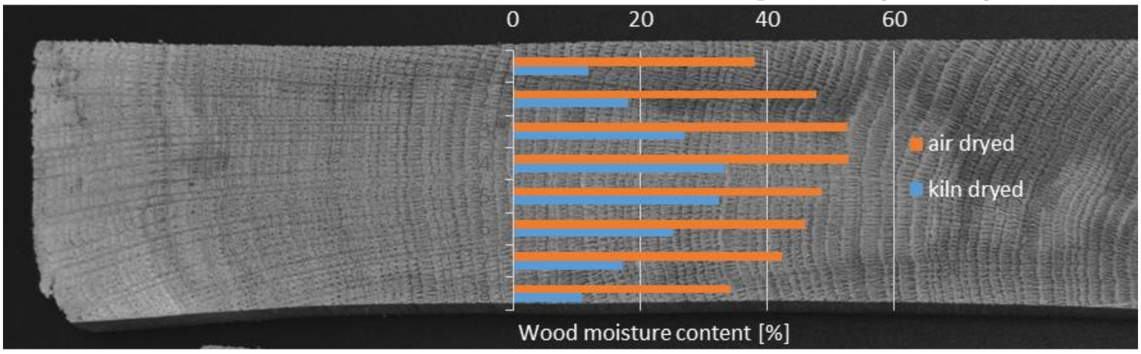

Figure2: Wood moisture content distribution along the board thickness after air drying and after kiln drying

The investigations showed that the darkening not only occurs from the outer edges to the centre, but also in areas around radial cracks (Figure1). This observation is manly an issue in veneer trunks (roundwood). While the edge born darkening was observed primary on sawnwood of bigger dimensions (≥ 50 mm).

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In situ CT-scanning for detection of internal checking and cell collapse during drying of hardwood species

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Keywords: CT-scanning, *Eucalyptus nitens*, wood drying, image processing, cell collapse

ABSTRACT

During the drying of sawn timber, hydrostatic tension forces within the cell may exceed the compressive strength perpendicular to the grain of the thin cell wall and the cell then collapses. This phenomenon is common in hardwoods such as *Sequoia sempervirens*, *Thuja plicata*, *Tsuga heterophylla*, *Juglans nigra* and many species of eucalyptus and oak. Usually, this leads to severe surface deformation, and both surface and internal checking (honeycombing) may occur. The quality of the final product is lowered by these cracks and deformations.

The aim of this study was to investigate, by CT-scanning samples throughout the drying process, whether it is possible to detect when and how cracking and deformation occurs and develops in specimens of *Eucalyptus nitens*. Based on this knowledge, better drying schedules can be developed to improve the yield and ensure a higher quality of the sawn timber.

Three specimens, one specimen in each drying run, of *Eucalyptus nitens* were used for the tests. Their cross-sectional dimensions, prior to drying, were 105x23 mm^2 and their length was 70 cm. A specially designed laboratory drying kiln that fits within the gantry of a Siemens Somatom Emotion medical CT-scanner was used (Fig. 1). With this equipment, it is possible to scan the inside of the kiln without interrupting the drying process.

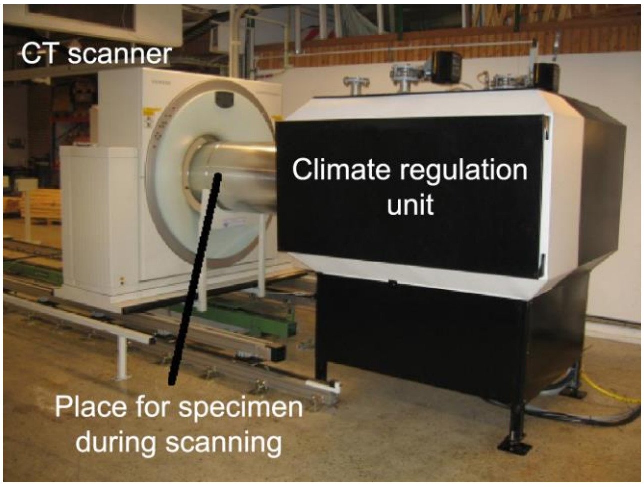

***Figure 1:** X-ray computed tomography (CT) with the climate chamber installed for CT measurements*

The dryer works as a regular heat and vent kiln, and the drying takes place under atmospheric pressure. Prior to drying, the specimens were soaked in water for 24 hours and the ends were sealed with a heat-resistant silicone. In the three drying runs, the dry bulb temperatures were set at ca. 50, 82 and 103°C respectively while the wet bulb depression varied as the drying progressed (Fig. 2). The warming-up took place in a saturated atmosphere at a rate of 30°C per hour. The specimens were scanned periodically and at different spans. Three thermocouples, type T, connected to a PC-logger (Intab AAC-2), and placed in holes drilled in the specimens, were used to achieve complementary data. Two of the thermocouples were placed in the centre of the specimen cross section and one at a depth of approximately 3 mm from the surface. The data obtained were used to make videos of the process following the changes in the specimens with the CT-images and a temperature graph.

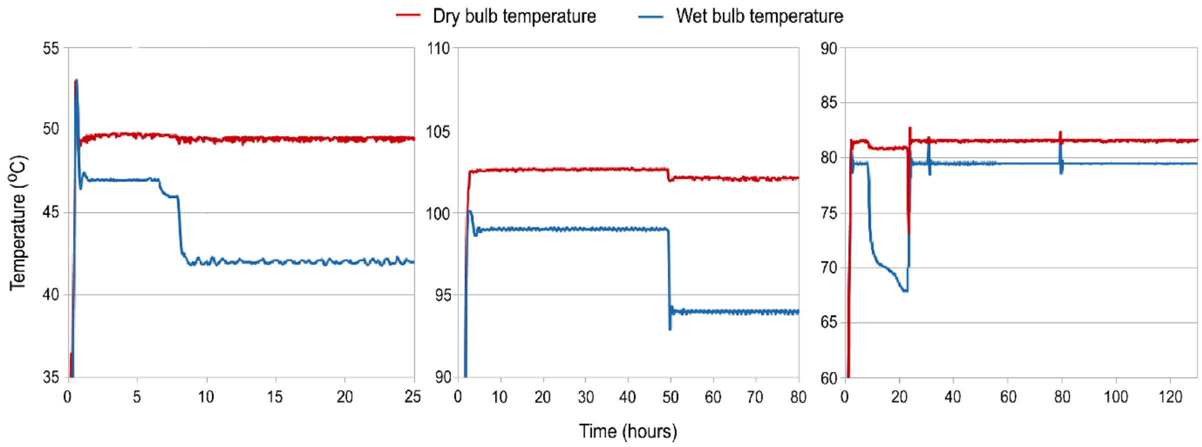

***Figure 2:** Wet bulb and dry bulb temperatures of the drying runs. From the left: | 2.1 dry bulb temperature 50 °C | 2.2 dry bulb temperature 82 °C | 2.3 dry bulb temperature 103 °C*

The method makes it possible to study changes in the cross section of the specimens at intervals during the drying process, such as how internal cracks start and develop. The pixel size of the images corresponds to 0.1 x 0.1 mm2 in the specimens. The depth of the voxel was 10 mm, so that the data given for each pixel corresponds to an average value of such a volume. It is possible to see a good level of detail with such parameters, but it could be possible to adjust the settings to achieve even higher spatial resolution. Collapse seems to become noticeable before any internal crack is visible. In the early stages of the drying process, a wavy deformation in the otherwise flat surface was clearly noticeable (Fig. 3).

This study shows that the CT equipment provides the means to study internal changes in wood during drying to a high level of accuracy, making it possible to better understand of the internal cracking and collapse behaviour during drying of Eucalyptus nitens or any other wood species.

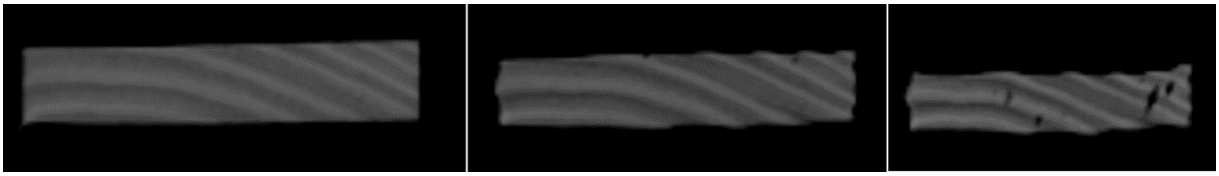

***Figure 3:** Sequence of the same specimen. From the left: | 3.1 beginning of the drying. | 3.2 collapse is visible at the surface of the specimen before any checking. | 3.3 internal checking is visible well after the collapse*

Influence of selected factor on Coefficient of wood bendability

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Keywords: Coefficient of bendability, cyclical loading, laminated wood, glue

ABSTRACT

Shaping materials by bending is a frequently used technology in many sectors wood industry. The measure of a material's bendability can be taken as the smallest achievable curve radius for the bent material. As bendability depends also on material thickness, this property is most frequently expressed as the ratio of the material's thickness and the smallest curve radius achieved. Theoretical expression of wood bendability is, however, rather inadequately studied. The present work focuses on application various definitions of wood bendability coefficient as well as the influence of various factors on its value. In the experimental part of the work, coefficients of wood bendability were defined for layered beech (Fagus silvatica, L.) and layered aspen (Populus tremula, L.) while considering the following selected factors: wood species (WS), material thickness (MT), type of glue (G) and the number of stressing cycles (NC) (0 versus 10.000). The study apply new quantitative expression of a bendability coefficient.

"Color authenticity" of oak wood in cases of intentional colouring

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Keywords: colour, wood, dark brown, oak

ABSTRACT

It is well known that in interior design wood as one of the essential materials is used in combination with many other materials, surfaces. The surface features of wooden elements such us floors, wall paneling or big volume furniture in interiors influence the overall impression. Preference studies reveal the changing tastes and trends in the globalized world.

In all combination cases in spatial design colour plays an essential role, but in the case of wooden surfaces the texture results to equally important. The homogenized "wood" colour alone without any texture does not get the highest appreciation by human beings, but superposing wood colour and wood texture exhibits the unique and delicate appearance of wood which is widely appreciated. (KOTRADYOVÁ, TEISCHINGER, 2012).
On the basis of earlier research we have set three categories for "wood colour" according to the parameter lightness *L*. (Fig.1): *light* with L-value > 80 where belong maple, birch, spruce, fir, poplar, hornbeam, lime and ash, *medium* with lightness L 65-80 such as oak, cherry, elm, beech, alder, acacia, and *dark* with lightness L < 45, which from domestic species includes only walnut. Also steamed acacia and thermally or chemically modified light wood species can reach dark coloration. All other naturally dark colored wood species like wenge, ebony etc. are from tropical climatic region.
In recent years darker wood species and colours have been leading the popularity charts. Our presumption is that there are at least three reasons for this: the association with well-being of the past aristocratic styles, the warmer aesthetic appearance and thermal contact comfort performance and the third is easier aesthetical combination with other colours especially in interior design.

There are many options of color modification of wooden surfaces with the intention of maintaining the texture visible, including the basic staining or pigmentation with oil glazing (lasuras). All of them change the original appearance of the wood surface. Intentional color modification can, of course arise from aging of wood such as proning to a photo-induced discoloration. Various wood species undergo different amounts of photo-induced discoloration from darkening to fading as shown and classified by Oltean et al. (2010).

The aim of this paper is to define the aesthetical acceptability ranges with regard to the "colour authenticity" of wood, especially the limits within which the sample is still judged and accepted as a certain species. For the first part of the study one of the currently most popular and frequently applied wood types in Europe have been selected: oak.

The paper will present results of the study of seven samples, whereas 6 of them will be treated in a different colour by regular stain ranging from whitish to dark brownish and one untreated reference sample. All samples are also treated by oil surface finishing. Intensive coloration by dark brown / black pigments causes that the wood texture is less recognizable and the colour starts to be dominant. The study is based on phenomenological research methods using psychometric evaluations. The colour appearance is measured visually and instrumentally in NCS. Quantification of the differences allows for an attempt at finding the decisive / conditioning factors and characteristics, the limiting values of acceptance - the range of aesthetic acceptability and visual authenticity of oak wood.
The subjective evaluation by observers and objective measurements using the Colour Scan are expected to yield statistically significant results.

Figure 1: Collages of light, medium, dark wood colors usually used in interior design

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Session II/2.
Processing Technologies II.

Some aspects in the production of MDF from hard hardwood tree species

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Keywords: MDF, wood of hardwood tree species, density, binder content, hot pressing temperature.

ABSTRACT

In the production of MDF from hard hardwood tree species, there is a number of technological difficulties related mainly to the lower slenderness ratio of the fibrous elements and the relatively small coefficient of compression. The negative impact of these factors may be compensated, at least partially, with a change in the technological factors during production.

In this paper, an examination with respect to the effect of some factors in the production of MDF has been presented. The effect of the binder content (when using phenol-formaldehyde and urea-formaldehyde resins), the effect of the density of the boards and the pressure during pressing have been examined. Regression equations have been worked out for the effect of these factors.

Optimum density of MDF from wood of hard hardwood tree species, as well as values of the pressure during pressing, at which this density shall be obtained, have been determined. Optimum durations of pressing at different temperatures have been determined in order to achieve best values of the physicomechanical indices of MDF.

The effect of the phenol-formaldehyde resin content in MDF to the amount of 6% to 14% and density within the range from 620 to 820 kg/m^3 has been examined and it has been recorded that the maximum value for bending strength is 33.4 N/mm^2. This strength may be achieved at phenol-formaldehyde resin (PFR) content of 12.9% and density of 820 kg/m^3 of the boards. The strength is considerably above the 23 N/mm^2 required pursuant to the standard.

When examining the swelling in thickness, a reverse relationship with the density of boards has been observed. Best swelling may be obtained at 14% PFR content and 620 kg/m^3 density of boards. When setting limitations in conformity with the requirements pursuant to the standard that the swelling in thickness is 17% at most and the bending strength is at least 23 N/mm^2, the dependences presented in Fig. 1 are obtained. In case of observance of the limitations for swelling in thickness, maximum strength may be obtained at resin content of 13.5% for boards with a density of 720 kg/m^3.

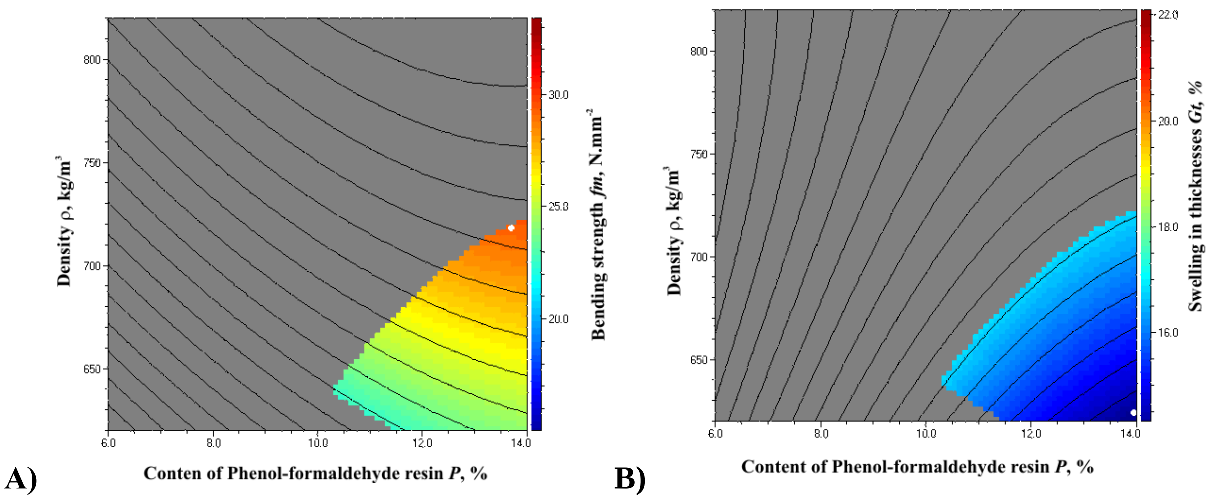

Figure 1. Optimum value of: A) bending strength and B) swelling in thickness of MDF in case of functional limitations for the two indices in order to achieve the values required according to the standard

Therefore, 720 kg/m^3 shall be shown as a recommendable density for MDF from hard hardwood tree species when using phenol-formaldehyde resin. At higher densities of boards, the limitation for swelling in thickness is not achieved.

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Application of Paulownia fibers in MDF manufacturing

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Keywords: Paulownia; nano-clay; MDF; modulus of rupture; modulus of elasticity

ABSTRACT

Paulownia (Fuotuni) has been planted in the north of Iran since 1991. In this study planted paulownia fibers (at two levels of 0 and 25 percent weight basis of total fibers) were mixed with industrial fibers (75 percent) provided from local MDF company. Urea- Formaldehyde resin (UF) resin was used (at rate of 10% of oven dry weight of fibers) as binder and nano-clay was added to UF at three level of 0,1,3, and 5 percent (weight basis of UF) as reinforcement. Fresh logs cut from local plantation were converted into fibers in refiner under pressure of 7 bar at 170 degree centigrade. Fibers were mixed with UF resin and formed into mats and hot pressed and MDF panes were produced. Physical and Mechanical properties of manufactured panels were evaluated. By adding nano clay to UF, MOR of MDF panels up to 43%, MOE up to 55 nvwn, IB up to 54 % and thickness swelling up to 47% improved. When paulownia fibers were added to industrial fibers above mentioned properties were improved 32%, 47%, 53% and 53% respectively.

INTRODUCTION

Medium density fiber board (MDF) is one of the most common products which are used in constructions. This product is applied in different parts of residential, commercial and industrial constructions. Dimensional stability and strength are the major issue which users are concerned about. Steam treatment, acetylation and chemicals are used in order to improve such properties of the MDF . Recently, researchers have investigated on modifying binders with nanomaterials because of their small size and their penetration in lignin and hemicellulose. Nano clay has been found that is very effective for improvement of wood products. In this study nano clay was used to modify urea formaldehyde (UF) resin which is a common binder in MDF industry. Paulownia is a light species which is planted in Iran . Paulownia fibers were applied as part of industrial fibers to enhance strength properties of MDF

METHODS AND MATERIALS

Industrial wood fibers were provided from a local MDF firm. Paulownia logs provided from a local plantation then converted into chips using a Palmman chipper. Chips were then steamed at 170 degree centigrade for 10 minutes. Fibers were dried to 2% and stored in plastic bags. Nano clay was added to UF resins at three levels of 1%, 3% and 5% .UF resin were mixed with wood fibers using a laboratory blender and formed into 400 X 400 mm mats manually. Mats were hot pressed at 170 degree centigrade under pressure of 30 bars for 7 minutes. . Samples for physical and mechanical tests were cut from fabricated boards following DIN68763. ANOVA technique was used for determining effects of variables on boards properties

RESULTS AND DISCUSSION

Adding nano-clay to UF resin has positive effect on MDF panels. MOR of control specimen was 20.18 MPa but MOR of boards made using UF resin containing 1%, 3% and 5% nano clay were 23.50 MPa, 26.84 MPa and 28.93 MPa respectively. MOR of Panels made with UF resin containing 5% nano clay showed 43 percent improvement in comparison with control panels (Fig.1). Modulus of elasticity of boards made using UF containing 1%, 3%and 5% nano clay were 3100 MPa, 3545 MPa and 4125 MPa respectively while MOE of control boards was 2651 MPa . These indicates that MOE of MDF enhanced up to 55% (Fig.1). Also Internal Bond of MDF panels improved by adding nano clay into UF resin so that when 1% , 3% and 5% nano clay added to UF resin, IB of panels were 0.40 MPa, 0.44 MPA and).51 MPa respectively, while that of control was 0.33 MPa. It means panels IB of MDF panels made with UF resin containing 5% nano-clay improved 55% comparing with control panels. Thicness swelling after 2 hours swelling in water was also affected by adding nano clay to UF resin so that it improved 47 %. All above mentioned results indicates that adding nano-clay has positive effect on MDF properties. Paulownia fibers also affect MDF panel properties so that in panels with 25% paulownia fibers MOR of panels improved 33% by adding 5% nano clay into UF resin. MOE improved 47 %, IB improved 54% and TS improved 53% (Fig 1).

Conclusion

The results of this study indicate that adding Paulownia fibers has positive effect on MDF panels. Adding nano clay has interaction effect on paulownia fiber effect . This means using these two materials together would be effective in MDF production.

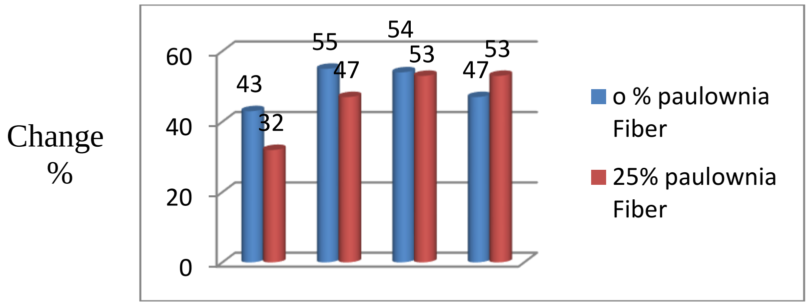

Fig.1 Effect paulownia fiber on properties of MDF manufactured using UF containing 5% nano clay

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Quality management and techniques in the wood industry

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Keywords: standards, industry 4.0, production systems, wood, timber, colour, image and video processing.

ABSTRACT

There are different production systems and techniques. Every company is unique in the industrial field and they have unique production systems. They use several same methods in their working from the 1950s. These methods' sources are inherited from Toyota (lean management, kaizen, 5S methods, kanban etc.) (Ohno 1988). These are standards nowadays.

Considerable technological advances appeared in the industrial sector in last years. Developments are based on the "Internet of things" idea, it's called "Industrial Internet" in USA. In Germany, the "Industrie 4.0" project started in 2011. Many experts think this is the fourth industrial revolution, the version 4.0 comes from that idea. The goal of these projects is to create live connections among all industrial machines, tools and the central units. Some techniques and tools, e.g., sensors, big data, cloud computing, 3D printing, robotics and artificial intelligence, support the IT developments also. The decision making in the industry will be automated and quick because of the new methods and tools. In our research, we extended some of these guidelines.

The production is the most important activity in the life of factories. The continuality of the production process must always be secured. However, it is not a trivial task. The systems' failures or the bad quality of the materials can always happen. We worked with a given company of the wood industry area. Its working is also unique, therefore we had to create a specialized, self-developed production system. The old solution was not so solid, it had a lot of disadvantages. The colour determination process was not exact. The process was tested several times with the same timber and we got different results of colour. The process did not deal with the failures of the timbers. Wood failures also have influence on colour. The colour determination software was not accessible for the wood company. It was able to access only by the informatics company, which is not exists now. Besides, the colour determination process was not "mistake-proofing". An operator was able to change some input parameters' value easily, which can be led us to the wrong decision of timbers' colour. These problems eventuate the need of a new development. Our system monitors the most important production progress, which is the determination of the timber's colour after shave of timbers. In the wood industry, the properties of timber are equivalent with the quality. Our solution has several functionalities: (1) database communication, (2) ERP communication, (3) controlling different devices of the production (e.g., camera, printers, sensors).

The natural wood colour depends on brightness, saturation and tincture. The wood colour is based on the number of conjugated double bonds. The more the conjugated double bonds are, the darker the wood is and vice versa. Therefore, the colours of the wood species are different. The wood colour can be affected by incidental materials, their types and quantities. For example, the cause of the tawny (yellow and brown mix) colour of wood is that the wood

consumes the 90% of light's blue part, however, the yellow and red colour are reflected (70-80%). The light consumption of the wood depends on frequencies (Tolvaj 2013).
The wood colour changing has several influential factors, such as physical, chemical and biological effects. The colour can be affected by the production site. During the growth of the tree, the colour of annual rings created in the older ages are darker, than younger ones. The moisture content of the tree also influences the colour. The less the moisture content of the tree is, the lighter the colour is and vice versa. Photodegradation means the chemical changes caused by the sunbeam. Photodegradation can modify the colour of the wood. The colour changing can be formed by attacking of bacteria and funguses (Németh 1998).

Figure 3: Timber's structural failures

We can see that the precise determination of wood colour is not a trivial task. Having studied the literature, there are IT solutions for image or video processing. We exanimated ProAnalyst and Tracker solutions, but we chose the open-source OpenCV library. This library can be programmed in C++ language and it contains several thousand algorithms to analyse images and video streams. The self-developed software has the capability of (1) image manipulation, (2) shape detection, (3) timber failure detection, (4) determination of timber's colour. We sought failures in the given timber surface. In other words, our solution can determine those areas, which colour are different from the neighbourhood areas. The software can calculate how big the factor of sub region's colour to the whole area colours.
It is difficult to collect the necessary information for the quality management to rank the suppliers. We need a higher integration and automation level, however, these will be initialized with the new video stream analysing system.

Figure 4: Timber's colour result: dark, ok and light

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Visual and acoustics grading of beech wood from standing tree to final product

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ABSTRACT

Assessment of the quality of wood is for the forestry as well as for the wood industry a big challenge. The great variability and heterogeneity of wood exhibit at different levels more or less hidden structure which often determines its quality. Many wood defects are being disclosed during processing of wood to smaller and smaller assortments. The evaluation may be doubtful and assessment or classification is therefore risky and uncertain. Visual grading of logs or sawn timber is still dominant, but every day different nondestructive methods were established (c.f. GRABIANOWSKI AT AL. 2006, HANSEN, 2006 ILIC , 2001).

The aim of the research was to determine the reliability of visual and/or acoustics nondestructive method of evaluation of wood quality through the entire production line; that is from the standing tree to the final wood product.

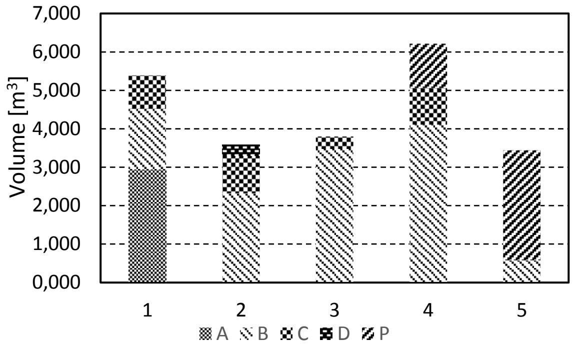
The material was selected on three samples forest plots from different region in Slovenia. Two trees from each quality range on 5 step scale (total 10 trees), with breast diameter greater than 30 cm, were chosen from each plot. After felling and cutting the trees to logs, the logs were assessed after visual standard procedure and with nondestructive acoustics method. The logs were cut into boards which were also assessed with both methods.

Assessment of the quality of standing trees was estimated according to internal instructions; generally apply for evaluation of standing trees in Slovenia. The quality of logs was evaluated and classified after the European standard (EN 1316-1: 2013). The length and the mean diameter of the logs were measured in accordance with EN 1309-2: 2006. The dimensions of sawn timber were measured in accordance with the rules set out in EN 1309-1: 2000; the volume of sawn timber was calculated in accordance with the requirements of EN 1312: 2003. With acoustics method we measured the speed of sound and frequency response from which we calculate the dynamic E-module.

The quality of standing trees is rather optimistic (Figure 1 - left), since the assessment is based only on external appearance and many defects relevant for the classification appear after felling the tree. A large part of defect occurs also during manipulation.

Dynamic E-module is quite good correlated with visual classified logs (Figure 1 – right). The exception is the worst quality logs that requires the also the visual inspection.

In assessing the board we get equivalent results, with better and more reliable classification as after sawing more defects may be integrated into the final results. Also in the evaluation of boards we can recognise the weakness of acoustic method (Figure 2 – right), as the measures dynamic E-module at the worse quality of boards is too high. The acoustic grading method shows more reliability on dry wood.



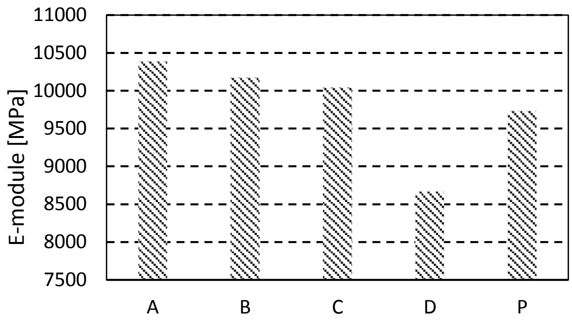
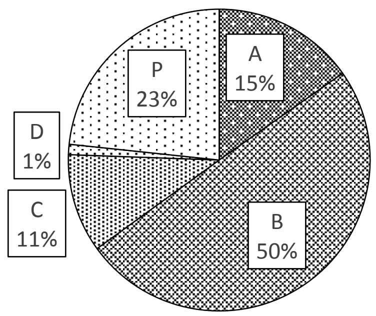


Figure 1: - The volume of classified logs according to the quality assessment of standing trees - left. Dynamic E-module of logs, classified with visual criteria- right. (1 – 5 – estimated class of standing trees; A, B, C, D, P – visual classification of logs).



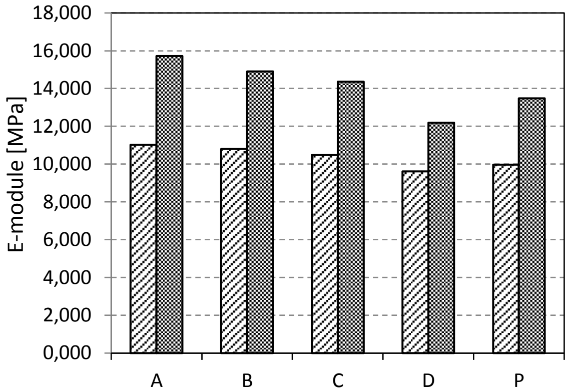


Figure 2: - The percentage of visual classified boards - left. Dynamic E-module of wet and dry boards, classified with visual criteria (A, B, C, D, P – visual classification of boards).

The acoustic method could also be a good tool for grading of beech logs and boars but also with essential visual inspection.

ACKNOWLEDGEMENT

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Session III.
Products and Market

Low value hardwood timber – unused potentials?

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Keywords: Low value hardwood, wood material use, new applications and possible uses

ABSTRACT

Since the mid-1990s the annual raw wood consumption in Germany has been showing an increasing growth rate. While the harvested timber and wood consumption showed numbers of 48.5 Mio. m^3 respectively 47.7 Mio m^3 in 2002, the values grew up to 68.4 Mio. m^3 and 72.4 Mio. m^3 in 2010. Due to an EU-wide program aiming to raise the renewable resource share in primary energy consumption to 20 % until 2020, wood as a thermal resource plays a particularly important role today. This development will continue within the next years and therefore there will be consequences for the wood industry (SEINTSCH & WEIMAR 2012).

In 2012, softwoods covered more than 75 % of the total 70 Mio. m^3 annual felling. While 80 % were used in construction wood, wood products etc., 20 % were processed for energetic use. For hardwoods the proportion of the total felling of 17.4 m^3 was the opposite.

Therefore, in the future it will be necessary to use hardwood more extensively in a non-energetic way to meet upcoming demands. To ensure future resources for the wood industry, new strategies for the utility of unused, thus mostly energetically used low value hardwood are needed.

German forests are at present stocked (11.4 Mio. ha) with approximately 54% of coniferous tree species and 43% of hardwood tree species. Hardwood forest area grew around 7.3% from 2002 to 2012, while softwood forest area shrunk by 4.3% in the same time period.

For spruce the use of wood was 15 % higher than the stainable growth rate. While the available softwood in German forests is used extensively, there are still considerable potentials for the use of hardwood. Beech and oak wood is widely used by its potentials (beech mainly energetic) whereas species like birch and ash have possibilities for more applications (SPELLMANN 2013).

The above mentioned situation with respect to the raw wood market was the starting point for a joint project between different research institutes in the field of wood science (Table 1). Aim of the project is to find an ecologically acceptable, non-energetic and sustainable solution for the use of low value hardwood timber. Along the value chain of the potentially useable hardwood species developments are on their way (Table 1).

Table 2: Research institutes and projects

Research Institute	Research project
1. Northwest German Forest Research Institute (NW-FVA)	Tree species specific potential analysis of the hardwood timber with expected quality and diameter
2. University of Göttingen: Department of Forest Economics and Forest Management	The value chain of hardwood with regard to the material use of low value ranges
3. Frauenhofer Institute for Wood Research (WKI)	The use of industrial defibered technology and the production of fibreboards with low value hardwood
4. University of Göttingen: Department of Molecular Wood Biotechnology and Technical Mycology	Production of new wood composites with special focus on particle boards and fibre boards
5. University of Göttingen: Department of Wood Biology and Wood Products	Low value hardwood timber in the sawmill industry; special focus on yield and drying method
6. University of Göttingen: Department of Wood Biology and Wood Products	Production of wood fibre insulating materials with low value hardwood

First interviews with different partners from the sawmilling and forest industry show very different regional aspects of availability and demand for different hardwood species. The reasons are diverse, e.g.: Wood species like ash are expected to show a major decrease in the next years (parasites). Species like birch are available but only in single stems in the stands. Some tree species are not harvested, because their wood is not "en vogue" at the moment. Many trees of low value are still in the forests due to expensive costs of felling and little payment for the quality. Moreover, the species and assortment range of hardwood trees is higher compared to softwood trees, therefore sorting and storage is more complicated and more expensive.
The University of Göttingen, Department Wood Biology and Wood Products choose the wood species oak and birch for first investigations – mainly because of the availability and demand in the future. Studies in the past (e.g. VAN DE KUILEN ET AL. 2014) show a huge optimisation potential regarding the process of producing hardwood gluelam. The cutting to a shorter length of stems mainly for reducing the curve of the stems is a possible solution for a better yield. Another focus is set on drying processes. So far there are hardly any drying schedules for drying low value hardwood timber available. Hot steam drying and alternating climate drying are promising options in order to reduce drying time and or improving drying quality. Alongside with mechanical tests, a conclusive picture for further usage of low value timber of these species will be given.

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Comparative study on two tropical hardwoods thermally modified by Thermowood® and Thermovuoto® process

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Keywords: colour, fungal discolouration, mass loss, metil, neem, thermal modification

ABSTRACT

Thermally modified hardwood species, e.g. limba, is now being marketed in Europe for cladding and other external applications. The timber is supplied from West Africa and treated thermally in the EU. This approach opens very good possibilities for commercialisation of lesser-known tropical wood species that are hardly used nowadays. The objectives of the study were to treat thermally metil (*Sterculia appendiculata*) and neem (*Azadirachta indica*) timber originating from Mozambique under industrial conditions applying two well-recognized methods namely thermal treatment by steam (Thermowood®) and under vacuum (Termovuoto®). Matched boards were treated in industrial facilities under identical treatment conditions (temperature of 212ºC, duration 3 h). Colour changes were characterised with CIELab method and it was proved that the thermal modification under vacuum generates lighter colour than that caused by steam treatment. Mass loss of the boards were measured; the difference was statistically significant for the mass loss being higher in Thermowood® process namely, 9.9% after vacuum and 14.1% after steam thermal treatment for metil and 12.1 and 14.2% for neem respectively. This probably can be explained by the fact that the applied vacuum removes partly the produced acetic acid from the material which catalyses sugar degradation. On the other hand, anatomical and chemical features may also play a significant role concerning the applied atmosphere. For instance, it should be noted that metil wood is more permeable than neem wood.

In general the mass loss is an important predictor for the mechanical properties that are expected to be somewhat lower after thermal modification. Both thermal treatments showed good ability to mask fungal discolouration which is typical for the processing conditions in the tropics.

Investigations towards dynamic properties of modified Sycamore maple for utilization as highly stressed tonewood

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Keywords: Carbon fibre reinforced plastics, dynamical properties, Sycamore maple, thermal modification

ABSTRACT

Highly stressed components for utilization as tonewood are the necks of stringed instruments, such as guitars, bass guitars, double basses and cellos. The neck of stringed instruments is responsible for resisting and transferring high forces owing to the stretched strings as well as for the sound of the whole instrument (Zauer ET Al. 2016). The wood must have a high dimensional stability, high speed of sound (low damping) and should be free of growth stresses. Hence, the wood for the use as neck material requires a very high quality. Usually, tropical hardwoods or sugar maple (*Acer saccharum* Marsh.) were applied as neck material owing to their magnificent properties compared to European wood species. To achieve the mentioned acoustic and mechanical properties, the wood must be stored over a period of many years (natural wood aging).

Thermal modification (TM) of wood leads to higher dimensional stability and higher speed of sound (low damping) as well as the thermally modified wood is free of growth stresses (Zauer and Pfriem 2016). However, the static and dynamic strengths decrease as well as the coefficient of variation of the mechanical properties increase significantly owing to thermal modification.

In principle, one way to increase the strengths and decrease the coefficient of variation of wood is a reinforcement procedure of wooden components by means of fibre-reinforced plastics (FRP), such as carbon fibre reinforced epoxy resin (Zauer ET Al. 2014).

This paper deals with investigations of dynamical properties of untreated and thermally modified (TM) Sycamore maple (*Acer pseudoplatanus* L.), both unreinforced and reinforced with carbon fibre reinforced epoxy resin using a total fraction relative to the wood cross-section of 3 % and a fibre volume fraction of the FRP of 35 %. The dimensions of the samples were 20 mm x 20 mm x (300) 360 mm (R x T x L). The FRP were arranged on both the tension side and the pressure side of the specimens, each in tangential direction (Fig. 1).

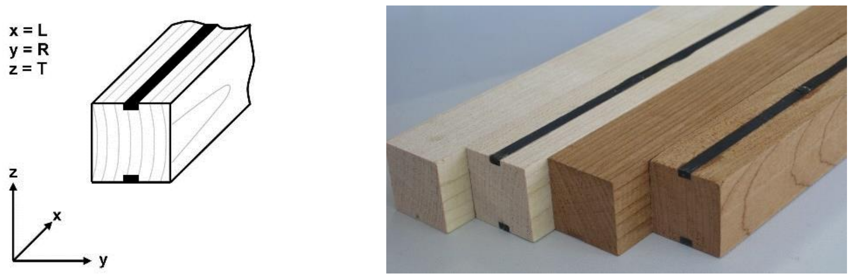

Figure 1: Example of the untreated and thermally modified, unreinforced and reinforced test bars of maple

The reinforcement procedure of the cross-sections was conducted as a one-step-process by means of the resin injection method (Zauer ET AL. 2014). TM was performed on lab-scale at a treatment temperature of 200 °C and a treatment time of 4 h under nitrogen atmosphere.
The investigations were conducted by means of impact bending tests according to DIN 52189-1 and the experimental modal analysis (EMA) according to Zauer ET Al. 2016. All investigations were conducted at 20 °C and 65 % relative humidity (RH).
The resulting equilibrium moisture contents (EMC) were 11 % for untreated maple and 6 % for TM maple. Average raw densities of 590 kg m^{-3} for untreated maple and 560 kg m^{-3} were determined. The absolute mass lost owing to TM was 4 %. In Fig. 2, the impact bending strength and dynamic modulus of elasticity (MOE) are presented as box plots displaying five-point summaries (median, the two quartiles and the two extreme values).

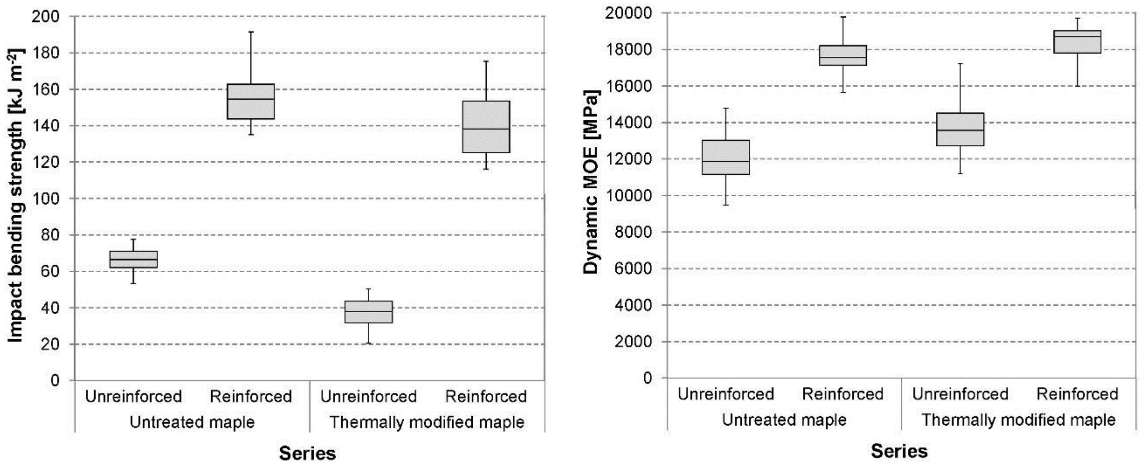

Figure 2: Comparison of the impact bending strength determined by means of impact bending tests (left) and dynamic modulus of elasticity (MOE) determined by means of experimental modal analysis (right)

As expected the impact bending strength of TM maple is lower than the values of untreated maple and increases significantly owing to the reinforcement with carbon fibre reinforced epoxy resin. The dynamic MOE of TM maple is higher compared to untreated maple owing to the lower EMC. That means the speed of sound of TM maple is higher than that of untreated maple. Likewise, the dynamic MOE as well as the speed of sound increase strongly owing to the reinforcement procedures.

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Withdrawal resistance of staple joints constructed with OSL and poplar wood

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Keywords: Oriented strand lumber(OSL), Withdrawal resistance, Upholster furniture, Staple joint, Poplar wood,

ABSTRACT

Several structural composite lumber (SCL) such as laminated veneer lumber (LVL), parallel strand lumber (PSL), laminated strand lumber (LSL) and oriented strand lumber (OSL) were developed recent decades. The use of low diameter and fast growing species such as poplar is one of the major tasks in production of such products. Among the structural composite lumber, OSL cost less than the others and solid wood; therefore, the use of OSL in upholstered furniture frames can reduce the cost of production and produce more profits. Modifying a product or designing a new one requires reliable information about the performance of materials and joints that are going to replace traditional ones in order to maintain the quality and to meet the consumer expectations. In order to encourage the furniture industry to consider OSL as a new material for their products, technical information on the performance of OSL as a framing member must be made available for the industry. The strength and stability of furniture mainly depend on the design of the frame pattern and the strength and stability of its joints (ECKELMAN 2003), therefore the goal of this study was to investigate the strength of joints manufactured with OSL and poplar wood with staple (most commonly used to join frame members in upholstered furniture) and adhesive.

OSL panels were prepared poplar strands (*Populus deltoids*). The dimension of the strands was 1× 15× 150 mm (thickness ×width × length). The strands were initially dried to moisture content about 3% and then were coated with UF resin (10% by dry weight of strands). The glued strands were formed to a mat and hot-pressed at a temperature of 160 °C and peak pressure of 50 kg/ cm^2 for 10 min. The solid wood samples were also prepared from the similar poplar logs. Face and edge withdrawal resistance of joints fabricated by OSL and solid wood and staple (with and without glue) were measured (ERDIL ET AL.2003). Configurations of the face and edge withdrawal specimens are shown in Fig. 1.

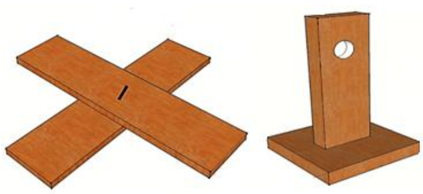

Fig.1: Configurations of the face (left) and edge (right) withdrawal specimens

The results showed that the type of joint member, penetration deeps of staple and glue significantly influence on the withdrawal resistance of joints. Generally the OSL exhibited higher withdrawal resistances than wood both in edge and face (Figs 2 and 3). Fig. 2 shows that staple withdrawal resistance increased with the increase of penetration deep both in wood and OSL. From Fig. 3, it is found that the use of glue improves the withdrawal resistance of staple joints in wood and OSL. The highest face and edge withdrawal resistances were obtained for joints manufactured using OSL and glued - 17 mm penetrated staple.

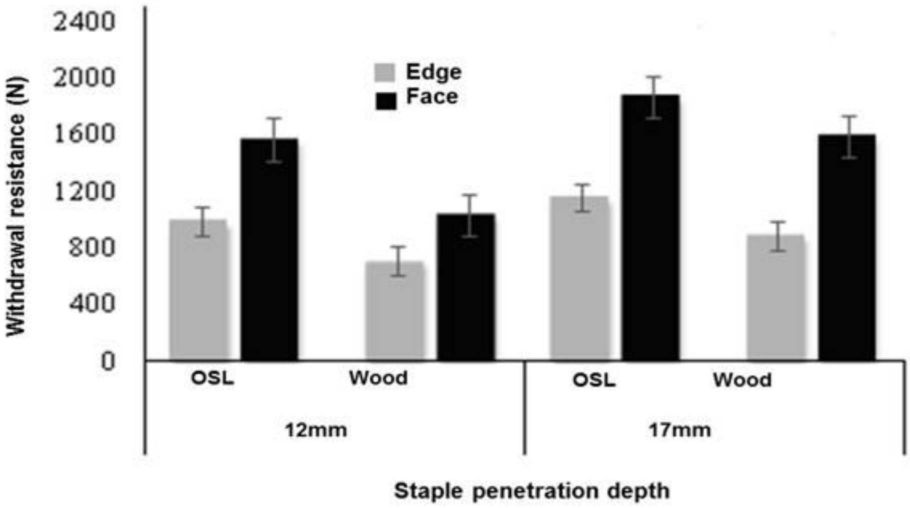

Fig. 2: Effect of staple penetration depth on face and edge withdrawal strength in OSL and poplar solid wood

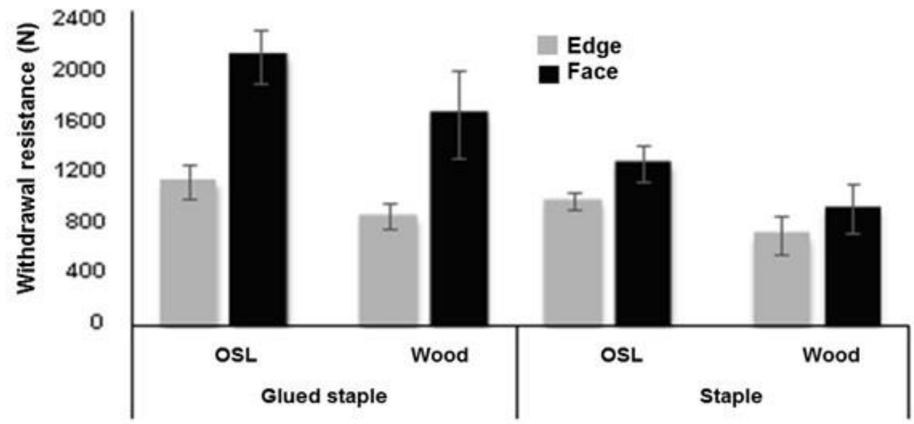

Fig. 3: Effect of glue on staple face and edge withdrawal strength in OSL and poplar solid wood

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Alternative oil-based wood preservatives utilising low-value products from the olive oil industry

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Keywords: olive oil, lampante oil, wood preservative

ABSTRACT

Olive and olive oil culture in the Istrian region of Slovenia has a long established tradition dating back to the 4th Century BC. The “Istrska belica” variety of olives (Istrian white olives) produced in Slovenian Istria have been praised for their ability to withstand low temperatures, high oil content, good taste, high levels of monounsaturated fatty acids, and their high levels of biologically active molecules including biophenols (phenolic compounds), squalene, and tocopherols (STARK AND MADAR 2002). These characteristics may serve another purpose as well: providing protection against degradation in wood products.
Direct use of extra virgin or virgin olive oil as a wood preservative would prove to be an expensive option, however, less valuable products from olive production and the olive milling process also possess favorable characteristics. Much of this material is in the form of agricultural residue (e.g. leaves, branches) after beating and picking the olives or after seasonal olive tree pruning and would require further processing, extraction, and refinement before use. Other options are lower quality oils including olive-pomace oil and lampante virgin olive oil. These oils are typically further refined or used in technical applications (APARICIO AND HARWOOD 2013). However, using olive oil as a wood preservative is still a very limited field of study and the use of plant oils in general has several challenges associated with it.
One of the largest challenges in using plant oils in a wood preservative system is the tendency for the oil to leach from the wood after treatment. This is due to the oil not being bonded to the wood cell wall material, but rather being stored in the cell lumens. Also in this state, there is limited oxygen which slows the drying of the oil, keeping it in a liquid form and subject to exudation.
Based on early successes with chemical modification of lampante oil to be used as a wood preservative and its impregnation into wood specimens (Fig. 1), it is possible to now consider the use of some of these other low quality products in a wood preservative system which will drive down the cost of the treatments as well as provide a value added product to otherwise low value products. This is especially interesting for Slovenia and other countries with strong olive agriculture. These products have the potential to be utilized as a natural source of wood preservatives, particularly as an alternative to other oil-based preservatives currently in use (HUSSAIN ET AL. 2013).

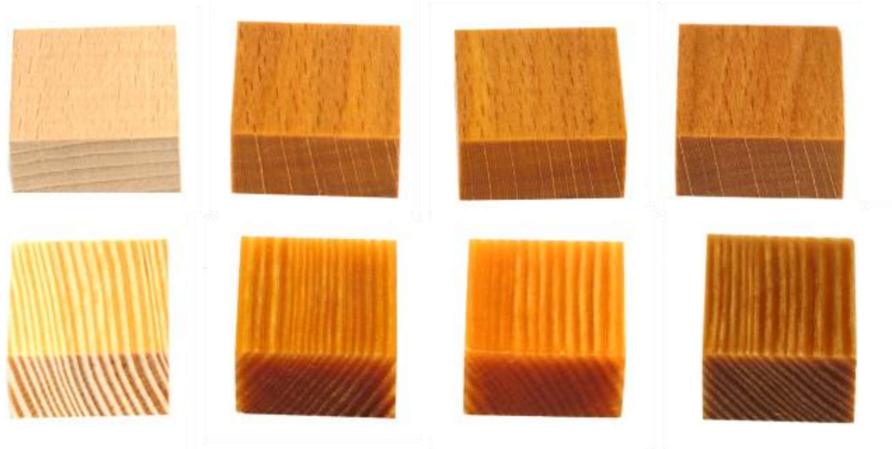

Figure 5. Beech (top row) and pine (bottom row) specimens; Left to right: untreated, un-modified lampante oil, modification 1, modification 2.

This project is an ongoing joint collaboration between the University of Primorska, the BioComposites Centre at Bangor University, the Norwegian Institute for the Bioeconomy (NIBIO), and the Biotechnical Faculty of the University of Ljubljana.
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Innovative use of eucalyptus timber for structural applications in South Africa

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Keywords: Eucalyptus, lumber, green-gluing, finger-jointing, edge-gluing, shear strength

ABSTRACT

South Africa is a timber-scarce country, with a relatively small share of only about 1% of its total land area being used for commercial forestry, and will most probably experience a shortage of structural softwood lumber in the near future. The approximately 1.27 million ha of forest plantations consist mostly of pine (51%) and eucalyptus (40%) (DAFF 2015). Unlike softwood saw log resources, South Africa produces more eucalyptus logs than the local processing industries can consume, and large volumes of eucalyptus chips are exported each year. Eucalyptus timber is rarely processed into structural lumber in South Africa mainly because of processing problems associated with splitting of the wood due to growth stresses, brittle heart, dimensional instability and collapse after seasoning that result in low quality lumber (MALAN AND GERISCHER 1987, KOJIMA ET AL. 2012). If these problems can be overcome, eucalyptus timber, and especially *Eucalyptus grandis*, might be a promising raw material for structural lumber products.

Recent research at Stellenbosch University has focussed on assessing physical and processing properties of eucalyptus and developing new products and processing strategies to increase the application potential of eucalyptus timber in structural applications (e.g. CRAFFORD AND WESSELS 2016, WESSELS AT AL. 2016).

One study evaluated the potential of using young, green finger-jointed *Eucalyptus grandis* lumber for roof truss manufacturing. Some of the inherent problems of using eucalyptus for structural products can potentially be overcome by finger-jointing or laminating the boards while they are still green and unseasoned. The tested material had very good flexural properties in both the green and the dry condition compared to current South African pine lumber resources. The tensile parallel to grain, compression parallel to grain and shear strength were also comparatively good properties for this product. The 5th percentile values of tensile perpendicular to grain and compression perpendicular to grain strength, however, did not conform to SANS requirements for the lowest structural grade (CRAFFORD AND WESSELS 2016). These two properties, together with warp, checking, splitting and shrinkage from a strength related point of view, are of lesser importance in nail plated roof truss structures. Based on the result of this study Biligom® structural timber was developed and is now commercially available on the South African lumber market.

A different study, also employing the principle of green gluing, is investigating the potential of using *Eucalyptus* for laminated board products like cross-laminated timber (CLT). Edge-lamination of sawn boards before drying is considered to possibly inhibit unequal shrinking of the material while losing moisture during the drying stage and thus limit checking, warp and

splitting. The first step was to investigate the significance of processing variables on the quality of edge-wise bonded *Eucalyptus grandis* boards, using a moisture-curing one component PUR adhesive. Shear test results showed that the shear strength for all samples was well over the required 3.5 N/mm^2 (EN 14080). While clamping pressure and adhesive amount had no significant influence on the shear strength a higher moisture content (~60%) and density (>550 kg/m3) yielded better results. Results indicate that a higher moisture content positively influences adhesive penetration and the formation of a strong bond line (Fig. 1). A continuation of this study will compare the warp, splitting and checking in boards from green-glued panels and unglued boards after drying.

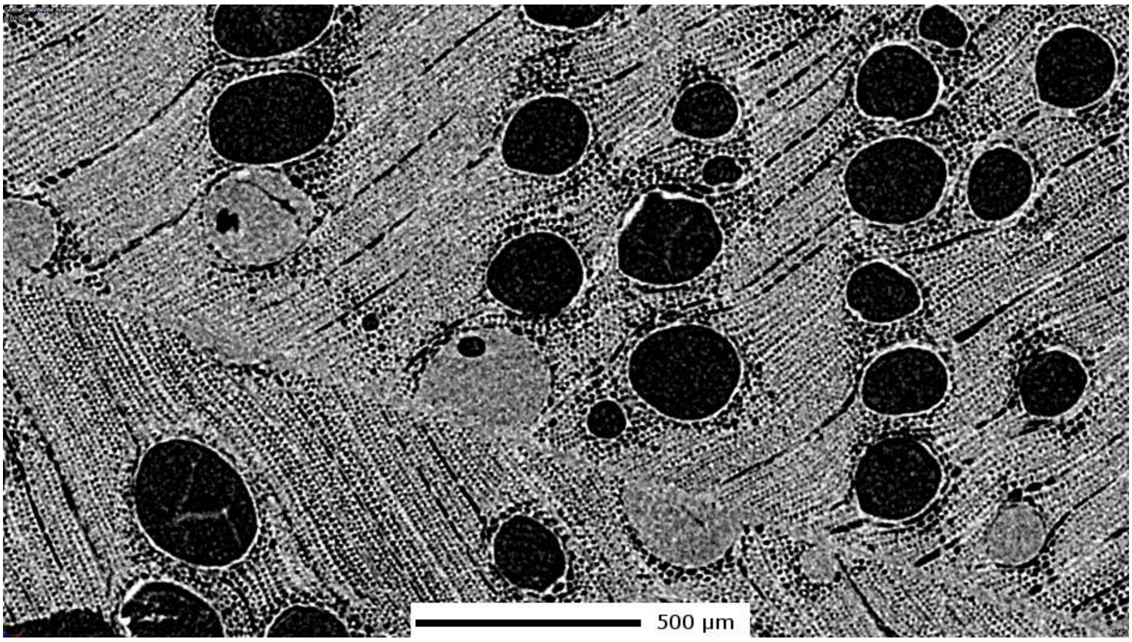

Figure 1: Micrograph of high shear strength bondline of Eucalyptus grandis obtained using X-ray computer tomography

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Future challenges for multi-layer parquet – a Norwegian case study

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Keywords: cup, cracks, indoor climate, multi-layer parquet**,** squeak, wooden flooring

ABSTRACT

Based on 50 customer complaints about wood flooring in domestic and commercial buildings in Norway, the current paper shows that multi-layer parquet installed floating is the prevalent type of wooden flooring in Norway. Issues related to wood moisture content (cup, cracks and gaps) are identified as crucial reasons for customer complaints. These issues are explained by peculiarities of indoor climate in northern countries and modern building practices. The necessity of product enhancement with regard to expected future use conditions of multi-layer parquet in Europe is pointed out.

INTRODUCTION

Today, multi-layer parquet (MLP) has the biggest share in wood floorings in domestic and municipal buildings. This trend is apparent also in the 50 cases of customer complaints handled by the Norwegian Institute of Wood Technology (Treteknisk) during the last three years. Multi-layer parquet was issue of concern in 34 cases. Oak was used in the top layer of the MLP in all but three cases; the most frequent designs of the MLP were 1- and 3-strip (respectively 21 and 11 cases). Lacquer accounted for the coating in 16 of the 34 cases, followed by oil in nine and hardwax-oil in four cases. The MLP was glued down in five cases and installed floating in the majority of cases. Underfloor heating was used in 19 cases. Solid hard- and softwood flooring boards were issue of concern in seven cases, the remaining nine complaints were related to solid wood parquet and end grain flooring.

REASONS FOR COMPLAINTS

The following analysis of reasons for complaints related to MLP is based on those 28 cases that Treteknisk considered justified based on relevant standards and expertise. Cup stands out as the dominant reason for complaint, followed by surface defects, product defects and gaps, installation issues and squeak, and cracks (Fig. 1). Squeak describes a phenomenon were customers experience squeaking sounds of varying extent from their MLP when walking on it. Seasonal variation of squeak is observed quite frequently, a fact that suggests variations of indoor relative humidity as cause for the sounds.

DISCUSSION

A moisture content of 7 ±2 % at production of multi-layer parquet for the European marked is specified in EN 13489 (2003) *Wood Flooring Multi-layer parquet*. This moisture content is assumed as equilibrium moisture content (EMC) at the average European indoor climate. Consequently, manufacturers of MLP specify 30-60 % indoor relative humidity as appropriate for the use of their products. The combination of cold outdoor air during Scandinavian winter and heating of this air to room temperature results in relative humidity as low as 20 %. In modern buildings, however, the overall relative humidity is reduced by moisture removal through balanced ventilation systems in combination with airtight building envelopes and the prevalent use of underfloor heating.

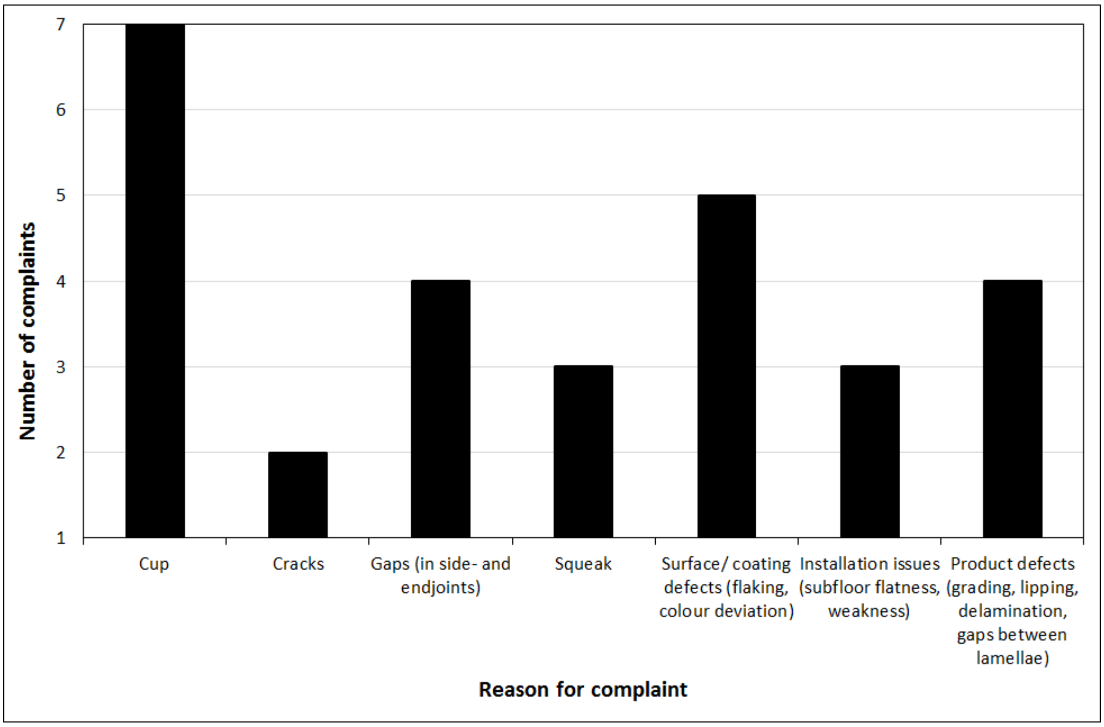

***Figure 1:** Number of justified complaints and their reasons. Each complaint is listed only once.*

Furthermore, improved insulation gives room for increased average indoor temperature, a factor that results in even lower indoor relative humidity and pronounced drying of MLP after installation. Measurements in modern apartments conducted by Treteknisk showed indoor relative humidity as low as 12 % during winter. Even during summer, the time of year with traditionally high indoor relative humidity, readings hardly exceeded 40 % relative humidity. The author considers intensive drying of the MLP after installation due to low indoor relative humidity as major reason for the frequent occurrence of cup, cracks and gaps in MLP in Norway.

CONCLUSIONS

The combination of pronounced temperature difference between in- and outdoor air and modern building practices might be unique for Scandinavian countries like Norway. Efficient building practices, however, are promoted by many national building codes in Europe. Therefore, altered use conditions for MLP throughout Europe can be expected, and the author considers further development of MLP as essential to retain the technical competitiveness of this product. With regard to production of MLP, potential improvements might be thinner top layers, generally lower moisture content at production or coated or lubricated interlocking systems. Optional suitability ratings of MLP based on independent laboratory testing, and applicable markings of approval should be mentioned as an alternative and consumer oriented approach.

Hardwood Technology Road Map in Lower Austria

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Keywords: Technology road map, hardwood, innovation

ABSTRACT

Climate changes and resulting forest restructuring measures, lead to significant changes within the composition of raw material supply. As a result a noticeable increase of hardwood and a decrease of softwood availability can be observed. Although hardwood supply increases, usage stagnates and partially significantly decreases, leading to decreasing raw material prices, especially for mass assortments like oak or beech.

Wood working industry is in a big part specialised in softwood processing. This specialisation entails a strong softwood demand, leading to softwood shortages whereas at the same time hardwood supply increases within the near future. To address an increasing hardwood supply and simultaneously enabling a value-added hardwood usage, novel products as well as technologies need to be evolved. Therefore a Central European Hardwood Centre for Technology, Product development, Innovation and Design shall be developed, including partners of the concerned areas. Wood K plus Tulln will appear as Lead Partner, connecting partners from science and industry within the Technopol Tulln area and Clusters from Lower Austria but also partners from abroad from the surrounding areas.

A so called Technological Road Map for Lower Austria is serving as an initial impulse for a technological planning process, which is carried out in collaboration with experts from industry and science. The Road map functions as a kind of foresight model assuming that the future should be created proactively. As several examples from the past have shown, a Technological Road Map is a proven method to address future industrial challenges (ANONYMOUS 2003, 2005, 2006).

By means of the so called Hardwood Road Map needs concerning research, technology and innovation as well as necessary political measures are revealed, to solve future problems and to show the need for necessary technologies or technology alternatives. Consequently, suggestions for the hardwood value-chain as well as supporting measures, i.e. research, development, education, etc. are derived.

Within the Hardwood Road Map a multi-disciplinary approach is followed, including economical, ecological and technological experts. To ensure a comprehensive view of things onto the whole value-chain, actors as well as stakeholders have to be included. Hence, the holistic strategy considers various aspects along the whole value-chain ranging from the raw-material availability and logistic issues to feasibility studies, technological concepts, product innovations, but also novel concepts like combinations of decentralised and centralised production units.

The whole process can be divided into three main steps:

- Definition of future needs, i.e. market development
- Definition of future requirements of products, services, technologies
- Definition of key technologies and critical research topics

Following these steps the Road Map enables the identification of specific research needs by which structured research priorities can be derived. Thereby a comprehensive picture along the whole value chain develops. Subsequently this picture allows the identification of critical technologies as well as of technology gaps which is the basis for efficient investment decisions (TEISCHINGER AND TIEFENTHALER 2008) additionally allowing bundled efforts of various specialised institutions.
Based on the results of the Road Map further subsequent national and international projects will be developed dealing with specific identified technological aspects.

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Poster Discussion

Analysis of Condensation Products of Poplar Wood during a Drying Process

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Keywords: wood extractives, vacuum drying, FT-IR Spectroscopy

ABSTRACT

The idea of cascading is becoming more and more importance in the industry because of the protection of natural resources, which is a big motor for innovation and research. Also, the consumers in industrialist countries are interested to use sustainable resources for their daily products. Various strategies for exploitation of natural resources (e.g. bio refineries) were discussed in the last years (e.g. BARAKAT et al. 2013).

Many studies are dealing with the quality and quantity analysis of the chemical components in the air and their different condensation processes during the wood seasoning process in conventional kiln chambers (e.g. LAVERY AND MILOTA 2001). Various organic constituents (e.g. solvents, acetic acids and resin acids) were determined in laboratory and industrial wood drying chambers for conifer woods (e.g. spruce, pine and larch) of European tree species.

Based on the different chemical compositions hardwood species were not a focused on this research field. For particular specifications of the woods (e.g. high wood quality or short drying time) a vacuum kiln chamber can be used (cf. RESSEL 1994). Such vacuum chamber is a closed system with defined input and output interfaces. Therefore, the drying emissions (e.g. water and volatile components) can be condensed into a liquid effluent. Then this liquid can be collected easily. McDONALD et al. (1999) show the results from an experimental vacuum kiln chamber for pine wood, where the volatilised wood components together with vapour were condensed and collected. However, in the literature there are not any detailed results about volatile components form hardwood species during the vacuum wood drying process.

Therefore, it is interesting to analyse the condensation from the poplar wood which evaporated in the drying process from a labour size vacuum chamber to obtain the first imagine of possible components of one hardwood species, which is an important tree for the wood and paper industries and also a fast going species in central Europa. The first research part of this study deals with the analysis of quality and quantitative information of the poplar wood extracts.

Three various techniques (Soxhlet extraction, hydrodistillation, vacuum chamber) were used to collect different poplar wood components and compared to each other. The wood extractives from the fresh poplar wood in form of powder were isolated by hydrodistillation for 6 h using a Clevenger apparatus. Furthermore, 5 g of the powder were used to determent the amount of extractives in a hot-water soxhlet excretion. In addition to that five samples of poplar wood were selected and place into the vacuum-drying camber (Binder), where the samples were dried at temperature of 70°C and a pressure of 100-70 mbar for two days. The vapour, which evaporated from the wood in between this time, was then travelling through a cooling system till it turned in to condensation. To analysis the condensation various methods have been

approached for example the Fourier Transform Infrared spectroscopy (FT-IR) and the high-performance liquid chromatography (HPLC).

The first results show that the compositions of extracted products are different depending on the techniques which have been used. This behaviour can also be observed for the amount of wood products in the condensation phase. Furthermore, the results indicated the need of further studies to improve the existent methods for extraction and analysis.

This means for the future there is a new way to utilizing wood resources which would add economic value and provide a sustainable source for other industries for example the chemical industry.

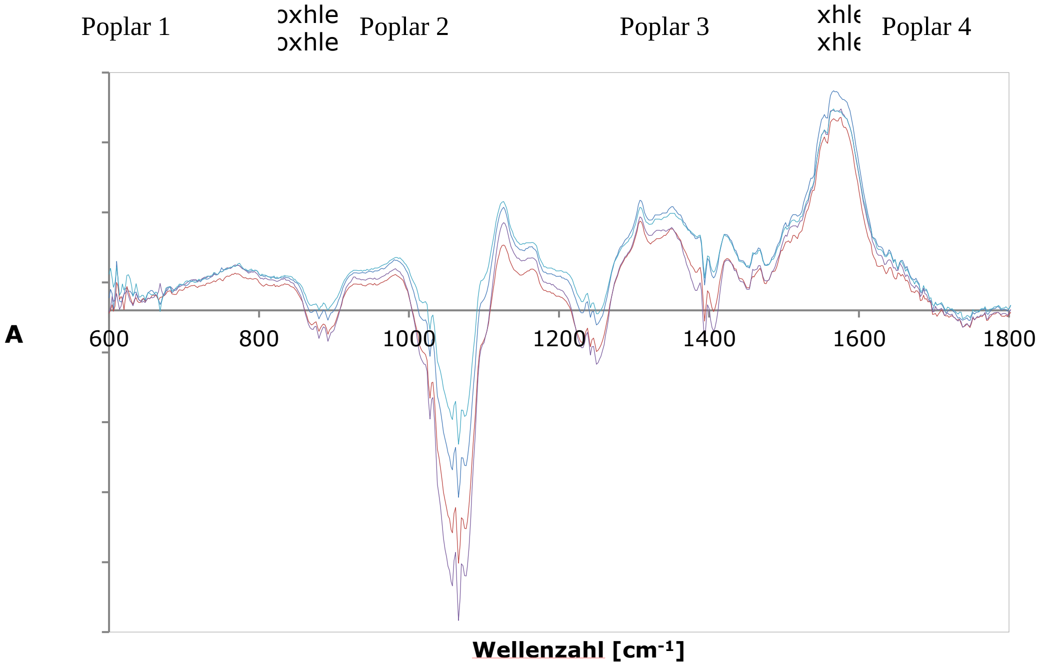

Figure 1: FT-IR differential spectrum of poplar from a Soxhlet extraction

Acknowledgements

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Wood properties of Hungarian cultivated Paulownia wood (*Paulownia tomentosa*)

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Keywords: *Paulownia tomentosa*, physical properties, mechanical properties, density

ABSTRACT

The Paulownia tree (or to its well-known name Chinese empress tree; *Paulownia tomentosa*) is classified among the most variable wood species of the world concerning usability. Its cultivation in Hungary in form of research plantations has just started in the last decade, first of all for the investigation of energetic properties. Due to this the information related to the physical-mechanical properties of the wood was still not determined, from which aspect this study is essential.

Its wide utilization spectrum ranges from industrial applications (furniture and building timber, base material for paper industry, biomass for energy purposes etc.) through apiculture and medical industry (bark, leaf, inflorescence) to decoration function (park tree, base material of exquisite wood-carving). Owing to its machinable timber of decorative texture it is used in Japan as traditional timber, where a high quality log counts as valuable base material. The less valuable base material can be utilized on other areas such as for example chipboard (KALAYCIOGLU 2005), however it is applied as heat and electric insulation material (AFBI 2008) respectively. Its specific weight is 217-274 kg/m^3 (Jun-Qing et al. 1983). It is used in the production of OSB (oriented strand board) panels and veneers (Bergmann 1998), for the production of musical instruments but also for pulping processes (Olson, Carpenter 1985).
Paulownia tomentosa has an expressly light, soft wood, which is proven by the measured density values. The air-dry density received corresponds with the average of the values in the literatures (Kanehira 1933; Senelwaa, Sims 1999; Flynn, Holder 2001; Kalaycioglu 2005; Akyildiz 2010).

Table 1: Values of the measured densities

density	kg/m^3	min.	max.	st. dev.
air dry (u=12%)	300,18	262,33	360,18	26,59
oven-dry	275,46	240,00	328,15	23,52
basic	264,20	224,39	309,09	23,04

From the low density value of the wooden material it is inferred that the different strength values are not high as well. It is proven by the results received, which often have not reached that of the poplars with similarly soft wooden material.

Table 2: Mechanical properties (parallel to the grain; MPa)

Test type		average	min	max	st. dev.
compressive		22,14	19,63	25,24	1,78
tensile		33,23	21,86	52,96	8,90
shearing		7,03	6,08	8,00	0,52
MOR		41,51	28,65	48,65	4,68
MOE		3492,86	2595,13	4142,07	472,61
Brinell hardness	cross	26,74	20,78	31,89	3,22
	tangential	9,13	5,59	13,61	2,16
	radial	9,51	6,53	13,39	2,17
impact bending strength (J/cm^2)		1,59	1,27	1,90	0,17

The wooden material properties of *Paulownia tomentosa* cultivated in Hungary do not show any significant deviation related to the ones cultivated in other parts of the world. Due to its low density and strength values it is not suitable for structural purposes; however it can be a serious competition for broad-leaf tree species, first of all due to its growth characteristics. Based on our investigations its properties can be compared first of all to poplars. The cultivation experiences and the current research related to the physical-mechanical properties of wooden material can establish the more significant extension of the species in the region.

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Heat pressure steaming of selected European hardwoods

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Keywords: heat pressure steaming, wood colour, wood modification,

ABSTRACT

The modification of established wood colours is demanded by industry mainly for aesthetic reasons, to provide a wider pallet of colour combinations for the design of wood products. Wood modification via heat pressure steaming is a very time efficient way to change the colour of wood without additional chemicals like ammonia. Beside the time benefit of only 1/10 (approximately) compared to conventional steaming process, it provides a homogeneous changed colour thru the whole cross-section of the treated wood boards. In this study selected European hardwood species were investigated according to their behaviour under heat pressure steaming. Therefore the process parameter temperature, process time and pressure were varied. The investigation showed, that the different species respond individually on the applied parameters of the modification (Fig. 1). In general, with increasing treatment intensity, the colour change was bigger. However for some species the colour saturation (C*) gets lower when a certain treatment intensity is overrun.

The reason for the individual colour change behaviour for each species is found in the individual composition of wood constituents, especially hemicellulose contend and extractive content.

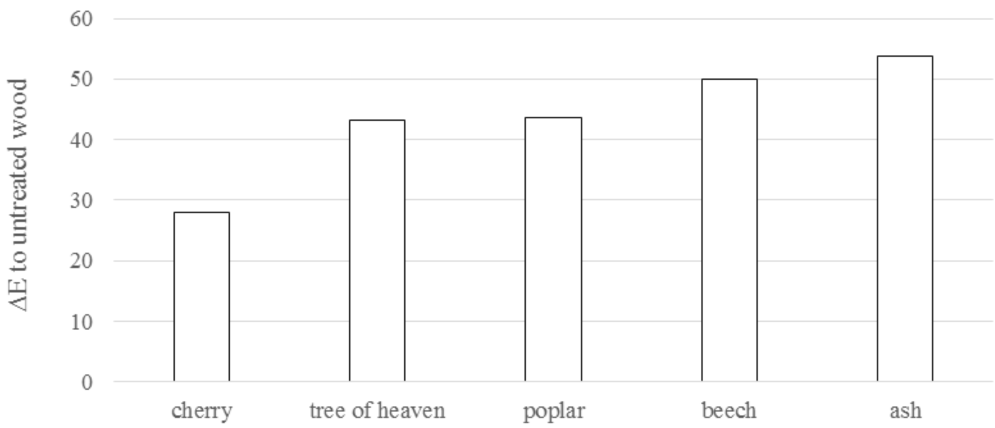

Figure 1: Colour difference ΔE of different Hardwood species after heat pressure steaming at 140°C for 24h compared to untreated wood (CIE Lab colour space)

Breeding of high quality timber producing black locust (*Robinia pseudoacacia* L.) TURBO OBELISK clonal variety group

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Keywords: black locust, clonal variety, breeding, quality timber

ABSTRACT

Black locust *Robinia pseudoacacia* L. is one of the most important tree species of Hungary. Despite the fact that it originates from North-America, Black locust occupies 24% of Hungarian forests. Its stands show a composite picture, as there are numerous low quality, curved, forked trees, which are applicable only as firewood or low-class assortments. There is a massive need for breeding new varieties, clones are especially capable to produce quality wood. The selective breeding process has been started more than 40 years ago at the Forest Research Institute, with the aim producing vegetative propagated clones from shipmast form Black locust tree. These varieties have good stem quality but their growth is slow.

The *Robinia pseudoacacia* TURBO OBELISK variety group has been selected from the *Robinia pseudoacacia* Turbo progeny test stands of the clonal seed orchard.

The breeding process was started in the early 1980s with a multiple-stage selection methodology mainly focusing on rapid growth in the early years, based on the idea of Imre Kapusi. He has selected saplings with excellent growth from the tree nurseries on the Great Hungarian Plain between 1983 and 1988. Afterwards, these selected saplings were planted in experimental forest plantings.

***Figure 1:** From progeny test selected second generation plus tree, situated in Helvécia Variety Testing Station. 27 cm DBH at age 14 years, at age 17 years 32 cm*

Plus trees were assigned to the forest plantings when they were 8-12 years old, primarily for numerically proven better growth and yield compared to the surrounding trees. 125 plus trees were selected and documented in total as the breeder source population. The top 20 plus trees from the performance ranking were involved in the establishment of the Turbo clonal seed orchard, based on two progeny tests.

It became apparent during the progeny tests that there were numerous trees in the experimental areas with excellent stem shape and outstanding volume at the same time. This allowed for these trees to be selected and used as plus trees for high quality wood producing clones.

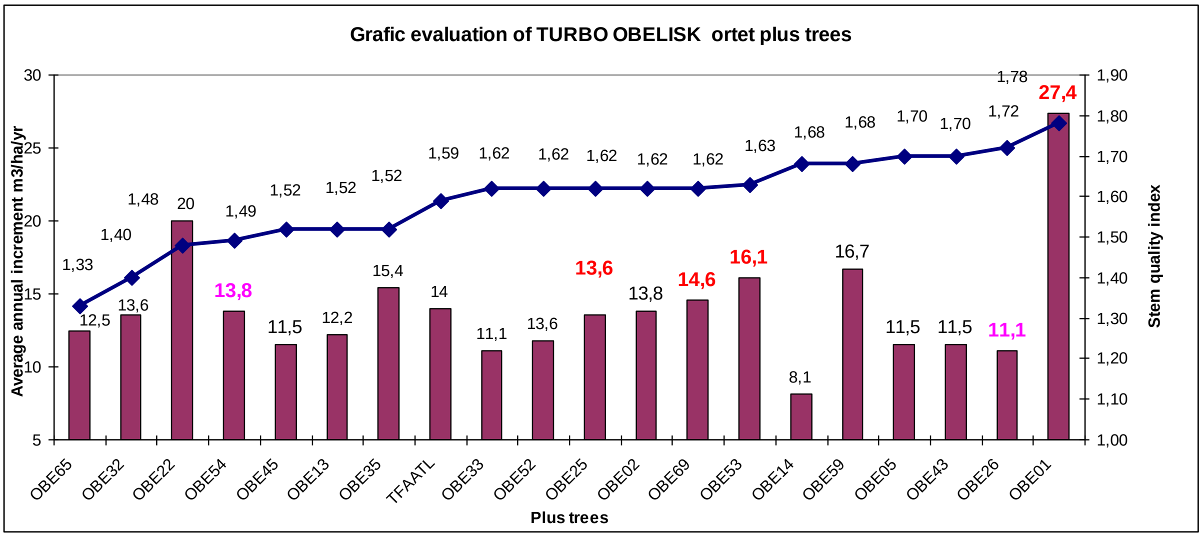

***Figure 2:** Graphical evaluation of TURBO OBELISK variety group's ortet plus trees. Variety candidates marked with coloured numbers.*

70 plus tree candidates were selected for quality wood production via the process described above, which have as good stem shape as shipmast form Black locust but have much better growth. The result of this new breeding methodology is the TURBO OBELISK variety group. The originally selected 70 individuals were reduced to 19 clone candidates after a qualification and clarification process. The individuals of the new variety group were planted in clonal experiments, which are still being researched. Six variety candidates have been reported to NÉBIH.

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Additive manufacturing in wood industry

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Keywords: additive manufacturing, 3D printing, hierarchical structures, lignin based filament

ABSTARCT

The rapidly advancing additive manufacturing (AM) technologies or 3D printing enables the direct conversion of digital data into physical objects. Based on the AM processes, rapid prototyping (RP) have been widely adopted as common practice in product development. In the past few years, advances in material, process, and machine development have enabled AM processes to evolve from the prototyping stage to direct product manufacturing. Knowing the additive manufacturing methods, understanding the advantages and limitations of AM technologies is important for future engineers in developing new engineering systems and identifying emerging opportunities in developing products for mass customization. This presentation introduces the actual developments regarding 3D printing in wood industry from objects realization to lignocellulosic based printing materials. Additional case studies reveal some scientific issues related to 3D printed hierarchical structures and to the printing parameters affecting the printing quality when a newly developed lignin based filament was used.

Compression strength of veneer based sandwich panels

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Keywords: sandwich structures, veneer honeycomb, compression strength, corrugated core, factorial design

ABSTARCT

Sandwich structures, originally developed and used in aerospace industry have found applications in other industry branches such as marine, automotive and sports goods industries. Typical sandwich structures are made of a low density core material bonded with thin, strong skins at top and bottom resulting in very efficient load bearing structures. This paper describes the evaluation processes of physical and mechanical properties of a recently developed veneer based sandwich composite. In the honeycomb-like construction of the product the veneers provide strength and stiffness, sets the final dimensions in thickness while the polyurethane foam has lateral supporting effect. The effect of honeycomb geometry and number of constituent layers on the compressions strength was analyzed by 3-level, 2-factor robust parametric design (3^{II} RPD). Standard test results confirmed the improved compression force resistance; while the cylindrical geometry over performed the sinusoidal shaped core reinforcements. The intended use of the developed composite includes: carrier substrates for counter tops, interior door leaves, indoor heat insulating and acoustic insulation panels, as well as structural insulated panels (SIP).

An effect of a thermal treatment on selected properties of ash wood

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Keywords: high temperature treatment, density, EMC, swelling, ash wood.

ABSTRACT

A thermal modification is a modern way of wood protection. This study focused on changes of selected physical properties of ash wood caused by a thermal treatment. Samples 32x32x120 mm were treated at the temperatures of 160°C, 180°C and 200°C during 3, 6, 9 and 12 hour processes in the oxidized atmosphere and the ambient pressure. We determined wood density, equilibrium moisture content, transverse swelling and speed of sound in wood parallel to the grain. We found out that the density can be 12% lower comparing to untreated wood. In the standard environment the equilibrium moisture content reached minimum 5,2% and swelling in transverse direction 1%, respectively. The optimal treatment (1h at 200°C) was based on the overall performance of the treated wood.

INTRODUCTION

A thermal treatment changes wide range of wood properties. For the exterior wood, shape stability and moisture properties are important ones. LAGANA ET AL. (2014) showed a 40% decrease of equilibrium moisture content (EMS) at the temperature of 200°C comparing to untreated oak wood and a small but significant decrease of EMS even at temperature of 160°C. Similar changes showed several authors (BOONSTRA ET AL. 2007, ZAWADSKI AND RADOMSKI 2013). The low bound water content consequently leads to low swelling (ROMAGNOLI ET AL. 2015). Changes in wood properties are caused by alterations of the chemical structure due to a high temperature treatment. Decomposition of hemicelluloses and polymerisation of cellulose are the most significant (KACIKOVA AND KACIK 2011).

MATERIALS AND METHODS

Clear ash wood (*Fraxinus excelsior,* L.) specimens of size 32x32x120 were assorted and randomly selected in order to homogenize sample groups for different thermal treatments. Before a treatment, the specimens were oven dried, weighted and dimensions were measured. After that they were thermally treated (TT) at the temperature levels of 160°C, 180°C and 200°C during 3, 6, 9 and 12 hours. Each group contains 13 specimens. After the treatment, specimens were cooled down in a desiccator and the density was determined. Consecutive, specimens were conditioned in the standard environment (T=20°C and RH=65%) until they reach EMC. After that, the cross sectional swelling and sound velocity at the EMC were determined.

RESULTS AND DISCUSSION

Density after TT dropped down due to decomposition of extractive substances, hemicelluloses and partially the cellulose (KACIKOVA AND KACIK 2011). Results show that the temperature level has higher effect than the time of the treatment. EMC of untreated ash wood was between 8 – 9%. After TT at the temperature of 200°C during 12 hours, the EMC changed to 5,2%. Similar to the density, the EMC changed more with temperature than with time of the treatment (Fig. 1). Consequently, transverse swelling followed the same path and changed negatively with the temperature level of the treatment down to 1% at EMC. Sound velocity of wood increased up to 3 hours TT at 200°C (Fig. 2). Longer treatments reached values comparable to untreated samples. The highest speed of 4500 m.s^{-1} was measured after 9 h treatment at 160°C and 3h treatment at 180 °C.

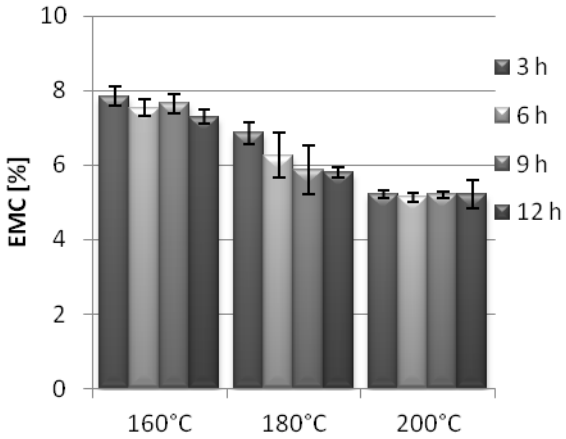

Figure 1: EMC after TT

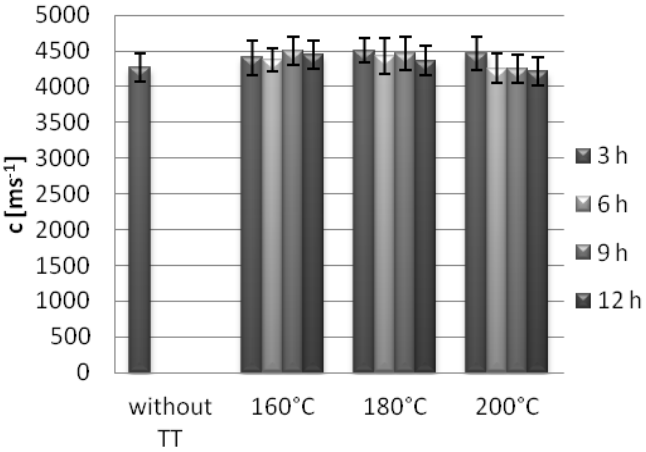

Figure 2: Sound velocity after TT

CONCULSION

From the moisture content and the dimensional stability point of views, the 3-hour thermal treatment at the temperature of 200°C was the most optimal. Nevertheless, one should take into account a slight drop of elastic and strength properties of ash wood.

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Chemical and structural changes of heat treated Turkey oak and hornbeam – Overview and preliminary results

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Keywords: heat treatment, thermal treatment, hornbeam, *Carpinus betulus*, Turkey oak, *Quercus cerris*, chemical and structural changes, Fourier Transform Infrared Spectroscopy

ABSTRACT

The aim of the presented project was to promote exchange of scientists and students between the Institute of Wood Science of the University of West Hungary Sopron and the Department of Wood Biology and Wood Products of Georg-August University of Göttingen during the international cooperation. Research studies have been planned both in Germany, as well as in Hungary. The main objective of the project is the analysis of the structural and chemical changes of xylem of the so-called secondary wood species like Turkey oak (*Quercus cerris* L.) and hornbeam (*Carpinus betulus* L.) by using various thermal modifications. The modifications have been carried out in Göttingen under water vapour pressure (closed system), while the schedules in Sopron have been represented dry processes without additional water vapour and pressure (open system). The researcher in Sopron are responsible for the micro-spectroscopic investigations and the micro-structural changes are exploring in Göttingen. The test material has been provided by the TAEG Ltd. Sopron. Samples for both treatment systems have been cut out from the breast height area of a trunk. In the project have been aimed three different degradation levels of the specimens by reaching 3%, 7-8% and 15% of their average mass losses. The so-called dry-heat treatment as an open system has been carried out in the plant in Sopron using 200°C reaction temperature. The mass loss, after reaching the oven dry conditions of the samples (MC=0%), could be controlled by opening the door of the plant during the modification. The thermal modification processes in Göttingen have been performed in a closed reactor system. Within this project a relative vapour pressure of 90%, and 145-175°C reaction temperatures have been applied. By using an increased vapour pressure similar mass losses could be achieved to dry heat treatments in Sopron despite the significantly lower processing temperatures. Altgen and Militz (2016) have published detailed description of the reactor system, the process flow and the determination of mass loss.

It has been established, that macroscopic were all samples free of visible defects or cracks. According to the SEM analysis in Göttingen the samples were almost free of defects, cracks or visual cell wall changes independent of the modification processes. Cell wall defects have been only found occasionally in the form of small, longitudinal cracks on radial surfaces. These cracks have been often associated with the pits of the cell walls (Fig. 1). These defects appeared independent from the applied modification processes and have been in some cases also in untreated wood samples recognizable.

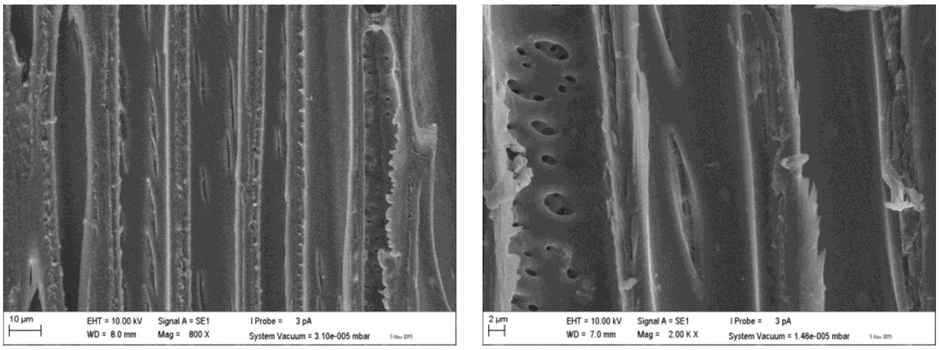

Figure 1: Examples of longitudinal micro cracks on radial cell wall surfaces; left: by open dry system modified hornbeam; right: by closed reactor system modified hornbeam (175°C, 0,79 MPa);

The chemical analyses have been performed by FT / IR-6300 Fourier Transform Infrared Spectrometer with a Jasco DR PRO410-M Accessories in Sopron. DRIFT techniques (diffuse reflection) in the NIR range (wave numbers: 400-4000 cm^{-1}) have been used with two-baseline correction (at 1900-850 cm^{-1} and 3800-1900 cm^{-1}). Qualitative analysis has been based on the difference spectra specified from the spectra of the untreated and treated samples. The difference spectra show that the two applied modification methods have different effects on the IR reflection spectra (Fig. 2).

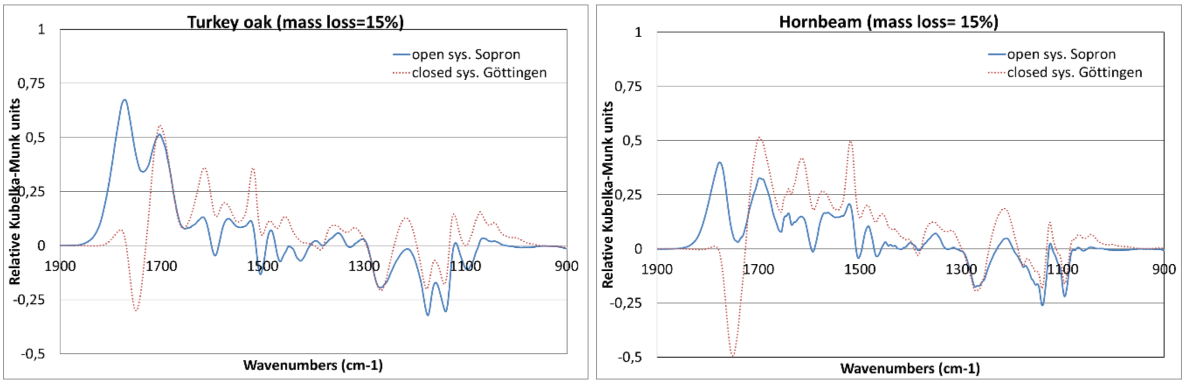

Figure 2: Difference IR spectra (Kubelka –Munk functions) of treated samples with a mass loss of 15%

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Effects of pre-treatment on wood surface properties and performance – Overview and preliminary results

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Keywords: dry heat treatment, ageing, beech, *Fagus sylvatica*, artificial Xenon radiation, average mass loss, surface tension

ABSTRACT

Surface properties of wood are crucial features that influence technological processes and performance of wood and wood products. The objective of the bilateral research has been to address effects of pre-treatment on wood surface properties. Wood surface properties significantly affect wood wetting by liquids (Mantanis, 1997) and adhesion of liquids (adhesives and lacquers) to wood. Thermal treatment significantly changes physical and mechanical properties of wood surface (Sernek, 2008), but ageing of thermally treated surfaces also induces further changes (Gindl, 2004). The thermal treatment creates a specific layer that performs different properties than bulk wood. Description of such layer and the changes occurring during ageing will help in understanding wettability, thus gluability or paintability of the heat treated and aged surfaces and help to improve serviceability of these wood products. For evaluation a ring porous species: beech (*Fagus sylvatica* L.) with relatively homogeneous structure (Molnár, 2006) has been choosen. Samples of 40 mm×40 mm× 22 mm size and a total number of 15, has been subject of 3 different dry thermal treatments and afterwards of artificial Xenon radiation. In order to monitor wettability of the differently heat treated beech samples, contact angle has been measured and surface tension calculated. The dry heat treatment has been performed in the laboratory of the Wood Science Institute, in air, without added water vapour, at normal pressure. Contact angles have been measured in the laboratory of Institute of Wood Products and Technologies, using a PGX Goniometer, taking 20 measurements on each sample type. During the measurements a drop of liquid was placed on the surface of wood sample. It was assumed, that the liquid does not react with the solid. It was emphasized that contrary to ideal smooth surfaces, the drop of water is distorted along the grains, taking a form of a semi oval sphere. The volume of the measuring drop was of 0,5 μl, and the contact angle was automatically detected and measured at 1 sec after the release of the droplet, as previously agreed. As test liquid distilled water was used. Before each measurement the measuring instrument was calibrated. The contact angle was measured as the angle between the outline tangent of the smaller diameter and surface and the surface free energy was automatically calculated by the computer equipped Goniometer (Shuttleworth formula, 1950). Before treatment the average MC of samples has been 11,24%. The maximal reaction temperature has been 200°C, one set of samples has been kept on heat for 1 hour, the second set for 3 hours and the third set for 5 hours. After heat treatments the average mass loss related to the absolutely dry state has been reported being: 0,45; 1,57; and 3,47 %. Artificial ageing has been performed using an Original Hanau Suntest device, equipped with daylight filter, having 0,51 W/m^2 radiation intensity. The total ageing time has been 240 hours, and surface tension measurements have been performed after 1, 3, 5, 8, 10, 20, 30, 60, 94, 173, 240 hours of ageing. Average

surface tension of control samples decreased from 50,3 to around 45,1. Samples thermally treated for 1 hour started with an average surface tension around 46,9 and ended after 240 hours artificial weathering with 44,9. Samples thermally treated for 3 hours started with an average surface tension around 46,9 and ended after 240 hours artificial weathering with 44,5. Samples thermally treated for 5 hours started with an average surface tension around 47,8 and ended after 240 hours artificial weathering with 48,4. In the first 2 cases the decrease used to be systematic, but in case of samples thermally treated for 5 hours the surface tension of samples in the first 60 hours decreased from the original 47,8 to 44, 9 in the first 60 hours of artificial ageing and then a drastic increase showed up. The results show that from point of view of wetting the 5-hour thermal treatment is more favourable, as in this case the surface tension increases, which is considered associated with a better wetting of the surface than in case of lower surface tensions developed. On the other hand, further investigations are in progress in order to elucidate whether this measured increase in surface tension is really associated with a strong adhesion, - or the measured results are due to a dramatic change occurring in the surface topography of samples due to decomposition of the anatomical structure of the wood in the upper layer. Changes has been monitored by IR spectroscopy also, evaluation of data is in progress.

Researchers mobility was financed by the bilateral projects APVV-15-0235 on the Slovakian, and TÉT_12_SK-1-2013-0035 on the Hungarian side.

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The solid wood crushing's conditions

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Keywords: longitudinal compression, wood crushing, wood modification, redheart, moisture content, compressive force, bending

ABSTRACT

For the compression along the grain (also known as wood crushing) a knot-, diseases- and redheart-free, precise sized hardwood is needed, free from cracks and tortuosity, and with high moisture content and minimal fiber slope, cut from a straight grown tree. Two types of compressing faults can occur. The fibre disseverings or cracks that can be seen with unaided eye and the unequable compression rate. The cracks start up usually near the ray cells (Fig. 1Left). Compressing beech wood with redheart leads to a high waste, because the redhearted parts easily goes bad, as seen on the Fig. 1Right. At 73,0% of the beech samples with redheart appeared great fibre disseverings.


Figure 1: Fibre disseverings near the ray cells (Left) and just in the redheart (lower part), while the healthy upper part kept undamaged (Right)

The variability of the compression rate along the sample could be detected by the relative displacement of markings on the sample's surfaces. Unequable compression can be on account of the raw material's low moisture content, the insufficient plastification or the low compressing speed. The low compressing speed can also result fibre dissevering. The higher compressing speed reduces the failures during the process, but in case of cracking, the sample can impair the equipment. It is suggested to use a productive, but safe 9 - 15 $\frac{m}{m \cdot h}$ compressing speed, that allow a better than 90% yield. The relative compressing speed represents at unit time and unit length, what shortening occurs on the workpiece.

Figure 2: Yields and the mistakes during the beech samples crushing in the 1st experiment suite (1,8 - 5,4 $\frac{m}{m \cdot h}$) and in the 2nd experiment suite (12 - 30 $\frac{m}{m \cdot h}$)

During the first experiment suite many samples were too dry and had wood failures (redheart, fiber slope, knot, etc.), while the compressing speed was too low (Fig. 2). At the second experiment suite the moisture content, the wood quality and the equipment's adjustments were already enhanced. One mistake happened: all disabled samples existed redheart. If the redheart free samples considered only, the yield is 100% for 35 samples.
Before the compression procedure the wood has to be plasticized (Ivánovics 2006), so the raw material's moisture content should be at least about the fiber saturation point. During steaming the too low moisture content would increase, the sample would swell and twist, so it might be inadequate for the modification process. By the samples with lower moisture content fibre disseverings happened in many instances. In the beginning of the crushing the initial load was 7,5 - 12,5 $\frac{N}{mm^2}$ and rose coherently to 12,5 - 20,0 $\frac{N}{mm^2}$ till the reaching of the 20% shortening (Fig. 3). The required compressive force is depending mostly on the wood specie, the sample's preferences and the compressing speed.

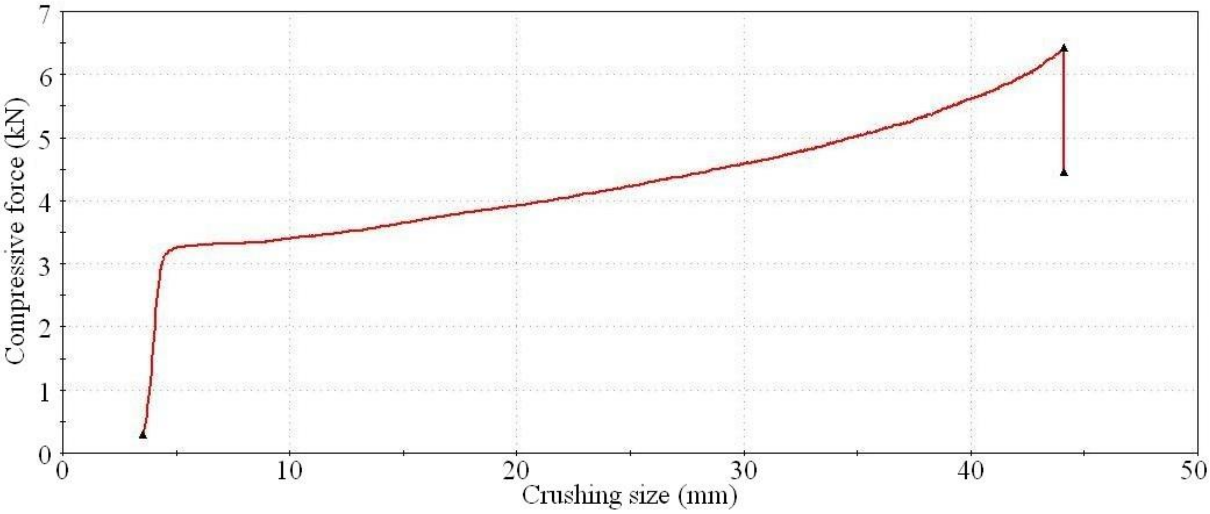

Figure 3: Ideally running y-F graf, made during the compression (Karl 2015)

The bending examinations proved that the data given by solid wood in the literature for the influence of moisture content on the mechanical strength is not valid for longitudinally compressed wood. Due to the compression the bending strength and the modulus of elasticity decrease dramatically, and ensures a high deformability (Ivánovics 2006).

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Liquefied liquid container adhesive for hardwood particle board

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Keywords: liquefaction, medium density fiberboard

ABSTRACT

Our investigation aims to explore the possibilities, for deriving environment friendly adhesives from lignocellulose, waste liquid container. This effort involves for example, the paper liquid container liquefaction process to obtain polymeric materials suited for adhesives. Because paper liquid container makes up the majority of the mixed recycled paper products, that product was focus of this study. Moreover that liquid containerboard can be liquefied easily without byproducts. Liquefaction was investigated by many authors in the last 90 years, but only a few research works was dedicated to adhesive production. Up to now, most of the industrial glue for wood based boards contains formaldehyde, which is unwholesome. It is most essential to understand the adhesive properties of liquefied liquid container and learn how these are fit to standards. Mixed, hammer milled hardwood residues were used for the base of the particle board.

Pinosylvins – potential biorefinery product from wood residues

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Keywords: pinosylvins, bioactive compounds, extraction, isolation, pine wood, residue

ABSTRACT

Plant polyphenols which are considered as health-promoting compounds received a lot of attention in last decade. One of the important group of polyphenols are stilbenes from which resveratrol was the most investigated compound (CHAN 2002, LINDBERG et al. 2004, VÄLIMAA et al. 2007) (Fig. 1). Another interesting compound from stilbenes group which attracted attention is pinosylvin due to its antimicrobial effects against various bacteria and dermatophytic fungi (Fig. 1) (LINDBERG et al. 2004, VÄLIMAA et al. 2007).

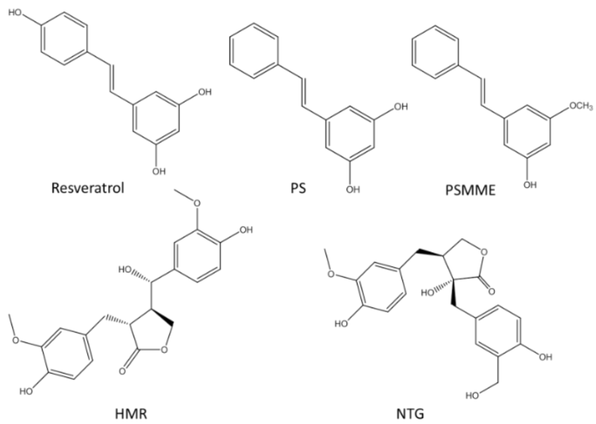

Figure 1: Structures of the stilbenes resveratrol (1), pinosylvin (2), pinosylvin monomethyl ether (3), and two lignans hydroxymatairesinol (4) and nortrachelogenin (5).

Pinus wood, especially knotwood of Pinus species is an abundant source of lignan nortrachelogenin and stilbenes, from which pinosylvin (PS) and pinosylvin monomethyl ether (PSMME) are the most characteristic compounds (Fig. 1) (WILLFÖR et al. 2003a; WILLFÖR et al. 2003b, PIETARINEN et al. 2006). The goal of our research work was to extract and isolate pinosylvin (PS) and pinosylvin monomethylether (PSMME) from pine / spruce wood residues. (KARPPANEN et al., 2007, LINDBERG et al., 2004, PIETARINEN et al., 2006, VÄLIMAA et al., 2007, VENÄLÄINEN et al., 2004). The main task was to isolate pure PS and PSMME with the non-chlorinated solvents.

The approximate content of an industrial sample of pine to spruce was 60/40. First extraction procedure was subsequent extraction by cyclohexane as non-polar solvent and ethanol/water mixture (95:5, v/v) as polar solvent (WILLFÖR at al., 2003a, WILLFÖR at al., 2003b). The second hydrophilic extract was obtained by extraction with water (WILLFÖR at al., 2003a, WILLFÖR at al., 2003b). Extraction was performed by ASE apparatus (Accelerated Solvent Extractor, Dionex Corp.) (WILLFÖR at al., 2006).

In order to achieve good separation of lignin and pinosylvins different TLC solvent systems in different ratios (v/v) were tested. The best results were obtained with the solvent system cyclohexane : ethyl acetate and petrol ether : ethyl acetate. On the TLC plates, the first spot with the highest R_F, is monomethyl ether of pinosylvin, the second is pinosyvin and the last one is nortrachelogenin (NTG). The spot at the start line of the TLC plates represents the two isomers of hydroxymatairesinol (HMR).

From the results of GC-FID analysis of ethanol/water extract of pine and spruce knotwood it can be seen that the main components in the ethanol extract are pinosylvin (7.8 % of total concentration), pinosylvin monomethyl ether (15.1 % of total concentration) and lignans NTG and HMR. On the other hand, the amounts of PS (3.7 % of total concentration) and PSMME (2.7 % of total concentration) are relatively low in water extract.

Flash chromatography (Biotage/Dyax; Flash chromatograph 1L) on normal-phase silica gel columns was used for isolation of pinosylvin, pinosylvin monomethyl ether and NTG. Pinosylvins can be perceived as potential biorefinery product with high added value obtained from wood residues.

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Selected presentations related to the conference „Climate protection through forestry, renewable materials, smart technologies and environmental education”

The future prospects of the forest nurseries in Slovakia in the light of the changing climate.

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Keywords: climate change, forest reproductive material, sapling production

ABSTRACT

Considering the expected climate changes it is very important to find the optimal way to develop forest nurseries. The production of forest reproductive material cannot be influenced by economic indices only, but primarily by biological indices so that the proper quality reproductive material suitable for the plantation of resistant forests must be ensured. The sources of seeds of the high quality forest reproductive materials are not sufficient for this, it is indispensably important to apply the new processing technologies in the storing of the seeds as well as in the growing, subsequent manipulation (nursing, storing and distributing the sapling, applying the appropriate method of planting). All these measures require significant investment in the development of forest nurseries. In order to make the introduction of the new technologies economically viable, a long term and stable concept must be developed and accepted for the plantation and cultivation of the forest, which provides some security for the producers of forest reproductive material. Following this concept it will be possible to find new solutions in forestry by research in the technological development of forest nurseries. Our Association aims to persuade forestry managers to pay more attention to the use of quality forest reproductive materials and to purchase from experienced individuals and companies who produce good quality saplings to renew their forests on the basis of long term cooperation.

Use and transfer of European beech (*Fagus sylvatica* L.) reproductive material: how could provenance trials help us to evaluate tree performance in a changing climate

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Keywords: European beech, provenance trials, climate change, forest reproductive material.

ABSTRACT

Covering approximately 14 million ha, European beech (*Fagus sylvatica* L.) is one of the most abundant tree species in Europe. Climate change will affect beech ecosystems negatively due to well known vulnerability of this species to drought. For that reason, there is widespread concern that adaptive evolution of beech may not proceed sufficiently rapidly to respond to rapid environmental changes. Although many European countries have recommendations and guidelines for selecting provenances based on use of local seed material, climate change is likely to increase the future demand for imported forest reproductive material that will be able to grow in altered environmental and climatic conditions. From this perspective, the selection of appropriate provenances that are better adapted to changing conditions would be of primary importance. Selection for generally adapted provenances based on overall performance and stability across sites might reduce genetic diversity and thereby decrease capacity of species to adapt to ongoing climate changes. Therefore, adopting a mixed-tree provenance approach is likely to be less uncertain than reliance on the planting of tree provenance material from a single geographic area. In other words, introduction of new provenances should be seen as complementing local seed sources, as it might enhance the fitness of local population via gene flow and changes in the genetic composition. Provenance trials provide an excellent basis to assess the potential of various provenances to adjust to different climate conditions and give recommendations regarding usage and transfer of reproductive material in the context of climate change.

The current situation of forest nurseries in the Czech Republic and future prospects

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ABSTRACT

Presentation provides basic information about Czech forestry and forest nurseries. It describes the specifics of a forest nursery in the Czech Republic and mentions the changes that begin to take place.

At the last time in the forests of the Czech Republic appear more and more changes. The weather course greatly influences the situation in the forest. As reactions are coming changes - changes in water management; changes in technology of growing of planting material; changes in composition of tree species; changes in handling planting stock; changes in dates of planting. Changes are already taking place or are planned and presentation discusses possible ways to implement them. Mainly is it: keeping water in the landscape; reduction proportion of Norway spruce at lower altitudes; increasing the proportion of containers plants; increasing care of plants during transport, storage and planting; increasing the ratio of the autumn planting.

From the presentation shows that owners of tree nurseries in the Czech Republic will have to invest more money into the hardware of their nurseries. It is likely that they will reduce the volume of production and will have to try to secure contracts with forest owners to provide planting material.

Information from the presentation used for the participants at the conference in Sopron (9.9.2016) and will be compared with the situation in other European countries.

Adaptability potential of forest reproductive material in Poland based on genetic trials

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ABSTRACT

The knowledge about adaptability of Polish provenances of main forest tree species, in relation to the expected climate change was studied using the provenance trails located throughout the country. In particular, we evaluated response to the transfer of the population tested in a new environment and to express it in so-called. "ecological distances" on the basis of data about their growth and climate conditions (concept introduced by prof. Mátyás). In response to climate and environmental change the species composition towards a higher share of drought tolerant species as well as the promote and use of more drought resistant provenances are considered as supreme actions in forest adaptation in Poland. The forest tree breeding work results can be utilised in the fight against climate change. Not always local origin are the best tests in terms of productivity and quality characteristics. It also happens that the origin considered to be local in the past have been introduced, and their primary origin has been forgotten. Therefore, in planning the composition of the newly regenerated forest may be other origin recommended under the tests results in addition to local. Transfer and appropriate use of FRM is one of the recommended ways to minimize the possible negative effects of climate change.

Stable and well grooving populations of Scots pine are the origin, Rychtal, Wyszków and Supraśl. Scots pine from Bolewice and Karsko grows very well, but only in conditions of western and central Poland. Based on IUFRO 1982 results some populations from France and Hungary verified in tests in Poland may be useful in terms of global warming. Their growth are comparable to or even surpass local origin, but quality characteristics, such as the stem straightness and branching are much worse compared to the Polish origin.

Polish populations of spruce show a high sensitivity to changes in the environment. Along with global warming decreases the productivity of the majority of the tested population. The best origins are Istebna and Zwierzyniec Lubelski characterized by very good growth and high plasticity.

Good growth and adaptability characterized the population of Polish larch and Sudeten larch. For these regions and seed orchard from established from this FRM should first of all get material for future forests. Because larch variability in Poland is caused mainly by genotype, so that the choice FRM should be done primarily at the level of specific tested genotypes.

The results of evaluation FRM in terms of ecological distances for survival and growth trials are not always clear, therefore cannot be directly applied in practice. This may be due to the fact that tests should be conducted in a broad of geographic and environment range, but our studies utilised mainly Polish provenances tested on the trials in Poland.

Adaptive forest, adaptive forest management

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ABSTRACT

What can we do today to prepare for the climate change? We must give greater space to natural selection. In artificial restoration we must establish a higher number of initial saplings by the planting oak. Where the conditions are given, we must apply natural restoration more widely than in the past, which is important not only because it is "natural", but also because it provides far higher numbers of initial saplings than the artificial restoration methods. We also know that we must solve a "small issue" too. The climate change fundamentally modifies the bases of future silviculture in terms of ecology (selection of tree species), growing technology (restoration, cultivation) as well as profitability. For example we must accept that in the contiguous forest steppe block of the Great Hungarian Plain (Alföld) space must be left for broken, open forest types in addition to closed forests. Forest management can only partially prepare for the expected unfavourable effects today, partly due to the lack of the necessary basic researches. However we must make it clear that we, foresters must play an initiative, responsible role in mitigating the yet not completely foreseen effects. We must not believe together with others that nature has solved the problems somehow.

Analysing the effects of climate change on forests we must take the way and extent of human interference into consideration, since we fundamentally influence the "operation" of genetic adaptation factors by our management. We cannot give up wood as a basic material for multiple purposes. We need to use our forests where studying the effects of the climate on the forests we must take a role of managing and controlling the processes. We must not see our forests as reserves because this way we leave them alone in a hostile world which we created.

Control of Forest reproductive material in the Single European Market

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ABSTRACT

When artificial regeneration is performed the selection of the proper provenance is of greatest importance. Forest reproductive material (FRM) of unsuitable provenance leaves the forest owner with high risks and low revenues. Today FRM is transferred across Europe in significant amounts. The existing legal regulations on FRM moved in trade can, however, only provide for an absolute proof of identity at an unproportionally intense level of controlling. The presentation will provide insights into the legal and policy frameworks for the production, marketing and control of FRM in Europe including recent developments and activities for harmonisation with the world-wide applied voluntary OECD Scheme. It will focus on similarities and differences in the implementation of the European Directive 105/199 in different EU Member States. Conclusions arising from it will be discussed, between them the demand for harmonized and more stringent control of FRM at all production and marketing stages and close cooperation between control agencies in different EU-member states.

The rapid development in the field of genetic investigations on forest tree species during the last two decades opened new control possibilities. New traceability systems using genetic methods have been developed in recent years and put into practice in a few countries generally applying private rules. Posibilities and limits for the application of genetic markers for proof of identity within private based certification systems will be presented for some species governed by the European and national regulations on FRM. For such private certification schemes uniform and generally accepted rules are necessary to assure their implementation with acceptable input.

The supplementary control systems do not replace the legal regulations but enforce their applications. Thus they secure a significant contribution to stability and yield of our forests.

Afforestation contra climate change

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ABSTRACT

Assisted migration of trees: what do we know and what we need to know to guide the reproductive materials transfer under climate change?

Climate change is associated with diverse risks. Drought and heat stress are the most important and the most often mentioned ones but not the only ones: changed temperature and precipitation patters may confuse vegetative and reproductive phenology, increase frequency of fires, induce winter desiccation, disturb reproduction etc. Assisted migration, most frequently suggested mitigation measure, currently largely relies on information from provenance trials. Especially large international experiments covering substantial parts of species' ranges in terms of both the number of provenances and the number of experimental sites allow reliable assessment of provenance responses to climatic transfer, which can be considered a proxy for climate change (space-for-time substitution). Nevertheless, identification of regular patterns and geographic trends in these responses serving as the basis for setting the guidelines for FRM transfer may be complicated, given the complexity of risks, and depends for appropriate choice of response traits and climatic predictors. The knowledge of the heritable basis of adaptive variation would be very useful in this respect; however, in spite of the progress of forest tree genomics, the identification of genes responsible for adaptive tratis is at the beginning. Moreover, epigenetics seems to play an important role in response of trees to climate and must be considered in FRM transfer decisions.

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ABSTRACT

Why is climate change an important issue for the Hungarian forest nursery sector? Abstract

Climate change is a business related subject. There are NGOs who kind of make a living from the issue. All professionals know that it is popular to raise this subject, since all public and private stakeholders must speak about it and have to listen to the speakers. However, in most of the cases stakeholders follow up the subject as a theoretical issue and a problem which can be delayed. Our association's aim was clearly not this kind of approach when we decided to organize this conference.

In some professions and businesses –and forestry is strictly one of them- climate change is not only a theoretical issue, which does not affect the day by day work, but it is an absolutely essential issue with several reasons and results.

There are three main corners of the profession of the forest nursery which highlight this case and underline why the Hungarian Forest Nursery Association organized the first central European conference on this matter.

The first reason for this conference, is the origin and genetical background of the Forest Replanting Materials (FRM). Europe wide foresters have to face the outcomes of the climate change in their daily work. This profession is a true „long run investment". Seedlings which are planted this year are to be the stands of the future forests. The question is an open one: what kind of climate will influence the habitat's weather conditions in which the planted seedlings are going to live in 20 years? Our professional mission is to listen to the researchers who try to detect and forecast the answer for this question, and so produce those varieties and seedling sub-species with origins, which will be appropriate for habitats in the future.

Stakeholders both in the public and the private sector must be aware of this question. Pure financial reasons should not drive the long run decisions in the FRMs market. FRMs which will not be able to cope with the future climate of the forests should not be sold and used on the market. Also the authorities have to be able to accept – or should force forest owners to use- FRMs from regions which might be pioneer nowadays but comes from a habitat where the climate is likely the one which will be here in 20-30 years. This means also that regulations must be changed to be able to accept- and promote or even support- the use of „new" geographical origins in FRMs.

The second reason why this issue is highly important for the forest nursery sector is that the producers must be prepared for hectically changing weather during the production seasons. This means that the producers are forced to invest into their business into new technologies which can help them to survive extreme weather conditions which can change day by day (eg.: drastically late frost, extreme heavy rains). Without technical investment our producers will not be able to face the challenges of the future, and their business will be handicapped in the sector

comparing to the international partners. Irrigation system should be developed, cooling houses should be built etc. Due to the present financial situations and market positions, the government should help producers to lift the level of technologies and to modernize their business through grant schemes. Without efficient funding producers are not likely to manage the investment.
The third most important reason, why our profession must take the issue of climate change seriously, is that there should be a strong political and professional will, not only to support the development of the nursery sector but also to drive the direction of it. In some countries there are professional decisions which go beyond short turn political reasons. Political players must come forward with strategic plans which should come into force, and will drive the whole forest sector to a system which will be able to answer the questions of the future. The forestry nurseries are growing the fundament of the future forest stands. Some countries have already made structural changes due to the climate change like turning the bare root FRM production into containered seedling production so they can lengthen the planting season, and also containered seedlings tend to survive the summer with higher proportion comparing to bare root ones. These kinds of changes can turn over the whole of the sector both on producer and end-user side. In order to enable our producers to produce the right products in the future the message from the political professional sector must be clear and direct.

Slavonian oak today and tomorrow

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ABSTRACT

Slavonia is a historical region in eastern Croatia located in the Pannonian Basin, largely bordered by the Danube, Drava and Sava rivers. I present a few historical facts of Croatian forestry.

In Slavonia region, at the forests of "Brodske Pukovnije" military regiments created the first forest regulation in 1755, which stated that only the foresters and the Slavonian "Kraišnik" meaning Border military command can take care of the forests. This Regulation contained many provisions relating the exploitation of the lumber from the forests but later it was banned by Empress Maria Theresa in 1769.

The Slavonian oak – Pedunculate oak (*Quercus robur* L) is one of the most precious types of the nearly 200 varieties of oaks. The Pedunculate oak forest in the mid-18th century covered about 750.000 hectares. Pedunculated oak forests play still a central role in the Croatian forestry today. Pedunculate oak forest covered 201.739 hectares from total standing volume of 415 million m^3 . The biggest forest of Pedunculate oak, called "Spačva" is situated in "Slavonia" eastern Croatia. The forest covers 40 000 ha.

The general data are as follows: annual air temperature 11 ^{0}C, mean altitude is 82 m, annual precipitation about 200 – 600 mm in the vegetation period, but not enough for forest survival.

In the forest of Spačva the alluvial soil is fresh, partly humid, or very humid in some places and flooded by the river Sava and by some of its tributaries. However the hydrological influence of the forest is also significant.

The current measurement and the previous measurement results of groundwater indicate the seriousness of the problems that can affect the long-term loss of oak forest in the area of the "Spačva" basin. Significant changes in the groundwater regime are noticeable back the last two decades, especially after 2000 noticeable decreasing trend in medium (minimum) level of ground water. The emergence of the episode with the absence of filling the ecological profile of the soil (through a series of 3-5 year). The emergence of extremely high groundwater (eg 2005, 2006 and 2014). In Spačva forests there are very old trees, and if in this way they continue to manage the year 2044 22% and in 2050 67% of the forest will be a young forest. So we will have the problem of natural regeneration. I think that great attention should be paid to seed production in clonal seed orchards to assist natural regeneration of forests Pedunculate oak.

Hardwood Research and Utilisation in Europe