WOOD – SCIENCE – ECONOMY
2nd International Scientific Conference

16-17 October 2017, Poznan, Poland

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Proceedings

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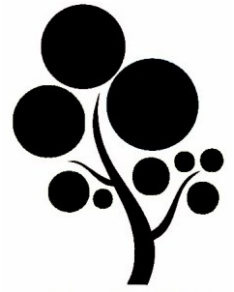
POSTERS

SESSION I

Wood market – economic and social aspects



NEW SOLUTIONS FOR THE FOREST-BASED SECTOR BASED ON SUSTAINABILITY AND DURABILITY IN A SOCIO-ECONOMIC CONTEXT

Joris Van Acker

Ghent University (UGent), Laboratory of Wood Technology (Woodlab), Ghent, Belgium

The forest-based sector is linked to the potential of forest production in both volume and quality. However, there is a growing impact of socio-economic parameters in the trends of today and tomorrow. Europe is in general concerned about the adequate and sustainable supply of resources. Timber, wood, lignocellulosic biomass or whatever name we give the material coming from forestry and related sectors, is an eminent renewable resource with high potential for sustainability and surely an excellent ecosystem service for our modern society. Terminology as cascade use and circular economy are surely not new for the forestry-wood chain, but are getting increased attention now. The balance between wood material use and bioenergy use will inevitably lead to higher competition for the same resource and could evolve into critical shortage in Europe even before 2030. Vertical integration alongside a better tree and wood quality concept should lead to a more structured approach dealing with whether some wood products needs to be prioritized and how we could deal with substitution of man-made (building) materials requiring more energy to be produced. This is clearly another option than direct production of green energy based on growing woody biomass. Hence, it is unrealistic to focus only on one use of wood when considering a sustainable approach for the silvicultural aspects of forests. In the overall circular economy approach, the end of life assessment is surely related to service life and the impact on life cycle aspects. Wood products have been criticized in this respect. Enhanced quality in relation to service life performance and related stimulation of innovation seems to be a better option than just direct energy conversion of harvested lignocellulosic biomass. Solutions can be found in innovative processing of trees into engineered wood products, the optimal quality use and performance enhancement through modification and finally by flexible integration using a multi-purpose approach of the forestry wood chain.

Keywords: *resources, material use, bioenergy, embodied energy, service life, innovation*

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CHALLENGES OF THE INTERNATIONAL FOREST PRODUCT MARKETS – THE EU PERSPECTIVE

Ewa Ratajczak

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Member States of the European Union are an important creator of the global market in wood and wood products. In 2015 forest area in those countries amounted to 4% of global forest area, but raw wood material removals exceeded 12% of global raw wood material harvest. That 12% was processed into 23% of globally produced sawnwood, 15% of wood-based panels, 20% of wood pulp, and 23% of paper and paperboard. The EU countries are also a baron of furniture production (23% of global production).

Although the EU hasn't got a uniform forestry policy, the European forest-based sector is subject to all important EU policies (concerning i.e. the climate change, power industry, sustainable consumption and production, resource effectiveness, ecology), which determine the lines of its development. All European countries face the same grand challenges which are: the climate change, the priority of life quality, demographic changes, growing and diverse social needs, limited resources of both raw materials and energy carriers, as well as: globalisation (and strong competition), knowledge-based economy, and the paradigm of sustainable development. This breeds specific tasks for economic and social sciences, of which the major is to achieve the balance of the system: environment-economy-society. It is important for the forest-based sector that this system is considered in terms of the whole wood chain.

Main trends observed in the European forest-based sector and international forest product markets include: the offer of products and services adequate to changing social needs (tailor-made products, mass customization), wood mobilization (search for additional/new raw material sources and enhancement of the effectiveness of use of wood biomass resources), continuous technical progress (innovation in newness, quality, efficiency and economy), as well as ecology and certification.

Megatrends and challenges of the European wood product market pose a series of questions for science and business that require investigation, analyses and solutions to the identified issues. Major questions are the following: is there any limit of innovativeness of wood products (due to the features of wood as a natural raw material); is innovation good for every market player; who is able to bear the cost of green investment and green final products; does new technologies and automation always mean fewer jobs; is certification of forest products an additional cost of production or attractive business; are countries with low production cost a real threat for the EU market?

On the microeconomic level, i.e. from the perspective of EU producers of wood and wood products, coping with competitors is a significant challenge in the short- and long-term, where competition means the rivalry between: countries with high production cost and the new competitors from "cheap" countries (Eastern Europe, Russia, China); wood and non-wood materials; new innovative wood products and traditional wood products; wood-based panel industry and green energy sector (for wood raw material). In this case major questions concern an effective way of benefitting from the positive characteristics of wood which give it a competitive advantage and the possibilities of declaring wood products a smart specialisation in the EU Member States.

Keywords: *EU, forest product markets, challenges, competition*

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SUPPLY AND DEMAND FUNCTIONS FOR THE GLOBAL WOOD MARKETS: SPECIFICATION AND PLAUSIBILITY TESTING OF ECONOMETRIC MODELS WITHIN THE GLOBAL FOREST SECTOR

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Forests cover about one-third of the land surface on earth. Actually, less than 7.5% of this forest area is defined as planted forest. The development of planted forest was dynamic in the last decades. Its area increased about 64% since 1990, whereas global forest area decreased about 3%. In the same time the production of wood increased about 37% and planted forests show responsible for about 45% of the global industrial roundwood production. It is therefore of great importance how production of roundwood from planted forests will further develop and how this might impact the supply from natural forest and wood markets in general.

The objective of this study was to determine the interdependencies of global wood markets and wood removals from different types of forest, like planted or natural. For this purpose we use an econometric approach to analyze in which way global markets affect the amount of wood supply, demand and trade. The supply side of roundwood markets was separated into removals which came from planted or from natural forests and the demand side into non-coniferous or coniferous wood. Nevertheless, estimations of supply functions were undertaken for each of the eight wood removal products ranging from fuelwood to industrial roundwood with the origin planted forests. Demand functions were estimated for 14 manufactured products ranging from non-coniferous sawnwood to paper and paperboard. The econometric models were estimated with panel data from 180 countries for 1992-2014. Ordinary least squares, fixed effects and random effects approaches were used for estimations.

As result in supply only planted forest removals response significantly positive on changes in price. The supply in all other products seems to be nearly inelastic. In demand every product shows significantly negative response on price changes.

For the plausibility of estimations testing, we implemented the obtained elasticities in an economic partial equilibrium model. For the matter of validation, we run the model 21 times, each for one starting year in a time horizon between 1992 and 2012. Each scenario simulates nine periods with a length of one year. Then the model results were compared with historical data. The results suggest that the nearly inelastic wood supply improves model simulations as these were closer to historical data. Now, the modified model will be used for possible future developments of the area natural and planted.

Keywords: *econometrics, planted forests, demand, supply, forest sector modelling, forest products*

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LANDUSE AND SOCIO-ECONOMIC TRENDS IN THE AREAS SURROUNDING THE CONCESSIONS OF AFRICAN PLANTATION FOR SUSTAINABLE DEVELOPMENT (APSD) GHANA LTD IN BRONG AHAFO REGION OF GHANA

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Forest plantation is reckoned to accounts for 7% of total global forest cover, and has the potential to provide 75% of the global industrial round wood supply. The study developed a detailed forest resource and infrastructural map, analyzed forest resource use trend, mapped out areas of high biodiversity conservation, and made recommendations to promote and sustain large scale plantation development against the background of anthropogenic pressure on vulnerable ecosystems and biodiversity management. The methodology adopted for the study involved the application of GIS and remote sensing techniques, field survey and community interactions. Major findings of the assessment include: Substantial landuse/landcover conversion from one category to another within the last twenty (20) years as a result of agricultural expansion, urbanization, charcoal production and woodfuel harvesting; Dense woodland and riverine forest experienced decline over the 20 year period whiles agriculture open woodland/grassland and settlement appreciated; Floral diversity was high in the dense woodlands with low regeneration potential due to persistent annual wildfires; Significant socio-economic and environmental impacts resulting in the following; conversion of woodlands, removal of riverine vegetation leading to drying out of streams; Charcoal production and shifting cultivation leading to decrease in soil productivity and poor crop yields which promotes poverty amongst the inhabitants.

This study was undertaken to increase understanding, awareness and appreciation of the diverse values of forest resources on the part of APSD and other stakeholders, to influence policy formulation and behavioral change required to conserve, develop and sustainably manage the forest resources within APSD Concession and areas surrounding the concession.

Keywords: *landuse, remote sensing, socio-economic trends, anthropogenic pressure*

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THE COMPETITIVENESS OF POLISH FURNITURE EXPORT

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Although 'manufacturing of furniture' is one of the leading branches in Polish export, many producers base their foreign expansion on supplying relatively cheap goods to large international partners, who sell them further under their own brands. There are also enterprises (usually SMEs) which rather than exporting directly, prefer to connect indirectly to global markets by supplying intermediates to other firms that export.

The aim of our research is to examine the competitiveness of Polish export of furniture using data on value added in export. With the use of OECD/Eurostat TEC and TiVA Databases we assess the propensity and intensity of exporting by Polish furniture producers with different firm's characteristics. Then, we present the domestic and foreign contribution to gross export and analyse the participation of Polish furniture industry in global value chains.

Our analysis covers years 2002-2011 and includes international comparisons with other CEE countries (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Romania, Slovakia, Slovenia) and leading European exporters of furniture: Italy and Germany. The results indicate that the patterns of gross trade in furniture differ from value added trade patterns and Polish furniture export is not as competitive in value added terms as in gross terms. Furthermore, the share of foreign value added in gross export increases as does the share of intermediate products' export in gross export. The above indicates, that the countries' participation in GVCs has increased in years 2002-2011. This may generate both opportunities and risks, which we discuss in the paper.

Keywords: *manufacturing of furniture, export competitiveness, trade in value added, global value chains*

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MARKETING AS A KEY FACTOR IN THE EXPORT OF KOSOVO WOOD PRODUCTS IN EUROPE

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The wood processing industry is an attractive, yet highly competitive industry mainly due to the increase in construction activities across the world and due to the rapid technological developments in this industry. Kosovo is one of the South-Eastern European countries with solid economic growth in the past decade. The wood processing industry has become one of the most attractive industries which contributed enormously to the growth of GDP in Kosovo. Moreover, the wood processing industry remains a sector with highly promising economic potential for Kosovo. As a relatively small country with only 10870 km^2, approximately 44% of its total area is covered by forests which counts up to 481 000 ha. Out of this total forest area, 38% its covered is privately owned, whereas 62% is state owned. The major portion of the forest area is dominated by hardwoods (90%), where-as only 10% of the total forest area is covered by softwoods.

To date, Kosovo passed thorough three important phases of economic development: the first phase was the emergency one after the war, the second phase was privatization of social enterprises and the third phase was the phase of sustainable development. The period after the war was very important for this sector because it has passed thorough the reconstruction process, privatization and development and became part of the domestic and international markets. Consequently, many domestic companies from other sectors, as well as foreign companies, have decided to penetrate into the wood processing industry in Kosovo and invest in resource-efficient processes and state-of the-art technologies.

Wood products manufactured in Kosovo are mainly from solid wood; however, the new technology enabled the use of other materials from wood such as MDF and chipboards. The major part of solid wood is used from the domestic market and just a small part is imported, whereas the MDF and chipboards are solely imported. The Kosovo wood processing products are becoming relevant and competitive also the in European market. Wood processing companies in Kosovo are developing customer-oriented product, with high technology innovations. The future of Kosovo's wood pro-cessing sector is being in step with new Western European approaches using state-of-the-art technologies and products that meet the customers' needs. Key factors for achieving success are the ability to anticipate changes in consumer needs and to quickly apply adaptations to them. For this reason, marketing is considered to be one of the key factors in increasing the exports of Kosovo's wood products in European markets. The aim of this study is to investigate the role of Marketing in wood processing industry in Kosovo as well as its effect in exporting wood products in European market.

Keywords: *Kosovo, wood processing industry, wood products, marketing*

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BUSINESS-ACADEMIA COLLABORATION AS EXEMPLIFIED BY THE TRANSFER OF INNOVATIVE WOOD TECHNOLOGY FROM WARSAW UNIVERSITY OF LIFE SCIENCES TO THE SME'S SECTOR

Marek Grześkiewicz[1]*, Agnieszka Laskowska[1], Michał Borowy[1], Tadeusz Nadolski[2]

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New wood technologies in Poland have become one of the leading national intelligent specializations. However most Polish small and medium enterprises (SME's) based on wood do not effort to provide their own R&D departments. This entities need to be able to compete in an environment of the knowledge based economy (KPE) by collaboration with academia and research centre. It is also a big chance for scientists to fulfil this economic gap.

On the one hand, the main purpose of this paper is to disseminate the innovative solution and research regarding thermo-mechanical wood compression to increase its hardness and, on the other hand, to show the effective path of this technology transfer from Warsaw University of Life Sciences to economic sector. The described invention was patented in 2014. Nowadays his method has been implemented by 4 business entities and it is still being developed in a big interdisciplinary scientific project financed from public funds.

Research part of paper presents information regarding thermo-mechanically oak wood veneers and solid wood densification in industrial conditions using high pressure press, selected mechanical and physical properties of this material such as Modulus of Elasticity (MOE), Modulus of Rupture (MOR), hardness, density profile, (Equilibrium Moisture Content) EMC and water vapour sorption. Above properties were determined according to PN-EN standards or own procedure. As a consequence for oak wood compression increase of MOE, MOR and hardness were observed. Water vapour sorption of densified wood was lower than for control wood. The densified wood samples had the same density in cross section. Densified wood in the case of densified veneers (initial thickness 4.5 mm) could be used as a top material for floor material and to cover solid wood panels for furniture to increase their hardness and scratch resistance.

Investigations financed in BIOSTRATEG2/298241/10/NCBR/2016 project "Intelligent systems for breeding and cultivation of wheat, maize and poplar for optimized biomass production, biofuels and modified wood" by National Centre of Research and Development.

Keywords: *wood innovative technologies, transfer technology, UtoB cooperation, properties of densified oak wood*

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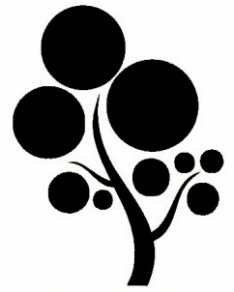
SESSION II

Challenges in forestry



FOREST SECTOR IN EASTERN EUROPE: DEVELOPMENT AND PERSPECTIVES

Orest Kiyko

Ukrainian National Forestry University, Lviv, Ukraine

It is possible to unite some branches which have deal with forest into forest sector, which we can consider as a very important sector because it offers a simple way to reduce the CO_2 emissions that are the main cause of Climate Change. The forest-based industries play very important role as they could develop an even stronger impact on regional production, employment and value adding on the basis of regional natural resources. The paper presents results of research performed for forest sectors of Eastern Europe. In the process of the researching the main economic parameters of the forest sectors, status and trends in employment, trends in reference to workforce development in forest sectors of Eastern Europe, the forest resources of the forest sectors, the contribution of these forest sectors to national GDP were determined and analyzed. The negative trends in forest sectors of Eastern Europe were identified: considerable decrease in the number of employees; aging of working staff; low salary; low safety of work; low attractiveness of job position within the framework of forest sectors, illegal logging, shadow manufacturing; mismanagement in forest sectors; insufficient communication with civil society and some others. In order to improve situation in regard to workforce development in forest sectors of Eastern Europe some actions and measures that will improve existing situation were suggested. An activity plan in this case can include the following steps: 1) Creating some organizational institution for forest sector, for instance, a public council of forest sector; 2) It is necessary to include in this public council representatives from all sub-industries that deal with such important resource as “forest”; 3) “Think tank” creation within the framework of the national forest sector for representing main ideas at the decision making levels; 4) Elaboration of national supporting and communicational program with determined amount of funding for intensive advance in two directions mentioned above; 5) Devising and implementation of some methods for monitoring of overall situation in the forest sectors and new tools and measures implementation.

Keywords: *forest sector; social aspects; main challenges and opportunities; sustainable development*

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FORESTRY INNOVATION: CHOOSING THE PATH OF DEVELOPMENT

Piotr Paschalis-Jakubowicz

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The present century brings dynamic changes in the surface and structure of forests around the world, raising the question of whether management methods and the real understanding of the importance and role of forests can be address by existing methods? So, must forestry be innovative?

The answer to these questions is the results of analyses relating to the consequences of changes in forest management caused by the increasing influence of selected factors: economic growth and demographic change, dependence on agriculture, income and well-being, aspirations and growing public interest in the state of the environment and changes. In the use of land and the evolution of forest policy.

21st-century forestry has begun the process of confirming that progress in any field of science and scientific activity is possible if we consciously and deliberately apply new research methods and innovative research procedures. The author presents selected directions of creative development in forestry, referring to bio-economy, degradation and potential of forest resources, space exploration, rapid tree plantation and the consequences of forest and carbon dioxide interaction. The selected scenarios for forest and forestry development are also present.

This paper also refers to the inconsistencies in the assessments and analyses of the future of forests and forestry in the world, found both in the literature of the subject and discussed during political negotiations.

Keywords: *forestry development, innovation, research procedures*

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ON HOW INNOVATIVE TIMBER PRODUCTION FOSTERS SUSTAINABLE DEVELOPMENT – A LOCAL CASE STUDY

Francesco Carbone

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In the "Castelli Romani" district most of the forest area is covered by chestnut coppice for timber production. Evidence of the long tradition in chestnut timber processing can be found in many historical buildings in Rome that were built using local chestnut products.

In recognition of the social value of this district, landscape and hydrological constraints are in place. Part of this area is also included in the "Castelli Romani" Regional Protected Area and also three small sites come under the Ecological European Network Natura 2000 protection program.

The current negative worldwide economic trend has had an impact on the local chestnut timber sector, which is the most important economic activity in the area. Private and public chestnut owners, local cutting companies and chestnut timber working industries have all registered negative effects.

Negative social and economic trends have led to cooperation between local institutions, entrepreneurs, NGOs and the University of Viterbo in order to find a feasible exit strategy for the sector. Informal governance process discussions have touched upon many aspects of timber production and forest and environmental policy.

The Lazio Region Rural Development Program 2007-2013 provided an opportunity to support a proposal for innovative timber production. Funds were obtained for these two main goals: qualification of chestnut roundwood and a prototype of chestnut glue lam. However, the project also involved other related issues, such as: i) improvement of local forest management; ii) promotion of forest planning and forest certification; iii) improvement of regional forest rules; iv) training for cutting company workers; v) updating timber working industry technology.

The University cooperated in defining local forest policy, taking into account the above mentioned issues. This process also analyzed coherence between local policy and related forest and environmental policies, proposed at European and International levels to contrast global regressive trends.

The aim of this study is twofold: a) to verify if timber innovation could be reconciled with local forest policy, related forest and environmental policies; b) to identify the necessary strategies in order to obtain the expected results.

Dedicated matrixes were submitted to local actors and forest experts. Their evaluations have been collected and elaborated using econometric approach.

Results show that innovative timber production could be an interesting tools for fostering local sustainable development, only if local institution, local stakeholders act for introducing changing in the current forest management and adopted policy tools that has been promoted ad international scale.

However, an improvement in the local forest governance is the most relevant innovation. This means that all forest actors should be operated according to a common strategy and commitment of each should be included in a dedicated agreement for the "Castelli Romani" forest area.

Keywords: *timber innovation; forest policy; forest-related policies; interviews*

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ASSESSMENT OF RECLAMATION TO FOREST PROFITABILITY BASED ON THE ANALYSIS OF WOOD HARVEST VOLUME FROM INTERMEDIATE CUTTING AS EXEMPLIFIED BY THE DUMPING GROUND OF THE SULPHUR OPEN-PIT MINE "PIASECZNO" (TARNOBRZEG REGION)

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The purpose of this study was to assess the effectiveness of forest reclamation of post-mining lands, based on the volume of intermediate harvesting, on the example of a wooded spoil heap of the Piaseczno sulphur mine located in the Vistula valley (N 50 33.622; E 21 34.185), southern Poland (the Tarnobrzeg area), handed over to the Staszów Forest administration district (Regional Directorate of State Forests in Radom). Presented in this study, production capacity of stands in the reclaimed spoil heap area analysis weremade on the basis of available documentation kept by State Forests Administration, including forest management maps and forest stand maps, Forest Management Plans for the Staszów Forest District covering the years 1992-2001, 2002-2011 and 2012-2021, SILP database, as well as the costs of wood harvested in the Staszów Forest District in 2006-2016. To determine the value of wood harvested in 2006-2016 and the profitability of reclamation, the analysis of black locust wood prices in force in the Staszów Forest District in 2016-2017 was made, and then the price of one cubic meter of black locust wood was determined on the basis of the average price of wood sale calculated on the basis of an average price of wood obtained by forest districts in the first three quarters of a given year according to GUS (Central Statistical Office of Poland). The analysis of intermediate harvesting showed that in the case of introducing black locust to habitats being created in degraded post-mining areas, their production capabilities are promising. At the current stage of stand development, black locust (*Robinia pseudoacacia* L.) has played a significant role in harvesting and achieving good economic effect. This species is characterized by good growth and high volume increments and groups of obtained assortments, thus, it can be concluded that it will become one of the most important species enabling the increase in profitability of the analysed spoil heap reclamation. High prices of black locust wood prove that black locust provides for better economic calculation related to reclamation. Therefore, whenever possible, this species should come back to the plans of afforestation of post-industrial areas, in particular in the case of planning which is alternative to forest planning, i.e. stocking-plantation reclamation or in the case of fill-in plantings on escarpments and spoil heap and excavation ledges.

Keywords: *landfill sites, afforestation, effects of reclamation, black locust, biomass*

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ANALYSIS AND MODELING OF TIMBER STORAGE ACCUMULATION AFTER SEVERE STORM EVENTS IN GERMANY

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Storm events are accompanied by variable amounts of fallen timber, depending on their severity. As a consequence of severe storm events timber supply increases and market reactions in terms of progressive timber price decreases can arise. To minimize revenue losses, forest companies take pressure off the market by storing surplus timber quantities, expecting timber prices to recover over time. In this study, we explore the determinants of forest companies' timber storage accumulation after severe storm events. This study is not only relevant in the context of the economic assessment of storm related consequences for forest companies. Furthermore the quantitative analysis of timber storage accumulation is beneficial for generating most accurate data for forest related accounting schemes.

The explanatory power of variables reflecting economic, institutional and tree species-related factors is tested via econometric analyses. The Forest Accountancy Data Network is used as database for the analysis of the storm events "Lothar" and "Kyrill" in Germany. Timber storage accumulation is assessed conducting a weighted multiple regression analysis based on damage quantity and timber price alterations as well as additional categorical variables. In addition the moderating effect of timber price alterations on timber storage accumulation is tested employing a hierarchical moderated regression analysis.

The results show a principal linear correlation between damage intensity and storage accumulation. The test of the categorical variables on storage accumulation shows significant differences within the variables (1) storm event (2) tree species group, (3) ownership category and (4) areal size class. Regarding the moderating effect of price alterations, empirical results provide general support for our assumption that timber storage accumulation is inversely related to price alterations. The implications regarding a future integration of timber storage accumulation in forest related accounting schemes are twofold. First we want to stress that due to a row of uncertainties, such as the small number of analyzable storm events, a general validity of our model cannot be assured. Second we want to emphasize that revealed variable expressions in terms of timber storage coefficients should be taken into consideration in respect with future timber storage estimations.

Keywords: *fallen timber, storage, forest companies, wind storms, moderation analysis*

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INTENSIFYING THE MANAGEMENT OF PROTECTION FORESTS IN THE ALPS

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In the Alps, forests are generally multifunctional, and they are classed according to their primary role as production, protection or recreation forests. The dominance of one of these roles does not exclude all the others, although it shapes management that must reflect the primary role of each forest. That is also the case of protection forests, which must also be managed for their secondary production and recreation roles. What is more, management is a vital requirement because it supports forest health, and therefore periodic harvesting remains a necessity. However, the physical conditions that characterize a protection forest (e.g. extremely steep terrain, sensitive soil, remote location etc.) and the prescriptions of a specifically designed silviculture tend to constrain harvesting and make it especially difficult. Special harvesting equipment, and novel approaches to harvesting are required in order to achieve environmental, social and financial sustainability. This study reports about cable yarding in a protection forest, under conditions that are representative of the challenges encountered when negotiating this forest type. Productivity of the yarding operation was 15, 14 min/m^3 SMH underbark for the yarding distance of 120 m, an average load of 0,89 m^3 and lateral distance of 20 m. Of the remaining trees, 27.1% were damaged during forest operations due to felling, log contact or falling rocks. Falling rocks have great influence on log quality and value. Consequently only 73% of conifers and 90% of broadleaves are 3rd class logs or other lower grade wood, making a large impact on the economy of the operation.

Keywords: *forestry, protective forests, forest harvesting, productivity, cable yarder, stand damages*

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THE INFLUENCE OF SAMPLE'S SIZE ON THE RESULTS OF MODELLING OF STAND GROWING STOCK VOLUME, BASED ON THE AIRBORNE LASER SCANNING DATA

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Current forest growing stock inventory methods applied in Poland are mainly based on field measurements of trees overgrowing round sample plots, along with the forest taxation. Such measurements are carried out with use of traditional equipment, i.e. calliper and range finders. After field works, GSVs of stands and forest districts are estimated by means of statistical methods. In order to ensure demanded accuracy, a proper number of sample plots is an issue of a high importance. High number of required sample plots obviously entails tremendous time and financial contribution. Nowadays, a remote sensing based on inventory techniques have greater popularity. For instance, they are commonly applied in Canada, or in some Scandinavian countries. Increasing number of studies are being conducted, in order to evaluate usefulness and applicability of such techniques for the forest practice. In many cases, an Airborne Laser Scanning (ALS) data allows to: (1) improve estimation accuracy of growing stock volume, (2) decrease related costs, (3) conduct an inventory on the district level, stand level, and even single tree level.

Remote sensing based on forest inventories still require a certain amount of ground sample plots, which serve either as reference data used for model calibration, and/or as validation dataset in order to assess predictions accuracy of modelled variable. Number of sample plots is not the sole issue influencing time and financial costs of field works. Among many aspects connected with conduction of field inventories also the size of sample plots impacts either accuracy, as well as time and costs needed to accomplish given inventory campaign. In this study, an influence of sample size (number of sample plots), and influence of sample plot area, on accuracy of ALS based GSV estimation have been investigated at sample plot level. Investigation object was Milicz forest district. Having set of 900 sample plots, with both: ALS and ground data determined, a statistical model used for ALS based estimation of plots growing stock volume was developed. Next, plots volumes were estimated using previously developed model, however calibrated based on ground data from 800 sample plots (an age class dependent sampling out of the full 900 plots set). Next, described routine was repeated for 700, 600, …, up to 25 plots. For every single sampling, following measures of discrepancy were calculated: RMSE, MAE, BIAS, and also R2, and distributions of such errors were analysed for particular variants. Additionally, statistically significant differences in means of plots GSVs estimated between particular alternatives and ground reference data were presented. It has been shown, that up to 200 sample plots, a great majority of computed errors maintain at really close level to those error obtained for 900 sample plots. A drop in accuracy starts below 200 sample plots. Only for BIAS, a drop in accuracy started at level of 500 sample plots. Deviations between iterations were at low level. We proved that sample plot area have underlying influence on accuracy of GSV estimations, for each number of sample plots. Results showed that it is possible to strongly reduce sample size, while still maintaining a decent accuracy level at least for presented study case.

Keywords: *ALS, LiDAR, forest inventory, stand growing stock, sample size*

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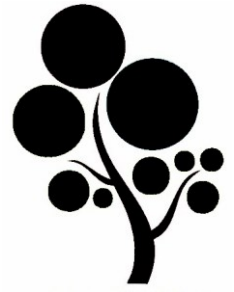
SESSION III

Wood properties



THE RELATION BETWEEN BIOMETRIC FEATURES AND OCCURRENCE OF RED HEARTWOOD IN BEECH (*Fagus sylvatica* L.)

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One of the major flaws of beech wood is red heartwood which considerably lowers the quality and therefore the value of the wood. This paper concerns the impact of biometric features on occurrence of red heartwood in beech tree trunks. It was presumed in this paper that biometric features of trees such as diameter at breast height (DBH), the plane of the horizontal projection, the surface of the tree crown as well as the length and volume of the crown all play a role in the occurrence of red heartwood in the trunks of beech (*Fagus sylvatica* L.). The research material came from the Regional Directorate of State Forests in Szczecinek, the Forest Inspectorate in Bobolice as well as from the Forest Districts in Dziupla and Chlebowo. Seventy-seven trees were measured in total.

Mathematical analysis revealed substantial statistical relationship between the selected biometric features and the relative and absolute value of red heartwood in the plane of the cut tree. The trees featuring a big surface of crown tops, big crown volume and length as well as those featuring DBH larger than average for the given group had a higher than average share of red core in their trunks.

Keywords: *beech, red heartwood, red core, wood quality*

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VARIABILITY OF SELECTED MACROSTRUCTURAL FEATURES, DENSITY AND COMPRESSION STRENGTH ALONG THE GRAIN OF THE "TABÓRZ" SCOTS PINE WOOD (*Pinus sylvestris* L.)

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The paper presents the results of research on variability of the annual rings width, share of latewood, density and compression strength along the grain of the "Tabórz" Scots pine wood (*Pinus sylvestris* L.). The wood samples for examination were obtained from the trunks of 260-year-old Scots pines felled in the "Sosny Taborskie" Nature Reserve. In total 106 samples were cut from trunks of three trees. The mean values for all the tested wood samples amounted to: annual rings width - 1.33 mm, share of latewood - 29.1%, wood density - 0.487 g/cm^3 and compression strength - 47.3 MPa. The smallest variability within trees showed wood density and compressive strength along the grain. Very high and positive correlation was found between wood density and compressive strength. High and positive correlations were found between share of latewood and wood density and between share of latewood and compressive strength.

As much as authors know, presented results are the first empirical data published concerning the features of wood macrostructure, density and compression strength along the grain of the "Tabórz" Scots pine, the trunks of which are considered in Europe to be valuable timber.

Keywords: *Tabórz Scots pine, macrostructure, density, compression strength, wood*

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ON WHETHER THERE IS ANY EFFECT OF SITE FERTILITY ON BEECH WOOD DENSITY

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Rate of tree growth depends i.e. on the site quality. It impacts the share of early and late wood and at the same time has the impact on wood density. Wood samples from European beech trees (*Fagus sylvatica* L.) taken from two sites of different fertility (lower and higher) were examined. Model trees were chosen from pure beech stands of different age, starting from 1st up to 5th age class. Wood discs were prepared from 3 heights of trunk. Samples according the European standard were dried in 105°C to 0% of moisture and then stereometric method of wood density measurement was performed. Axial and radial variability of wood density was compared. Additionally the influence of several defects of wood samples (cracks, rot, pith) was taken into consideration in the perspective of their influence on wood density. The research was carried out during Rembiofor project financed by NCBiR.

Keywords: *axial and radial variability, Fagus sylvatica* L.*, wood quality*

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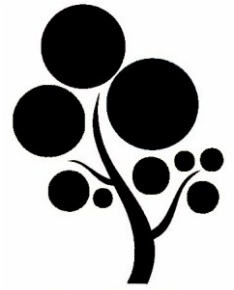
SESSION IV
Wood protection



CHANGES IN THE PROPERTIES OF SCOTS PINE HEARTWOOD DURING FOUR YEARS OF EXPOSURE TO UNDERWATER CONDITIONS AT THE ARCHAEOLOGICAL SITE OF GDAŃSK BAY NEAR ORŁOWO

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Many of wooden objects of cultural heritage are subjected to negative impacts of the marine environment that cause their degradation. A lack of adequately monitored storage places and the impact of these factors is still not sufficiently recognized. It is necessary to identify destructive factors, determine their role in the biodeterioration, establish the natural resistance of particular, mostly used wood species in the marine environment and their decomposition rate. The aim of the research was to determine the changes of contemporary wood properties as result of submerging in Baltic sea water during four years, as an indicator of changes that can occur in the wood of cultural heritage objects. The samples of Scots pine wood (*Pinus sylvestris* L.) from heartwood zone were tested using twin samples of wood exposed and unexposed to underwater condition. The samples were submerged at a depth of about 14 meters at the archeological site near the current resting place of wreck of the Swedish warship Solen in Baltic sea water at the longitude of Orłowo. The samples were fastened to the supporting ropes, which were attached to a special construction made of pipe on the sea bottom. They were removed from the seawater from the Orłowo location after 2, 3 and 4 years of exposition to sea water environment. A visual observations, description and photographic documentation of the wood samples was made. The external appearance and condition of the test samples were compared to the control one. Afterwards the test samples were cleaned with water to remove from their surface the biofilm and other marine organisms. After that the samples were undertaken to laboratory investigation of their physical, chemical and biological properties. A successive drop of mass loss of wood, its bending and compression along the grain strength, increase of equilibrium humidity, significant changes particularly of content of minor components of wood as well as total amount of minerals and certain elements were stated. The wood exposed to underwater conditions shows also some changes in the susceptibility to degradation caused by *Basidiomycetes* fungi. So, the immersion of wood in sea water caused significant changes to its physical, chemical and biological properties. It is assumed that the detected changes of properties of wood can be useful for monitoring underwater archaeological sites.

Keywords: *wood, pine, heartwood, sea water, submerging, properties*

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WATERLOGGED ARCHAEOLOGICAL WOOD SILANIZATION WITH MTMOS

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A wooden object that has survived in a wet environment is characterised by water saturation and is called waterlogged wood. The object of the study was elm piles, dating back to the 10th-11th century, excavated from Lednica lake archaeological site. Wooden piles showed a high degree of degradation, which was evidenced by their spongy and fragile structure. As a result of the biotic and abiotic degradation of the wood cell wall, a significant change in its chemical composition was observed. Decomposition of wood is a very complex process. The weakening of the wood structure and its increase in porosity are the result of cellulose degradation. The archaeological wood conservation method used so far is the polyethylene glycol (PEG). However, this method is characterized by significant defects, which have caused damage to the preserved object in many cases. It has been already found that alkoxysilanes are potential alternative to commonly used PEG. The purpose of the study was to determine the optimum concentration of methyltrimethoxysilane (MTMOS) for that elm wood conservation. The general aim of the study was to find an effective waterlogged wood dimensional stabilization through its silanization with MTMOS. After long-term dehydration with ethanol, wood samples were saturated with MTMOS at various concentrations solutions. Wood samples were treated through the oscillating vacuum-pressure method. Dimensional stabilization of the sililated wood was estimated through the anti-shrink efficiency (ASE) calculation. Waterlogged wood treated with PEG, was used as a reference sample. ASE value for PEG and MTMOS treated wood samples was 88.6% and 96.8% respectively. It was found that ethanol solution of 20% MTMOS is an optimum concentration for waterlogged elm wood dimensional stabilization treatment (ASE= 94.1 %). The other advantage of this method include short time of impregnation and low density of the preserved wood.

Keywords: *methyltrimethoxysilane, silanization, waterlogged archaeological wood*

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IONIC LIQUID FUNGICIDES: BIODEGRADATION IN SOIL AND INFLUENCE ON AUTOCHTHONOUS SOIL MICROBIOTA

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Little is known about the biodegradability of ionic liquids (ILs) in soil environment and their influence on autochthonous microorganisms. Currently, majority of the studies is focused on toxicity of ILs to single, isolated microbial strains, but the knowledge regarding the impact of ILs on complex microbial communities is lacking. Although there are no reports providing information about the presence of ILs in soil ecosystems yet, the increasing popularity of ILs in the industry is expected to lead to environmental pollution. ILs possessing antifungal properties are a novel group of chemical agents that can be potentially used in wood preservation. In this study, using urban park soil spiked with either ammonium-based ILs (didecyldimethylammonium 3-amino-1,2,4-triazolate [DDA][3AT] and benzalkonium 3-amino-1,2,4-triazolate [BDA][3AT]), or phosphonium-based ILs (trihexyl(tetradecyl)phosphonium chloride [P66614][Cl] and trihexyl(tetradecyl)phosphonium 1,2,4-triazolate [P66614][Tr]), the biodegradability in soil and impact of the ILs on soil respiration activity was evaluated.

The samples were prepared in triplicates as follows: 10 g of non-sterilized soil was added into bottles and then spiked with a methanol solution of each IL to reach an approximate concentration of 4000 mg kg-1 of IL per sample. Next, methanol was evaporated and untreated soil in the amount of 90 grams was added. The soil was later vigorously mixed. The microcosms were incubated at 20°C for 300 days. After 300 days three 0.5 g samples of each replicate were subjected to three-step ultrasound assisted extraction with methanol (3 x 1 mL) and analyzed by HPLC-MS to determine the residual masses of ILs ions. Additionally, the respiration activity of soil microbiota in each soil sample was periodically determined by measuring CO2 content in base traps (10 mL of 0.75 M NaOH in a 20-mL vial) placed in the microcosms.

The obtained results showed that after 300 days primary biodegradation of the studied ILs ranged from 21 to 33% suggesting potential for persistence of the four studied ILs in soils. The CO_2 evolution from the microcosms was in the range of soil background respiration rate, which may suggest no or small mineralization of the compounds (or their potential metabolites) and no or negligible toxicity to soil microbiota (respiration activity was slightly lowered only in the case of [BDA][3AT]).

Keywords: *ionic liquids; soil microbiota; biodegradation; fungicides; wood preservation*

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MATERIALS FOR GAP FILLING IN WOODEN ARTEFACTS EXPOSED OUTDOORS

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Conservation of wooden artefacts that are exposed outdoors is a very complex and difficult issue. The main problem faced by monument conservators is a fact that such objects are like "living organisms". Unceasingly subjected to a number of factors, such as alternating weather conditions and activity of microorganisms, algae or insects, they undergo continuous changes in response to affecting variables. Due to severe biological and physical degradation, wooden artefacts of this type are often characterised by larger or smaller losses, gaps, cracks or holes in wooden tissue. This creates a need for using special materials to fill the gaps and prevent a wooden object from further destruction. A preserving agent must not only protect the wooden object against biotic and abiotic degradation, but also possess requisite characteristics compatible with wood properties. Only such a set of properties allows the filling material to secure effective protection for wooden artefact.

A variety of substances, both organic and inorganic, have been used for conservation and gap filling in wooden historic objects over the years. The filling compounds typically consist of two components, of which one is a filler, and the second is a binder. Among inorganic fillers traditionally plaster has been used while the most popular organic fillers were wood powder, wood shavings, powdered cork and cellulose. Nowadays synthetic materials have become increasingly popular in conservation, such as acrylic or glass microballoons. Historically, mainly natural substances have been used as binders, like animal glues or waxes. Recently, however, various synthetic resins (epoxide, polyurethane or acrylic) have increasingly been used due to their lower biodegradability and better physicochemical properties.

This article discusses the filling compounds applied so far for gap filling in wooden artefacts exposed outdoors, outlining their advantages and drawbacks. According to their characteristics, different types of polymers deserve special attention. Due to the similarity with protected wooden objects, high elasticity and good adhesion to wooden surface, especially natural polymers seem to be the attractive materials. Their disadvantages, like high susceptibility for biodegradation, could be eliminated with the use of some modern, bio-friendly substances, providing effective protection for historic wooden artefacts.

Keywords: *gap-fillers, gap-filling materials, wooden artefacts, wood conservation*

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SILYLATED NATURAL OIL FOR WOOD PROTECTION

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Bio-based materials synthesized from sustainable and renewable resources are of great importance due to the environmental aspect. Natural oils are bio renewable molecules suitable for conversion to useful coating materials. The general aim of the investigation is to manufacture a non-film forming product for wood protection, based on sililated natural oil. The purpose of this action is to obtain an innovative oil-based product for the superficial wood treatment with a permanent hydrophobic effect.

Non-film forming material prepared from the reaction of soybean- or linseed oil and vinyl trimethoxy silane (VTMOS) was the object of the study. The silylation reaction occurs at high temperature and pressure in the presence of catalyst. Biobased products containing different molar ratios of oil and silane were synthesized and characterized. The goal of this particular study was to monitor the silylation process with the use of VTMOS and estimation of some physico-chemical properties of the obtained polymers.

Polydispersity index (PDI) and average molecular weight number of the modified oil were estimated through the GPC and GC-FID analysis. Monitoring of the pressure and temperature during the modification process, allowed to determine a total conversion point of the VTMOS. It was found that further processing above the total conversion point leads to increased molar mass of the modified polymer and gelation of the final product. The rapid rise of PDI suggests disintegration of the final product. In contrast to conventional self-polymerizing oils, the achieved polymers have medium molecular weight distribution. Its selected physico-chemical properties (eg. acid value, iodine value and viscosity) were also determined. The obtained results showed that the modified oil is stable during storage and its basic functional properties of a liquid state are comparable with reference products. Physical properties data indicate that the resultant biobased polymers are suitable for wood treatment as non-film forming products. Such modified oil may also be a potential component of a water-based oil emulsion or a raw material for binder manufacturing.

Keywords: *bio-based materials, oil, silane, sililation process, VTMOS, polymer, wood protection*

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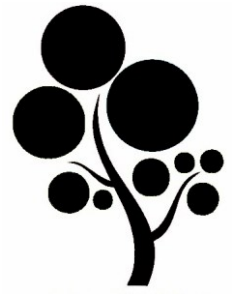
SESSION V

Biomass management and utilization



THE MOBILE FURNACE FOR ONSITE CARBONIZATION: A COMPARISON WITH OTHER FORESTRY PRODUCTS

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In Italy, charcoal production with the use of firewood has been historically a common activity, driven by the large use and availability of this natural material. Currently, the traditional use of wood products and byproducts has been complemented by a large number of new applications which are enabling the re-discovery of these activities, creating new value in the local production chains. Compared to the past, now this resource is used differently and with greater attention to quality rather than quantity. In order to allow economically advantageous production in our country, it is essential to implement new production methodologies directly on the raw material collection site. New interesting technologies, such as the horizontal mobile furnace, allow the onsite wood transformation and realize benefits such as reduction of time and cost production. This way, it is also possible to optimize the overall productivity and minimize the negative externalities. The research activities carried out in this study are included in the RICACCI project (acronym for Innovative Carbon Recovery and Activation of Coordinated and Inclusive Forest Energy Certification). This project is part of the new PIF initiative (EU's Rural Development Tuscany 2014-20), concerning the Forest and Energy production chain, called FOGLIE. The sites object of the study are the same ones where beech coppice conversion work is normally conducted; specific carbonization tests have also been conducted onsite, utilizing the horizontal mobile furnace. The analysis conducted were designed and aimed to compare various charcoal productions, such as firewood and chipboard, all of which are commercialized or employed in facilities within 100 km radius from the production site. Specifically, in addition to the analysis of CO_2 emissions, the technical, economic and energetic aspects of the entire process have also been compared. The reactivation of this type of furnace, allows us to restore the production of charcoal by creating a local production chain and increasing the economic value of poor wood assortments by ensuring a differentiation of forestry productions. Moreover, by positioning the mobile furnace close to the cutting place, it is possible to transform the material with virtually no transportation wood costs. Instead, it will be possible to directly transport charcoal which has a lower weight and volume as well as a value per unit greater than the assortments derived from the first transformation. Thanks to this research it was also possible to set the first basis for a subsequent LCA analysis both at process and product level.

Keywords: *charcoal production, wood energy, mobile furnace*

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DEMAND FOR WOOD BIOMASS FOR ENERGY PURPOSES – IDENTIFICATION OF PRESENT AND POTENTIAL SOURCES

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World coal, gas and oil resources according to different forecasts should be enough for 40-150 years, however in the light of contemporary problems of the development with important aspect from conversion them, there are pollutants generated by using them. The excessive emission of greenhouse gases threats the stability of the climate of the globe but the prognosis, in case of the lack of determined protective actions are worrying.

The partial solution of above problems could be the use of energy biomass, also from forest. Such hopes also exists in Poland and they were created by conviction, that we have huge reserves of forest biomass. Moreover practical aspects of biomass utilization show, that it is one of the simplest and what is important, cheapest (under the condition of economic supporting for its using) way to let to reach target in proportion of use of the renewable energy. Simultaneously a full permission exists, that the wood biomass, especially from forest should be a supplement of agro biomass.

Keywords: *renewable energy, conventional and non-conventional sources of renewable energy, forecast for wood biomass production*

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WOOD ENERGY CONSUMPTION IN PRIVATE HOUSEHOLDS IN GERMANY

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Private households in Germany consume ca. 30 Mio. m³ wood for heating purposes per year. This amount constitutes for almost half of the wood used for energy in Germany. Some of the forest products used for energy are also demanded by the forest based industry. An increased demand for wood energy could lead to rising wood prices and thus trigger a competition for the resource.

In Germany wood flows of the entire wood processing sector are monitored in a project called resource-monitoring for wood. Based on survey data this project provides valuable information on wood consumption for material as well as energy use. For private households, surveys were conducted for reference years 2000, 2005, 2010 and 2014. Each survey dataset comprises ca. 10,000 households where information on wood energy consumption, household properties and socio economic information is gathered.

Preliminary results shown that the number of households using wood heating systems increased in the years from 2000 to 2010 and kept constant from 2010 to 2014. Variables like age of the head of the household, population density or regional location of a household are correlated/associated with the outcome of whether a household consumes wood for energy or not.

A regressive model on wood energy consumption shows that a number of variables (e.g. heating technology, forest owner, degree days and rural or urban location of a household) are significantly correlated/associated with wood consumed for energy generation in German households.

Based on survey data quantitative information on the development of wood energy heater types in German households were found. It was possible identifying variables influencing wood energy consumption in private household. However, it appears difficult predicting wood energy consumption based on the specified regressive model.

Keywords: *wood energy consumer, wood energy consumption, private households, descriptive statistics, inference statistics*

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HEAT AND POWER PLANT FOR SAWMILL – TECHNICAL AND ECONOMIC ANALYSIS

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Increasing of energy efficiency and using renewable energy sources are considered as twin pillars of sustainable energy policy for regions or countries. The Energy Efficiency Act (article 2 point 3) defines energy efficiency as the ratio of the effect of a given facility, installation, technical device, building to the amount of energy consumed by that facility, technical device or installation, in its typical conditions of its use or operation. Improving energy efficiency brings many benefits, the most important of which is reducing greenhouse gas emissions and other pollutants, but also lowering operating costs, when energy savings are higher than the additional costs associated with the implementation of energy efficient technologies.

This paper will present a comparative technical and economic analysis of a project involving the construction, commissioning and operation of CHP plants for a wood processing company (sawmill). The analysis will be done for a medium sized sawmill, which annually processes about 50000 m^3 of wood, producing 5500 m^3 (5100 Mg) sawdust. It has also been assumed that the plant has a heat demand (to supply the different kind of wood dryers) with a installed capacity of approximately 4 MW.

As a part of this work, the concept of constructing a CHP plant with water as a working medium (steam plant) and with an organic working fluid (so called Organic Rankine Cycle power plant) and with thermal oil as an intermediate medium will be considered. CHP plants will be supplied with sawmill waste. On the basis of the actual data, heat flow analysis of the systems and economic analysis of the project will be made. The variants of CHP systems are mainly derived from the type of working fluid used in the power plant: water or MDM. The use of various working fluids has advantages and disadvantages. The use of water as a working fluid simplifies the installation, but it has lower efficiency and larger dimensions. The use of ORC systems requires the use of an intermediate medium in biomass boiler with thermal oil as heat carrier medium between the flue gases and the operating medium of a power plant. It also features a more compact design.

Keywords: *CHP, ORC, power plant, sawmill, energy, biomass*

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LIGNOCELLULOSIC BIOMASS LIQUEFACTION – AN ECO-BONDING APPROACH TO WOOD-BASED PANELS

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Various wastes and by-products are usually generated by wood processing industries. Small-sized and post-consumer wood waste are often considered as a problematic, however those may also be seen as a valuable source of raw material. Wood waste have become more frequently re-used, recycled and utilized as raw materials for platform molecules. Increased attention is being paid especially to the importance of biomass derived valuable green products, supporting a bio-based industry. Liquefaction of wood and the derived products is one of the most promising technology, possessing a great potential for practical implementations into various bio-resources converting industries. Current state of the art confirms possibility of wood residues transformation, including wood packaging waste, cork dust bark, by means of liquefaction.

In this research different types of post-industrial wood residues including mixed hardwood/softwood powder, bark, pine, and beech sawdust were liquefied at elevated temperature (130°C) with a mixture of solvents including polyhydroxyl alcohols (glycerine and propylene glycol) and p-toluenesulfonic acid as a catalyst. The resulting liquefied wood mixtures were characterized in terms of their physical and chemical properties and then tested as a partial substitute for synthetic urea-formaldehyde (UF) resin in the particleboards production process.

Series of particleboards containing post-consumer wood bonded with the UF resin with addition of the liquefied wood were produced in the laboratory. The standard mechanical and physicochemical properties of experimental particleboards were examined according to the standards (respectively). All tests were performed in comparison to the reference boards, bonded with unmodified urea-formaldehyde adhesive resin. Additionally liquefied products and particleboards were characterized by non-destructive spectroscopic methods, including NIR and XRF.

It was found that the type of wood waste used for liquefaction has relatively little effect on the resulting product. XRF analysis did not detect harmful contaminations both in raw materials and liquefied wood. It's possible to substitute UF resin with 20% of liquefied wood without reduction of the panels properties. Some particleboard properties (swelling, water absorption) were slightly improved when adding the liquefied wood blend to the UF resin. It was demonstrated that liquefaction process can be an alternative method for wood waste utilization.

The research is the subject of the project: "New biopolymer adhesives modified with silanes and ionic liquids for application in wood-based materials technology'' funded by the NCBR under the LIDER VII Programme.

Keywords: *biomass liquefaction, liquefied wood, bio-adhesives, wood-based panels, NIR spectroscopy*

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RECYCLING OF BALSA WOOD FROM ROTOR BLADES FOR THE PRODUCTION OF INSULATION BUILDING MATERIAL

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In 2016 in Europe energy plants (wind mills) providing about 12.5 GW of new additional wind energy power were installed. With a total installed capacity of 153.7 GW, wind energy now overtakes coal as the second largest energy source for power generation capacity in Europe. The installation of Polish wind energy plants was among the fifth greatest within the 28 EU states.

But knowing that the lifetime of these plants is between 20 and 30 years, a recycling concept for all the metal, reinforced-plastic and huge amounts of balsa wood has to be considered. For example, a 75 m long rotor blade has a surface of 550 m^2 and contains about 10 m^3 of balsa wood of different thickness varying from about 1 cm to maximum 5 cm.

It is well known, that balsa wood with its low density ranging from 50-300 kg/m^3 is an excellent natural insulation material, which is usually used only for special applications where good thermal insulation compared with high compressive strength is needed.

In laboratory tests done by another Fraunhofer Institute (ICT), the balsa wood from rotor blades was removed from the glass-fiber reinforced plastic to get more or less clean wood particles.

In the Fraunhofer Institute for Wood Research (WKI), the cleaner wooden blocks from industrial wood residues coming directly from the producer are treated in a refiner to get fibers with optimal material parameters for the production of new insulation boards. Different boards with various densities (50 – 200 kg/m^3), adhesives and orientation of fibers were produced within this project to get an optimum insulation board.

The quality of the boards concerning their thermal conductivity were evaluated using the standard guarded hot plate apparatus as well as the new hot-bridge technique.

The results of this recycling process as well as the production of the new insulation boards from this cascaded wood process will be demonstrated at on the conference.

Keywords: *recycling of rotor blades, recovery, balsa wood, insulation*

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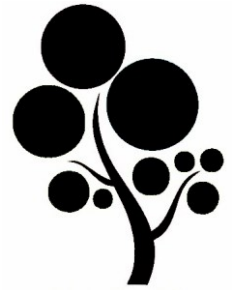
SESSION VI

Advancements in wood science



A METHODOLOGY FOR THE ASSESSMENT OF COMPLIANCE OF THE EXISTING WOOD-BASED PANELS PRODUCTION PLANTS WITH BAT REQUIREMENTS

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The reference document was prepared for wood-based materials production "Best Available Techniques (BAT) Reference Document for the Production of Wood-based Panels" (2016). All producers of the wood-based materials should know, to which extent is their facility in compliance with BAT requirements. This paper presents methodology with optimized procedure to evaluate the compliance of certain facility with BAT requirements which is verified on the example of existing wood-based panels production plant. Particleboard production consumes 500,000 tonnes of wood (actual weight – LUTRO) annually, the largest share is coniferous pulpwood with nearly 150,000 tonnes, sawdust around 110,000 tonnes and others. Approximately 400,000 m^3 of raw particleboard is produced per year, of which about half is laminated. The company manufactures annually almost 22 million m^2 of impregnated foil. There are 34 points at the plant where air emissions are emitted and all locations have been officially measured by an authorized measuring group. During the particleboards production, 9 kinds of other waste and 27 types of hazardous waste are generated. In addition, there are almost 40 types of resins, auxiliary materials and other substances, each type with an annual consumption of at least min. 1 t. The article is a brief information on the subject matter and the results of research. The methodology is the set of theoretical analyses, results of controls on site, analyses and measurements, which are processed in 16 steps. The operator shall prepare and submit to the competent authority a baseline report before starting the operation of an installation or before a permit for an installation. For the purposes of preparing a baseline report, a geological survey was carried out. In this article, we report the results of comparisons of the parameters of the permitted plant with the parameters of the best available technology. During the production, drying and shredding chips process are critical, or most demanding to meet the requirements of BAT – sawdust storage or sawdust handling and the chips dryer. The drying of chips is the main source of air pollution and a potential source of odour. Wet electro-static precipitator was implemented to minimize emissions from the dryer. Authorized emission measurement indicates average value PM 3.57 mg/m^3 (with 17% O2). The current emission limit is 20 mg/m^3. Results of authorized measurements TOC are 49 mg/m^3. The current emissions limit is 300 mg/m^3. The real values of the concentration formaldehyde measurements are low, below 0.76 mg/m^3. The calculated emission factor is around 0.35 kg/m^3 of produced boards. The current emission limit of the sum of the concentrations of formaldehyde, acetaldehyde, phenol and formic acid is 25 mg/m^3. Thorough environmental management analysis of the existing particleboard production plant compliance evaluation has a positive impact on several environmental and economical solutions. Moreover, a series of measures and communication with competent environmental protection authorities is proposed.

Keywords: *particle board production, BAT requirements, assessment, environmental management*

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DENSITY PROFILE AND HARDNESS OF THERMO-MECHANICALLY MODIFIED BEECH, OAK AND PINE WOOD

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Wood as an organic material is susceptible to elastic and plastic strain. It is therefore possible to orientate wood properties. One of the solutions applied in order to improve the physical and mechanical properties of wood is the thermo-mechanical modification. The effect of applying such a solution is an increase of density, and consequently of the hardness of wood. These characteristics are of particular importance in wood which is used as flooring material. Thermo-mechanical modification improves the functional properties of wood.

The research object was to determine the impact of thermo-mechanical densification on the density profile and hardness of beech, oak and pine wood. The wood selected for testing varied in anatomical structure. Consequently, it was possible to verify and compare the properties of diffuse-porous hardwood, ring-porous hardwood, and softwood subjected to densification.

Beech (*Fagus sylvatica* L.), oak (*Quercus robur* L.), and pine (*Pinus sylvestris* L.) wood were volume-densified by means of thermo-mechanical modification. At the first stage the wood was heated in a hydraulic press for 720 s at the temperature 100^{o}C, and then densified in order to achieve the compression ratio of 30%. The wood was cooled in a hydraulic press with unheated plates. Wood density profiles parallel and perpendicular to the grain were investigated. The analysis of wood density profiles was carried out on the basis of the following parameters: mean density, maximum density, the distance between the maximum density area and the wood surface, and the ratio of minimum to mean density of the wood. Wood hardness was determined using the Brinell method. A statistical description of the results was carried out.

The research results show that thermo-mechanical modification of wood has major impact on the density parameters of beech, oak and pine wood. As a result of densification, the wood structure became homogenous, which was reflected by higher minimum to mean density ratio. As a result of the densification, the hardness of beech, oak and pine wood doubled.

Keywords: *beech, densification, hardness, oak, pine, thermo-mechanical modification*

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THE EFFECT OF PHOTODEGRADATION AGING ON THE AESTHETIC FEATURES AND ADHESION OF WHITE LACQUER COATINGS IN UV SYSTEMS ON HDF SUBSTRATE

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The aim of the study was the determination of the influence of UV + IR radiation on selected coatings properties of UV acrylic lacquer systems. The cognitive aspect was the estimation of the aesthetic-decorative features (appearance, color, gloss) and the adhesion of the tested system to the substrate (adhesion, wettability).

Samples for the investigations in mat ("White Basic Gloss") and high gloss ("White High Gloss") versions were prepared in industrial on-line conditions of BORNE FURNITURE Comp. in Gorzów Wlkp. In the case of the mat system, 5 layers (100 ± 5 g/m^2) and high gloss 7 layers (115 ± 5 g/m^2) of lacquer products on roller device were applied.

The photodegradation aging acc. to the PN-88/F-06100/08 standard was carried out, exposing the samples to UV+IR radiation at 1, 2, 4, 8 h respectively.

A visual assessment of the surfaces after aging was conducted. The gloss was determined by the photoelectric method using the PICO GLOSS apparatus at three angles of 20, 60 and 85°. For evaluation color the colorimeter DT-110/145 (CIELab system) was used.

Contact angle was determined acc. to the PN-EN 828 standard using a microscope with goniometric head. Free surface energy with dispersion and polar shares for each lacquer coatings was calculated. The adherence acc. to the pull-off method (PN-EN 4624) was conducted.

Based on the obtained results, it was found, among others, that both tested coatings by favorable aesthetic-decorative features were characterized and showed good adhesion to the substrate. UV + IR radiation caused the biggest changes in the "White High Gloss" system. After 4 and 8 hrs interactions as yellowing of the coatings were observed, however high gloss did not change.

Keywords: *UV lacquer system, coating, gloss, color, surface free energy, adherence*

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THERMAL CONDUCTIVITY OF WOODEN FLOORS DEPENDING ON APPLIED MATERIALS AND CONSTRUCTION SOLUTIONS

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Determining properties associated with heat transport for construction products usually involves determining the heat transfer coefficients of the building envelopes in the context of thermal insulation. However, in case of underfloor heating application in the building the expectations are opposite – flooring elements with good thermal conductivity, i.e. low thermal resistance (below 0.15 m^2K/W).

Wood, as a traditional flooring material, is characterized by rather low thermal conductivity, so achieving heat resistance at the level ensuring good heat transfer from the heating system to the room is very important. This can be achieved by selecting the right materials or by applying appropriate construction solutions.

In the presented research the experimental tests and comparative calculations of the thermal conductivity of wood floor elements made from different materials and construction solutions were performed. The laminated elements of various designs and with different wood species applied were tested. The influence of thickness, density, moisture content and the structure of the layers on thermal resistance in laminated wood components was investigated. One of the findings was that the results of the empirical measurements of thermal resistance are higher than the results of calculations according to the current normative regulations, which in practice may lead to incorrect assessments with regard to the use of such materials as floor coverings on underfloor heating systems.

This work is a part of the research project funded by NCBR under the BIOSTRATEG program (BIOSTRATEG2/298950/1/NCBR/2016).

Keywords: *thermal conductivity, thermal resistance, multilayer wood flooring, construction product, underfloor heatings*

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BAYESIAN APPROACH TO TIMBER MACHINERY GRADING

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The grading acceptance criteria are formulated in form of boundary values for indicative properties which have to be matched to qualify a piece of timber to a certain grade. The European grading code EN 14081 prescribes an approach for the derivation of grading machine settings according to the machine control system. The machine's grading performance is compared with that of a perfect machine capable of grading each piece of timber to its optimum grade. The new point of view to this subject will be presented in presentation and paper. Assuming that a sufficiently large number of timber experiments have been performed regarding the relevant material property $X(I_i)$ of the ungraded timber, it is in principle a straightforward task to select a probability density function and to estimate the parameters of this correspondingly. The resulting density function might be considered as a prior density function $f_x^{'}(x)$. In structural reliability applications, it is necessary to be able to assess the probability distribution function of the relevant timber properties. The timber grading acceptance criteria to class is the rule applied for the categorisation of timber into different grades and also referred to as the grading machine settings. The grading acceptance criteria may be formulated in terms of the values of the indicators. Typically, the criteria have the following appearance:

$$A_i = \left\{ b_{L,i} \le I_i \le b_{U,i} \right\}$$

where $b_{L,i}$ and $b_{U,i}$ are lower and upper bounds for the indicator for a particular i grade.

In order to assess the representative probability density function use may be made of Bayes's rule, the timber yielding posterior probability density function $f_x^{"}(x)$, i.e. the probability density function, which can be assumed for the material properties, categorised into a particular grade by application of the grading acceptance criteria A_i :

$$f_x^{"}(x) = P(X = x \mid A_i) = \frac{1}{C} f^{'}(x) P(A_i \mid X = x)$$

Illustration of above equation presents Fig.1.

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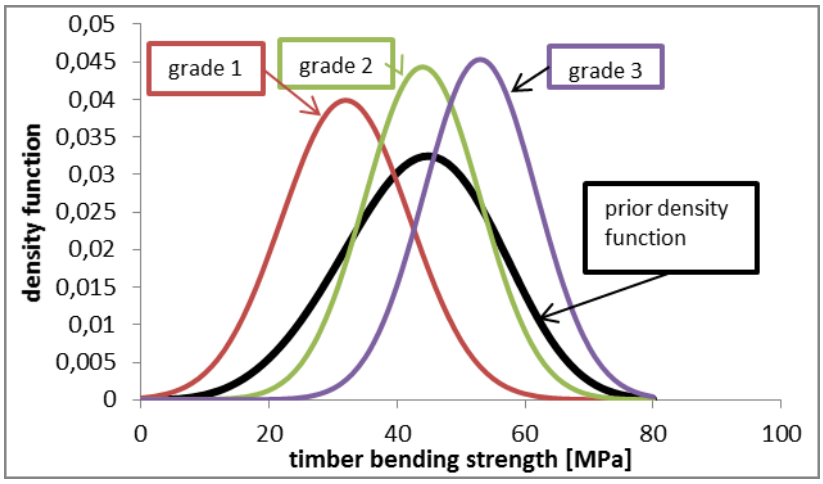

Fig. 1. Prior and posterior density functions of timber bending strength

Keywords: *wood, timber machinery grading, Bays theory, probability*

POSTERS

ALL ON EDGE: NEW METHODS ON TESTING OF FURNITURE EDGES AND RIMS

1

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The rapid development in the furniture industry, concerning the used materials and technologies, requires parallel development of suitable testing methods in order to assess the quality of the finished products. Edges and rims are known to be the weakest points of furniture elements. They are mostly subjected to destroying factors such as water, humidity, temperature and mechanical stress, resulting in several damage symptoms, e.g. cracking, blistering, delamination, swelling or impact marks. Those factors act individually or in combination, during furniture use in high humidity areas (bathroom, kitchen) and transportation in changing-climate conditions, shipped in containers where temperatures exceed the normal usage values range. The existing testing methods are often no more suitable for the new materials (comprising substrates, gluing solutions and surface treatments or edge bandings) and their combinations, providing no reliable prediction on the quality. Thus, there is a need for modern and accurate test methods especially for the edge and rim areas.

Within the European CORNET ALL ON EDGE Project, testing methods on edges and rims of furniture parts are being newly developed or modified. The aim is to develop methods which will be suitable for different product categories and reliable to discriminate between products of different quality levels. They must also have a good repeatability and reproducibility. Uniform and clearly defined research methods will let furniture manufacturers provide higher quality and durability of products.

The Polish and German researches, working together with an international User Committee, pursue methodological investigations on mechanical resistance and short-term as well as long-term prognosis methods. Methods for mechanical resistance consider impact resistance and adhesion on rims. Furthermore, the project also focuses on contact heat and temperature resistance as well as water and damp resistance test methods. In order to assure a long-term prognosis of furniture pieces, reliable methods along with changing climate resistance are being elaborated.

The presented poster gives an overview of the developed methods and preliminary results on the impact resistance. Until now, the ongoing Round Robin Test on impact resistance has shown good repeatability and reproducibility with good differentiation between different products qualities.

Keywords: *furniture edges, rims, testing methods, short-term prognosis, mechanical resistance, impact resistance, long-term-prognosis*

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THE COMPARISON OF ACID AND ENZYMATIC HYDROLYSIS OF PULPS OBTAINED FROM POPLAR WOOD (*Populus* sp.) BY KRAFT METHOD

2

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The topic related to renewable energy is currently of great interest. The bioethanol is an example of biofuel that can be produced from renewable sources such as sugar cane, maize or wood. Processing of lignocellulosic biomass to bioethanol consists of several stages: material pretreatment, enzymatic hydrolysis and fermentation. The material pretreatment and hydrolysis of polysaccharides are the most important steps, because they determine the yield of the resulting ethanol and profitability of the process. The aim of the study was to verify the potential of pulps obtained from poplar species by kraft method (as a potential pretreatment method) in relation to bioethanol production. To achieve this verification, acid and enzymatic hydrolyses were compared. The pulps obtained from wood of fast-growing poplar species (Populus deltoides x maximowiczii and Populus trichocarpa Torr. & A. Gray ex Hook) were used as a feedstock. The poplar wood was from experimental field in Wolica owned by the Warsaw University of Life Sciences. The age of trees was between 2.5 and 5 years. The delignification process by kraft method was carried out with 19% and 26% of active alkali (NaOH and Na_2S). The obtained sugars (xylose and glucose) were analyzed by high-performance liquid chromatography. On the basis of results it was concluded, that enzymatic hydrolysis process is better than acid hydrolysis, because higher content of sugars (especially xylose) was obtained. The xylose content, regardless of the active alkali content, after acid hydrolysis was between 8.0% to 11.9%. On the other hand, after enzymatic hydrolysis the xylose content was higher (by ca. 7%) being within the range of 15.8% to 18.8%. In the case of glucose, the content after acid and enzymatic hydrolysis was at a similar level and depended only on the content of active alkali. For 19% of active alkali, the obtained content of glucose was between 58.2% to 61.5%. However, for 26 % of active alkali the content of glucose was higher and reached the values from 64.3% to 71.9%. Additionally, we can conclude that after acid and enzymatic hydrolysis processes more sugars were obtained from Populus trichocarpa pulp than from pulp of Populus deltoides x maximowiczii. Moreover, a significant influence of tree age on sugars (xylose and glucose) content produced during hydrolysis process was not observed. In summary, the kraft pulps from wood of fast-growing poplar species are a good raw material for the production of bioethanol.

Keywords: *acid and enzymatic hydrolysis, kraft pulp, poplar, bioethanol*

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SEPARATION OF RESINOUS SUBSTANCES FROM PINE WOOD WASTE (*Pinus sylvestris* L.) USING SUPERCRITICAL CARBON DIOXIDE

3

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Carbon dioxide in its supercritical state is a commonly used solvent for extracting natural substances from plant resources. Supercritical extraction has gained wide acceptance as an alternative to extraction using organic solvents, as it is characterized by unique properties and is consistent with the rules of 'green chemistry'. This process can also be used to educe and fractionate resinous substances in wood. Scientific literature holds little information on this subject, and the elements which can be found are often contrary to each other. The previous research allowed us to establish that through the proper conduction of extraction using supercritical CO_2 it is possible to educe from pine wood not only resinous substances, but also to divide them into fractions which will vary in their chemical composition. The technology of conducting such process has become the subject of a patent "The method of obtaining powdered resin and other resinous substances from coniferous wood".

This text presents the results of extraction of resinous substances from pine wood waste (*Pinus sylvestris* L.) and their separation into three fractions: powdered rosin, semi-fluid mixture and turpentine. The process was completed in one stage of extraction through three-stage decompression. The aim of this text is to assess the influence of selected extraction conditions (temperature, pressure, CO_2 to resource ratio, level of fragmentation of material) and decompression parameters (pressure, temperature) on the effectiveness of the separation of resinous substances. The extraction process was conducted at a pressure of 33 – 46 MPa, temperature of 58 – 80 °C and the resource to CO_2 ratio of 1:92 and 1:138. Process research was conducted using a system by Waters with a closed circuit of carbon dioxide and the chemical composition of the obtained extracts was analysed using GC-MS.

The conducted research has shown that the fragmentation level of the material does not influence the effectiveness of the extraction. The most extract was obtained under the following conditions p=33 MPa, T=80 °C and a resource to CO_2 ratio of 1:138. As a result of two-stage decompression powdered resin was obtained at the first stage of decompression while semi-liquid resinous extract was obtained at the second stage. The obtained powder contained almost 93% of resin acids, and the plastic mass contained resin acids, diterpenes and sesquiterpenes. The third fraction, which was obtained after complete decompression, consisted almost entirely of pure monoterpenes. The benefits of obtaining resin acids and terpenes from pine wood waste are undeniable. The obtained resinous product fractions are a valuable, relatively pure resource which can be used in many sectors of industry.

Studies was carried out within the framework: S/ZWL/1/2014 and financed from the science funds for Ministry of Science and Higher Education.

Keywords: *resin, supercritical fluid extraction, powdered rosin, turpentine*

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TYPE OF WOOD AND DEFORMATION OF JOINTS IN TIMBER STRUCTURES

4

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The main species of wood used for the building structures are pine and spruce, likewise fir or larch are employed. Although in most constructions the softwood is a structural material, the hardwood timber also is exploited for structural elements, floors, stairs and window frames. In the case of hardwoods, native species such as oak, beech and alder are often used, as well as exotic hardwoods such as azobé or teak.

The mechanical properties of wood affect the way the structure works. Wood is an anisotropic composite material with various modulus of elasticity according to the direction to the grain. The modulus along the grain is several times higher than in the direction perpendicular to the grain. Structural elements show high capacity in parallel direction to the grain, while in perpendicular direction the capacity is low. The modulus of elasticity and capacity are connected with the deformation. The construction of joints causes that forces acting in one structural element along the grains are transferred to another and acting perpendicular to the grain. The force transfer causes significant deformation in element loaded perpendicular to the grain. The deformation makes the change of joint geometry and change its behavior during work.

Experimental tests allowed to find the way, how the cooperation of individual elements in joint takes place. The deformation of the joint differs distribution of forces between the structural elements in junction. It is important to find the function describing the deformability of the joint.

Experimental investigations of the connections corresponding to the joint of light wood-frame structures were carried out. Studies were conducted on micro-scale samples. Translational and rotational deformation of simply supported timber beams were investigated. The research was carried out to reach the limit load capacity of the sample. Because of the material heterogeneity of the elements, the damage was due to different values of external load. This caused the deformability for two load levels, corresponding to approximately 10 and 40% of the average load capacity of the sample beams.

The vertical translation of nodes of the sample beams were recorded. The results allow to determine the interference into the surface of the beam, as well to determine the angle of rotation of the sample beam relative to the support.

The study was conducted for different tree species, both coniferous and deciduous. The obtained results were analyzed, showing differences in deformations and indicating that due to the deformation, the displacement values obtained from the tests are higher than the values obtained from the simplified beam model working in the elastic range.

Keywords: *deformation of joints, semi-rigid joints, various types of wood, experimental tests*

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IMPACT OF SEMI-RIGID JOINTS ON THE BEHAVIOUR OF LIGHT WOOD-FRAME STRUCTURES

5

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Although timber structures are not as popular as in North America, Scandinavia or Germany, this type of buildings can also be found in Poland. Polish factories also manufacture a large number of precast walls, floors or roof elements for export. The diversity of structural systems starting from traditional one to various types of light wood-frame systems enforces necessity of recognising the behaviour of this kind of structures.

Buildings built in lightweight wood-frame technology possess high material load capacity, but the problem is to ensure overall stiffness of the entire building. Due to the high flexibility of the wood to external burden and relaxation processes, the provision of high spatial stiffness of the building becomes problematic. Joints are the most vulnerable points of the structure for loss of capacity and stiffness, so become the object of analysis and experimental tests. The impact of joint stiffness change on the work of the entire structure is best seen on the basis of the deformation of the elements in the joint.

Semi-rigid behaviour of joint work affects on lower spatial stiffness of the entire building. The connection of structural elements in light wood-frame structures, such as walls to other walls, walls to floors or to roof elements, works differently to the junction in masonry or reinforced concrete structures. Joints behave partially similar to the joints of steel structures. The M-ϕ characteristics is representing the behaviour of the connection, but due to the high deformability of the timber, simultaneously the P-Δ characteristics also have to be taken into account.

There are several characteristic points in light wood-frame buildings where the semi-rigid behaviour of joint significantly influences the distribution of internal forces in individual components as well as the deformation of the building. The most susceptible to variation of stiffness is the wall-to-floor joint, due to the method of construction and loading.

The analytical calculation model was used to recognize the operation of the joint. The stiffness of the semi-rigid wall-to-floor joint, precisely the stud-to-joist joint, can be determined on the basis of experimental tests.

The paper presents experimental micro-scale experimental tests conducted for single connections. Research experiments have been carried out for joints modelled in simplified manner. The joist-to-upper beam and stud-to-bottom beam joints have been tested. The studies were conducted in different configurations for different boundary conditions.

The work of the joint of light wood-frame structure is presented, emphasizing differences in its behaviour in relation to the work of joint in masonry, reinforced concrete or steel structures.

The conclusion contains observation about the joints behaviour and their influence on the work of entire building in three-dimensional system.

Keywords: *light wood-frame structures, semi-rigid joints, deformation of joints, experimental tests*

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THE THEORETHICAL WOOD WASTE POTENTIAL IN EU

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Estimates were made for spatial unit's NUTS-2, which are regions with geocode standard for referencing the subdivisions of countries for statistical purposes. In 2014 EU-28 countries generated 2 589 million tonnes of waste. Based on Eurostat data "Waste indicator on generation and landfilling- monitoring sustainable development" in 2014 EU-27 produced 60 million of wood waste. The most valuable and detailed data on waste management in Europe come from Eurostat. According to 2006 IPCC Guidelines for National Gas Inventories the amount of wood waste in MSW depends on the region. The total theoretical biomass potential of municipal wood waste amounted to 22588 kt. The total theoretical biomass potential of demolition wood was calculated based on data from Demowood project, amounted to 51635 kt. The data about wood industry waste was obtained from the Renew project. The method of theoretical potential assessment was based on specific factors, which allowed for conversion of input data from the international database into amounts available for BtL uses. The estimation was based on the areas covered by forest available for wood supply, net annual increment and felling rates specific for each European country. The total theoretical potential wood industry by products amounted to 5580 kt.

One of the main goals of BioReg project is to identify and release unused wood waste at European level. It comprises five model regions which have set up renewable wood waste-based systems at different stages of the waste wood value chain and three recipient regions, where wood waste management is not well developed. The project will build a multi-stakeholder platform (http://bioreg.eu/platforme/) that will identify good practices and enable them to be implemented in regions with the unused wood potential. The platform will be designed through consultations with industry and policy stakeholders with differing regional needs and requirements.

Keywords: *bioeconomy, wood waste, waste management*

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PROPERTIES OF POPLAR WOOD AFTER MODIFICATION IN NITROGEN ATMOSPHERE

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Wood modification is a thermal process, which improves mechanical and physical properties and biological resistance of wood against fungi and weather conditions. Currently, poplar wood is not a popular species used in Poland. Modification of this wood gives new possibilities for applications of the new product. The material used in the experiment was black poplar wood (*Populus nigra* L.). A tree was cut in Mazovia region, then was cut in "Marchel" sawmill, drying to 10% humidity. Planks were cut to small beam. Material only with radial rings was used in the next step. Experimental material was split into 15 groups (each had 30 samples) and then treated by heat in nitrogen atmosphere (thermal modification). The temperature and heating time was variable (temperature from 160°C to 220°C, and time from 2h to 6h). After modifications mechanical and physical properties were measured (modulus of elasticity, flexural strength, compressive strength along fiber, hardness, density, color in CIE-L*a*b* standard). At the lowest temperature of modification, changes of mechanical properties were small, but with increase of the processing time the changes were more visible (color, mechanical properties). Similar dependence was observed when the temperature increased from 180°C to 220°C. In higher temperatures, the changes were observed in shorter time. A 6 hour treatment in temperature of 220°C was unsuitable. Wood samples in this temperature had little cracks and the shape of the cross section was not rectangular. Most mechanical properties of poplar wood after modification were better compared to native samples – in lower temperature. Hardness, MOE, flexural strength, compressive strength along fiber, color coefficient a and b, have increased. Only two parameters have decreased i.e. density and L (color parameters). After modification the difference of wood color ΔE was lower than before temperature treatment. The highest modification temperature destructed structure of the wood – most of mechanical parameters were worse in comparison to native sample.

Keywords: *poplar wood, thermal modification, nitrogen, mechanical properties, colour*

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VOLATILE ORGANIC COMPOUNDS EMISSION FROM CHOSEN SOFTWOOD SPECIES

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Wood of various species, especially resinous softwood, due to its chemical composition is a natural source of volatile organic compounds (VOC) emission. Therefore, products made of wood have an influence on indoor air quality. VOC emitted from softwood are primarily dicyclic and monocyclic monoterpenes, followed by aldehydes produced as a result of the oxidation of unsaturated fatty acids contained in wood. Considering the different anatomy and chemical composition of heartwood and sapwood, compounds emitted from these zones differ in quality and quantity. The type and amount of the emitted VOC is also influenced by habitat, geographic location, and tree growth conditions.

This study aimed at determination of VOC emission from fresh softwood of various species. Tests were carried out for pine (*Pinus sylvestris* L.), larch (*Larix decidua* Mill.), spruce (*Picea abies* (L.) Karst.), and fir (*Abies alba* Mill.). Wood for tests was sampled from trees of similar age (ca. 100 years) at breast-height, originating from the same biosocial class (dominating trees). The emission was determined from cross-section, separately for the heartwood zone and the sapwood zone. Dimensions of the test samples were chosen to provide the test chamber load ratio equal to 1 m^2/m^3. The tests were carried out in the chambers acc. to standard PN-EN ISO 16000-9, and VOC chromatographic analysis was performed by the method TD-GC/MS.

Compared to the values of TVOC concentration indicated for individual species, it was observed that pinewood was characterised by the highest VOC emission from heartwood. Irrespective of the exposure time, the VOC emission from that part of the cross-section was approximately 17 times higher compared to larch and spruce. In the case of fir wood the differentiation was greater. In this case, the VOC emission was 25 times higher (on the third day) and 40 times higher (at the end of the exposure period). Such high differentiation of TVOC values observed for pine, larch and spruce was not recorded for the sapwood zones. After the third day of exposure the highest TVOC concentration was observed for spruce sapwood (1746 $\mu g/m^3$). This concentration was approximately 1.2 times higher compared to TVOC recorded for pine and larch, and 13 times higher compared to fir. The obtained results proved that there was a difference between TVOC concentrations determined for the tested species, as well as between TVOC concentrations for an individual species, depending on the cross-section zone.

Keywords: *emission of volatile organic compounds, VOC, sapwood, heartwood, pinewood, larch wood, spruce wood, fir wood*

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OPERATIONAL MODAL ANALYSIS OF FRAME BUILDING MODULE DURING ROAD TRANSPORT

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A real structure performance does not necessarily match the way the structure's numerical model reacts to a load applied – even though it was constructed by specialists in the field and with the use of a state-of-the-art generation of software based on the finite element method – FEM. Inconsistencies are even greater, when the construction material is not as uniform and isotropic as steel, but wood, whose mechanical properties depend on a greater number of variables, like whether the loads apply longitudinally or across the grain.

In such cases, it is necessary to customise a previously developed numerical model (model calibration) to fit real conditions of the performance. More and more frequently, to carry out experimental modal analyses, some measuring equipment and software is used to this end, which allows for estimation of credible structure modal parameters, i.e. particular normal mode shapes and their equivalents of natural frequency and modal damping values, which are necessary for credible calibration of a numerical model developed in FEM. It is not in every case, however, that one can excite vibration in a structure by means of classical modal exciters or modal hammers. Being a relatively new approach in the structure modal analysis, vibrations present in immediate surroundings of a tested object are used for this purpose. An analysis of such type is called the operational modal analysis.

This study seeks to estimate credible modal parameters for one of the wooden modules of a multi-storey, multi-unit residential building, constructed by UNIHOUSE in Bielsk Podlaski, during its test road transport to its project site.

The operational modal analysis of the frame building module was conducted with the use of a dedicated software LMS Test.Lab Spectral Testing.

Measurements of vibration accelerations were carried out in 12 measurement points of the tested frame building module using a 32-channel and 24-bit data acquisition hardware type SCADAS Recorder from SIEMENS with 130 dB dynamic range and signal to noise ratio – minimum 106 dB, as well as a set of 10 high sensitivity triaxial piezoelectric accelerometers type TLD356B18, manufactured by PCB Piezotronics and two uniaxial, high sensitivity accelerometers type 333B50 – also manufactured by PCB Piezotronics.

As a result of the tests and analyses executed on the proposed structure modal model, it was possible to estimate modal parameters of a single module of a frame multi-storey building, which may be used for calibration of the structure numerical calibration in the FEM software. The modal parameters obtained may also be used to develop guidelines for drivers of vehicles transporting such frame building modules with the aim to describe vehicle engine rotational speeds to be avoided because of possible resonant vibration present in transported wooden structures and possible damage caused thereby.

Keywords: *frame building module, operational modal analysis, modal parameters*

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WALNUT SHELLS AS A FILLER FOR POLYMERIC MATERIALS

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Engineering materials, including among others polymeric composites modified with wood derivatives, are widely applied in automotive, furniture and construction industries. Such natural modifiers are gaining more attention, with coconut being the most commonly used. Due to increasing customers' environmental awareness, introducing of food industry waste into polymers, e.g. walnut shells, became crucial.

This work presents selected properties of polypropylene-based (iPP) composites modified with an organic filler, namely walnut shells (NUT). Two series of composites were prepared via twin-screw extrusion process, followed by injection molding. The first series, named iPP/NUT, contained 10, 20 and 40 wt.% of walnut shell powder while the second, abbreviated iPP/NUT/MAPP, apart from nut filler included polypropylene-graft-maleic anhydride (MAPP) which aimed to promote adhesion between the polymer and filler. The aim was to describe an influence of the walnut shell filler and compatibilizer on selected properties of the composites. The following measuring techniques were applied: differential scanning calorimetry, thermogravimetry, dynamic-mechanical thermal analysis, melt flow index and scanning electron microscopy. The conducted measurements revealed a distinct influence of the filler on properties of iPP/NUT composites in comparison with unmodified polypropylene. It was proved that addition of polypropylene-graft-maleic anhydride to the formulation enhanced interfacial bonding between the polymeric matrix and filler. Moreover, introduction of organic filler to the polymeric matrix increased its stiffness without influencing polypropylene crystallization kinetics.

Keywords: *composite, walnut shells, polypropylene*

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BIODEGRADABLE COMPOSITES MODIFIED WITH WOOD FILLER

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Polylactide (PLA) is a biodegradable polyester that can be obtained from renewable agricultural sources. Recyclability and compostability are the greatest advantages of PLA, which, thanks to these features, outstands other synthetic polymers. Physical and mechanical properties of PLA can be easily manipulated through the polymer architecture. Moreover, its production costs have been decreased in the latest decade, which, coupled with increasing environmental awareness, makes PLA one of the most extensively researched and utilized biodegradable and renewable materials.

This work investigates properties of polylactide-based composites modified with wood filler (WF). Two series of composites were prepared via twin-screw extrusion and compression molding process. The first series, abbreviated PLA/WF, contained 10, 20 and 30 wt.% of wood filler while the second, named PLA/WF/3-APE, apart from wood filler included 3-aminopropylthrietoxysilane (3-APE) which aimed to promote adhesion between the polymer and filler.

The aim was to describe the influence of the wood filler and silane coupling agent on mechanical properties, crystallization kinetics, thermal stability and structure of the obtained composites. The following measuring techniques were applied: static tensile tests, differential scanning calorimetry, thermogravimetry and scanning electron microscopy. The conducted measurements revealed an increase of Young's modulus of iPP/NUT composites in comparison with unmodified polylactide. It was proved that introduction of silane coupling agent to the formulation enhanced interfacial bonding between the polymeric matrix and the filler. Moreover, a distinct influence of the filler addition on PLA crystallization kinetics and thermal stability was noted.

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***Keywords:** polymer composite, wood filler, polylactide, mechanical properties*

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MARK-HOUWNIK COEFFICIENTS OF CELLULOSE IN LiCl/DMAc SOLVENT FOR DETERMINING MOLAR MASS DISTRIBUTION

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The method of molar mass distribution analysis of cellulose using size exclusion chromatography (SEC) was optimised. Differences between viscometric measurements and those obtained with SEC were discussed along with the influence of equation applied on calculated average polymerization degree. Ubbelohde viscometer was used to experimental determination of intrinsic viscosity of two cellulose samples obtained from poplar wood by Kürschner-Hoffer method. Series of cellulose solutions of decreasing concentration in N,N dimethylacetamide/lithium chloride (DMAc/LiCl) were tested. Strong dependence of DMAc/LiCl viscosity on LiCl concentration was found. Thus, careful and precise sample preparation was necessary for reliable results. Dependence of viscosity number and logarithmic viscosity number was determined and extrapolated towards infinite dilution. Excellent agreement of extrapolated values was achieved. SEC analysis was performed and Mark-Houwink coefficients were optimised by numeric method to obtain values of intrinsic viscosity equal to viscometric ones. New values were obtained: $K = 4.58 \times 10^{-3}$ cm^3/g and $\alpha = 0.957$. Average molar mass of cellulose tested showed satisfactory agreement with standard viscometric method involving cupriethylenediamine hydroxide (CUEN) as solvent.

Keywords: *cellulose, Mark-Houwink coefficients, size exclusion chromatography, DMAc*

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RHEOLOGICAL CHARACTERIZATION AND STORAGE STABILITY OF NANOCELLULOSE REINFORCED UF RESIN COMPOSITIONS

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Currently, approximately 90% of wood-based materials all over the world are produced based on synthetic amino-formaldehyde resins, which generate formaldehyde emission both during the production process and from the finished product. Taking the growing concerns about environmental pollution into account and in the light of formaldehyde reclassification (Carc. 1B acc. to the Regulation of the European Commission No. 605/2014 of 5 June 2014) new alternative solutions, especially bio-based adhesives are of great importance nowadays. Due to high mechanical strength modulus and tensile strength, nanocellulose can be utilized as nanobuilding block for development of new multifunctional materials. The current state of the art confirms the suitability of nanocellulose for the composite wood products technology.

The aim of this work was to investigate the influence of nanocellulose addition on rheological properties and storage stability of UF-based adhesive compositions for wood-based products. Three types of urea-formaldehyde resins characterized by different molar ratios of F/U were used for the research. Resin modification with nanocrystalline cellulose (NCC) and nanofibrillated cellulose (NFC) content of 1.0 to 5.0% by dry weight of resin were prepared and mixed with homogenizer to achieve a proper distribution of nanocellulose in the UF mixture. The measurements of viscosity and flow curves characteristics were performed with Brookfield Rheometer LV DV2T EXTRA in controlled shear rate mode and at temperature (23±2°C), taking into account the constant volume of the test sample (9 ml), the type of spindle used (SSA, SC4 31) and the measurement time after which the viscosity was read (30 s). The storage stability of UF-nanocellulose compositions was evaluated by monitoring the viscosity during 4 weeks of storage at room temperature (23±2°C).

The flow curves of the used NCC and NFC at 2.0% and 2.5% concentration, respectively, exhibit a shear thinning behaviour. In contrast to NCC, UF resins shows Newtonian flow behaviour over the whole measuring range. Using NCC in UF resin leads to lower viscosity of composition with the higher NCC content, but it did not lead to change in the flow characteristics. However, for NFC reinforced UF resin compositions, especially for the NFC content of 4.0/wt. and 5.0%/wt. the viscosity was higher than viscosity of neat UF. Moreover, the flow curves began to possess the shear thinning behaviour. The research demonstrated the suitability of nanocellulose as a wood adhesives' novel component, characterized by the desired properties in terms of its technological usefulness. Modified resins keep their rheological behavior and the proper viscosity during 4-weeks storage in the limits which allow to use them in wood-based panel industry.

The research was carried out within the project: "New biopolymer adhesives modified with silanes and ionic liquids for application in wood-based materials technology'' funded by the NCBR under the LIDER VII Programme.

Keywords: *nanocellulose, UF adhesive, rheology, storage stability, wood-based products*

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THE INFLUENCE OF SELECTED TECHNOLOGICAL PARAMETERS ON EMISSIONS OF VOLATILE ORGANIC COMPOUNDS FROM PINE VENEER AND PINE PLYWOOD

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In last years more attention has been paid to air quality tests. The interest of many scientific institutions in this issue stems from the fact that indoor air contains a broad spectra of various pollutions, which strongly influence physical comfort and health of room users. According to the information from technical literature people spend more than 90% of time inside buildings, in which they are isolated from the outside environment. One of the causes of indoor air pollution is emission of volatile organic compounds from wood elements and wood products such as plywood, particleboard, OSB, MDF of indoor equipment.

The influence of selected technological parameters such as: time of seasoning, temperature and time of pressing on emissions volatile organic compounds from pine veneer and plywood has been investigated. Tests were performed using chamber method and TD-GC/MS method according to PN-EN ISO 16000-9 and ISO 16000-6.

The main compounds emitted from pine veneer and plywood were monoterpenes and carbonyl compounds.

The extent of VOC emissions depended on the seasoning time and temperature treatment for pine veneer, and temperature and time of pressing for pine plywood.

In both cases the composition of the analyzed air was dominated by monoterpenes and carbonyl compounds. Significant decrease of the content of monoterpenes along with the formation of carbonyl compounds was observed during storage (8 hrs to 48 mouth) and temperature treatment (6min/120°C) of pine veneers or increasing temperature (120 to 140°C) and time (6 to 18 min in 140°C) of pressing of pine plywood.

The highest emissions were observed for α-pinene and Δ3-carene and β-pinene and D-limonene among monoterpenes and for hexanal among carbonyl compounds.

Keywords: *pine veneer, pine plywood, emission of volatile organic compounds (VOC)*

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INFLUENCE OF THERMAL MODIFICATION ON THE SELECTED ACOUSTIC PROPERTIES OF BLACK POPLAR (*Populus nigra* L.)

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Poplar represents fast growing group of trees with significant potential for plantations. Poplar wood from plantations has low density, mechanical properties and durability. Black poplar wood has the lowest 5th durability class and very high porosity, over 70%, which affect high acoustical isolation at high frequency of the sound. Thermal modification of poplar wood changes the acoustic properties of this material, which has important meaning when the wood is used for wall panel, bottom layers of the floors and acoustic isolation partitions. Testing correlations between parameters of thermal modification and acoustic properties of modified wood allows for its more rational application.

The research object was to determine the influence of thermal modification in overheat steam at temperature 160°C, 190°C and 220°C on the selected acoustic properties of black poplar (*Populus nigra* L.). Modification was carried out in the laboratory conditions. Acoustic properties were tested for two levels of wood moisture content. In this work the ultrasonic waves propagation velocity, dynamic modulus of elasticity and acoustic isolation of black poplar wood were determined. Longitudinal waves velocity and the dynamic modulus of elasticity were tested using the non-destructive ultrasonic method. In the tests based on the method of ultrasounds transmission, ultrasonic defectoscopy equipment was used. The low values of longitudinal ultrasonic waves velocity and the dynamic modulus of elasticity parallel to the grain were noted for black poplar wood, which is also characterised with the low density of this wood. The tested properties show differences between wood modified at various temperatures.

Keywords: *thermally modified wood, black poplar wood, porosity, longitudinal ultrasonic waves velocity, dynamic modulus of elasticity*

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INFLUENCE OF WOOD MOISTURE CONTENT ON THE COMPRESSIVE STRENGTH AND HARDNESS OF THERMALLY MODIFIED BLACK POPLAR (*Populus nigra* L.)

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Application of thermal modification allows improving some properties of wood. In the literature the influence of technological parameters: time and temperature modification on the properties of wood is particularly analyzed. As indicators of the quality of thermally modified wood most commonly are used: shrinkage, swelling, equilibrium moisture content for normal conditions, static bending strength, modulus of elasticity and colour change. There are limited data regarding influence of moisture content on the compressive strength and hardness of thermally modified wood. It is important to identify these dependencies because thermal modification of wood changes its hygroscopic properties and other properties correlated with moisture content. During the modification, the wood undergoes partial pyrolysis, which changes its chemical composition. Under the influence of high temperature in the range of 160-220oC, hemicellulose and part of cellulose are degraded, some of the extractives are removed, which may affect not only the physical properties of wood but also the mechanical properties. Therefore, it is reasonable to conduct research on the influence of moisture on the mechanical properties of thermally modified poplar wood. This is also particularly important because of the fact that the poplar wood belongs to low density species (density below 500 kg/m^3), which may also determine the relationship between the tested properties of thermally modified wood.

The research objective was to determine the impact of wood moisture content on the compressive strength and hardness of thermally modified black poplar. Wood was modified in overheated steam in a laboratory conditions. The modification temperatures were 160°C, 190°C, 220°C, while modification time reached 2 h. The influence of moisture content was determined at three levels: 0%; equilibrium moisture content for normal climate (temperature 20°C±2°C, relative humidity 65%±5%); moisture content in the state of maximum saturation of wood. Black poplar hardness was determined using the Brinell method. Statistical analysis was performed using STATISTICA Version-12 software of StatSoft, Inc. The significant differences were found in the compressive strength and hardness of thermally modified black poplar wood, depending on the moisture content and thermal modification parameters.

Keywords: *compressive strength, hardness, moisture content, black poplar, wood thermal modification*

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CHANGES OF WATER SORPTION IN WOOD AFTER MODIFICATION BY IN SITU COPOLYMERISATION OF STYRENE AND MALEIC ANHYDRIDE

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Wood is very important material in everyday use. Starting from big constructions, elevations, floors, furniture and ending with small items like jewelry and other. Unfortunately, it has a poor resistance to weather and biotic agents, what limits its working life. Extending the durability of wood is important question from the viewpoint of timber managing. Very important clue is to use a nature-friendly ways to improve wood properties. Styrene can be obtained from discarded waste of foamed polystyrene and other products made of polystyrene.

The aim of this work was to investigate water repellence of wood due to in situ polymerisation in lumen. To obtain styrene a foamed polystyrene was subjected to distillation with the application of laboratory apparatus. Polymer degradation was performed at the temperature of 250 °C. Volatile products of this reaction (mainly styrene) were collected at receiver.

Wood of four native species – ring-porous oak and ash, diffuse-porous beech and poplar – was used. Samples with dimensions of 20 × 20 × 30 mm were oven-dried as long as required to reach its stable dry weight, then weighted and preciously measured with caliper.

In the first step, wood was vacuum saturated with a mixture of styrene, maleic andhydride and benzoyl peroxide as an initiator. In the next step, treated samples were weighed and the polymerisation was started by temperature rise to 105 °C, heated overnight to complete polymerization process. Once again samples were weighed and measured. WPG was calculated by mass difference before and after modification.

The objective of this study was to determine possible relation between the styrene-maleic copolymer presence in wood and water sorption in long and short-term tests. It was found that the rate of water sorption is much lower for modified wood. The results strongly differ between used wood species, but in all cases, for an hour of soaking, water sorption was at least 2 times or 10 times lower for ring-porous wood and poplar wood, respectively.

Keywords: *wood modification, in situ polymerisation, styrene, maleic anhydride, water sorption*

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COLLAGEN AND KERATIN AS ENVIRONMENTALLY FRIENDLY NATURAL POLYMERS FOR MODIFICATION OF WOOD ADHESIVES

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Collagen and keratin, naturally occurring fibrous biopolymers, are secondary raw materials from leather and food industry. These biomaterials are suitable for a range of different technical or medicinal applications. In this study they were chosen and tested as potential agents in lowering the emissions of formaldehyde from urea-formaldehyde (UF) adhesives.

The experiments with modified collagen and keratin confirmed the possibility to alter the viscosity of adhesive mixtures, significant decrease of formaldehyde emissions from condensed UF adhesives and plywood, while maintaining the original stability of the glued joint.

ATR-FTIR spectra of collagen and keratin samples showed similarity, with respect to the bands typical for protein materials. Presence of sulphur groups was also proved for keratin samples. The MALDI-TOF spectra of both keratin and collagen samples showed a wide distribution of molecural weights, while showing a great importance on type and length of hydrolysis applied. The results of dynamic viscosity measurements showed, that collagen and keratin are suitable viscosity modifiers. Results of laboratory tests confirmed, that collagen and keratin, prepared from leather waste, are suitable additives for lowering of formaldehyde emission from wood products glued with UF adhesive. Formaldehyde emissions were assessed from five-layer plywood according to JIS A 1460 (2001). “Building boards. Desiccator method” Quality of gluing was tested according to standards EN 314-1 and EN 314-2. Tested plywood fulfils the requirements of the standard for class of gluing 1 – they are suitable for application in normal interior environment.

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Keywords: *collagen, keratin, biopolymer, formaldehyde, emission, gluing, plywood*

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POLYLACTID MODIFIED LINSEED

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Polylactide (PLA) belongs to the group of biodegradable polymers. It is a thermoplastic polymer belonging to the polyester group. Produced by the synthesis of lactic acid. The lactic acid required to make the polymer is obtained, inter alia, biologically and petrochemically. PLA is characterized by high transparency, high stiffness, ease of processing, high density, resistance to fats, UV resistance, high odour barrier and low thermal resistance. A number of these qualities create many uses for the PLA, the main ones being: medicine (threads, implants), packaging industry (bottles, food containers, foils). The aim of the study was to evaluate the properties of linseed modified polylactide and the addition of polyethylene-graft-maleic anhydride compatibilizer. Test samples were first extruded using a 16 mm screw coil screw extruder with a L / D ratio of 40, ZAMAK, then standardized test specimens were injected (Mining Chemical Products piston injection molding machine). The injection temperature was 160°C and the injection pressure was 6 bar. Based on the research, it has been found that the introduction of linseed into the polylactide matrix results in a decrease in mechanical properties (tensile strength, Young's modulus). Note that the compatibilizer additive improves the polymer / filler miscibility, resulting in improved properties of PLA / linen composites. In addition, the glass transition temperature and cold crystallization temperature were found to be in the direction of lower temperatures, which may be indicative of the plasticizing effect of linseed.

Keywords: *polylacide, linseed, DSC, mechanical properties*

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THE COMPARATIVE ANALYSIS OF VARIABILITY OF SELECTED FEATURES OF MACROSTRUCTURE AND DENSITY OF SPRUCE WOOD (*Picea abies* (L.) H. Karst.) FROM STANDS LOCATED IN TWO DIFFERENT NORWAY SPRUCE RANGES IN POLAND

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The aim of the study was to compare the annual ring width, latewood share and density of spruce wood coming from the north-eastern and south-eastern Norway spruce range. The twelve trial plots were located in twelve forest districts within the north-eastern Norway spruce range (Warmia and Mazury region), whereas within the south-eastern range (the mountainous region) eight trial plots were established in six forest districts in the Sudeten Mountains and twelve trial plots in seven forest districts in the Carpathian Mountains. In each trial plot the diameter at breast height was measured for all trees whose thickness was equal to or exceeded 7 cm. Moreover, for every trial plot fifteen spruce trees were chosen, from which increment cores were sampled using the Pressler borer. Next, the increment cores had their surfaces smoothed and served for measuring the width of annual rings, latewood zones and the share of latewood. Then, the cores were divided into 2-cm sections, for which the relative wood density was determined.

The performed analyses indicate that annual rings were wider in trees growing within the north-eastern range (the Mazury region) when compared to those from the south-western range (the mountainous region). Similarly, the minimal increment width values were higher in the north-eastern range and the Kruskal-Wallis test revealed that the differences were statistically significant (p=0,0000). On the other hand, the latewood share showed the opposite dependence than the above-mentioned characteristic. The wood from the Mazury region was characterized by a higher proportion of latewood than the wood from the mountainous areas and the statistical test indicated that the differences were significant (p=0,0227). The analyses of wood density showed slight differences between north-eastern range wood density and that from the south-western. However, the Kruskal-Wallis test revealed that the differences were statistically insignificant (p=0,0665).

Keywords: *annual ring width, latewood share, the north-eastern Norway spruce range, the south-eastern range*

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BACTERIOSTATIC PRE-TREATMENT OF POLY(LACTIC ACID) VENEERS BY RADIO-FREQUENCY PLASMA

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Alginic acid coated poly(lactic acid) (PLA) veneers were studied with respect to the increase of surface properties and bacteriostatic performance against two most used bacterial strains, Escherichia coli Ec) and Staphylococcus aureus (Sa). Radio-frequency (RF) plasma treatment was followed with formation of bushes in vapor state from three selected precursors (allylalcohol, allylamine, hydroxyethyl methacrylate) and subsequently alginic acid (AA) was deposited on the polymer. Surface analyses using various techniques confirmed, that AA was immobilized onto the surface of PLA veneers, where has been grafted. AA can inhibit bacterial growth, which can be also affected by the brush type. In this case, the polyanionic character of AA as a carbohydrate polymer plays the main role in antibacterial activity. The cell wall composition of tested bacterial strains, i.e. Ec and Sa, had various level of efficiecy due to different level of bacteriostatic performance. Wettability changes of the PLA surface after the polysaccharides immobilization by the multistep process were determined using the contact angle measurements. For experiments, the surface energy evaluation (SEE) system with CCD camera (Advex, Czech Republic) was used and a sessile drop technique was performed. An adhesion between two materials was characterized by the peel strength. Measurements were performed as 90° peel test using 5 kN universal Instron 4301 (UK) dynamometer. The antibacterial activity of prepared samples was tested against bacterial strains Sa and Ec using the inhibition zone method (diffusion test) on agar. The samples were incubated for 24 h at 37°C and then diameters of the inhibition zone were measured in 5 directions to obtain average values for calculations.

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Keywords: *adhesion, antibacterial, poly (lactic acid veneers), radio-frequency plasma, surface energy*

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STUDY OF SURFACE PRE-TREATMENT OF WOOD BY RADIO-FREQUENCY DISCHARGE PLASMA

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The various sorts of wood (oak, beech, maple, ash) were pre-treated using radio-frequency plasma in air at the 100 Pa pressure and surface adhesive has been investigated. The rougness of RF discharge plasma-treated beech wood surface analysed by AFM and nanoindentation slightly increased, but no significant changes were observed using SEM. FTIR-ATR spectra confirm the increase of the wood polarity in all cases during RF treatment caused by the increase of –OH groups concentration due to irradiation by RF plasma. The amount of carbon during plasma treatment of beech wood conversely decreased. The content of COOH, C-O and C=O groups after treatment by RF plasma significantly increased. The surface energy (mainly its polar component) of wood treated by RF plasma in air increased. The decrease of the plasma-treated beech wood surface energy during aging was faster for two days after treatment. The shear strength of adhesive joint of all studied sorts of wood using polyurethane adhesive increases non-linearly with time of plasma-treatment. FTIR-ATR spectroscopy confirmed that RF plasma modifications of wood on the surface of all kinds of wood stems lead to some changes that are also dependent on the time of plasma exposure. For all investigated wood species, this trend was not entirely demonstrable, but it was observed that the content of hydrophilic groups increased compared to wood samples that have not been modified by RF plasma.

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Keywords: *beech wood, surface treatment, plasma*

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RESOURCE-EFFICIENT FUEL ADDITIVES FOR REDUCING OPERATIONAL PROBLEMS IN BIOMASS COMBUSTION

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A significant amount of virgin wood and wood materials that are nowadays burned in heating- and CHP-plants, in order to reach EU renewable energy targets, could be more efficiently used for producing valuable products. At the same time, to a higher extend, low-value biomass could serve for heat and energy production, especially lately, when competition for virgin wood in Poland has increased causing rising prices and raw material shortages. Unfortunately, the interest in low-value biomass combustion is conditioned by the inferior quality of this raw material which results in, among others, lower economic efficiency of energy production, higher emissions of hazardous compounds as well as problems related to ash and slag formation. These factors, in turn, increase operation and maintenance costs (O&M) in heating- and CHP-plants and cause that low-value biomass combustion is seen as problematic. For example, heat and electricity producers turn away from raw materials such as bark or forest residuals which, due to their high heterogeneity (high content of leaves, needles, soil particles) and alkali chlorides formation during biomass combustion may cause severe ash deposition and corrosion problems in biomass-fired boilers. One of the ways to reduce these problems is to use cheap additives such as gypsum and halloysite and blend them with biomass. This approach has been studied in 5 EU countries within the framework of the ERA-NET Bioenergy project called REFAWOOD with the aim: 1) to propose efficient and innovative fuel additive design concepts for reducing ash related operational problems in combustion of low-value biomass; 2) to perform full-scale combustion tests to demonstrate the effectiveness of fuel-additive blends; 3) to assess the fuel and additive value chain and the utilization of ashes and 4) to determine the environmental and economic effects of using fuel-additive blends in CHP/heating plants. The results of this project are expected to enlarge the market for the use of low-value biomass fuels in heating- and CHP-plants and to reduce O&M costs resulting from slag formation.

Keywords: *resource-efficient fuel additives, biomass combustion, corrosion, ash*

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UTILIZATION OF POST-FERMENTATION MAIZE WASTE TO THERMAL CONVERSION

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One of the essential requirements while running a biogas plant is the proper management of the by-product, resulting from the production of biogas, i.e. the post-fermentation mass. Its amount corresponds approximately to the mass of substrates used in the fermentation process. One of the possibilities to develop a fixed post-fermentation fraction is its combustion. In this study, the basic physicochemical properties of the post-fermented pulp obtained from maize waste have been determined in terms of their combustion potential. The parameters such as elemental analysis, moisture content, volatile matter content, ash content, combustion heat and calorific value were determined for the raw material without pre-treatment as well as for the raw material after chemical hydrolysis and extrusion. The tested material was subjected to both acid and alkali hydrolysis. Acidic hydrolysis was carried out with sulfuric acid (concentration 3 and 7%) and alkali hydrolysis with sodium hydroxide (concentration 1 and 3%). Within the pre-treatment, the raw material was also subjected to low- and high-temperature extrusion. The low-temperature extrusion was made at 110°C, while the high-temperature one was in the range of 140-160°C. The purpose of the pre-treatment methods was fragmentation of lignin – a substance not degraded by the enzyme hydrolysis. On the basis of the conducted research, the suitability of the analyzed raw material for thermal utilization was determined. After drying, the tested material was characterized by high calorific value, similar to calorific values determined for other types of biomass such as oats, wood, energy crops or straw. The high nitrogen content was the significant parameter that allowed for distinction of the studied material from other types of biomass. The high nitrogen content of the combusted fuel is not a desirable parameter as it can cause the formation of nitrogen oxides in the combustion process. The decision to burn waste should be preceded by careful analysis of its physical and chemical properties, as it allows for an appropriate preventive action.

Keywords: *maize waste, physicochemical properties, chemical hydrolysis, extrusion combustion*

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POPLAR WOOD AS A FEEDSTOCK FOR SECOND GENERATION BIOFUEL – RESEARCH CARRIED OUT WITHIN THE FRAMEWORK OF THE CROPTECH PROJECT

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The Total Primary Energy Supply (TPES) from renewable energy sources was 13.4% in 2015 and is gradually increasing. According to estimates, by 2050, this percentage has the chance to triple up. Energy from biomass is expected to constitute more than half of renewable energy by 2020 and about 11% of energy produced in EU countries. Acquiring of renewable, safe and valuable energy resources is a key direction for the industry and most desirable solution is to replace conventional fuels with full scale production of their substitutes. This topic has become one of the many goals of the project named “Intelligent systems for breeding and cultivation of wheat, maize and poplar for optimized biomass production, biofuels and modified wood” (CROPTECH) which is financed by National Research and Development Center (NCBR). The project includes production of wood pellets from Polish poplar plantations as well as determination of fuel properties of raw material and wood pellets (ash content, volatiles, bulk density, mechanical durability, gross calorific value, net calorific value, the content of: carbon, hydrogen, nitrogen, sulphur, zinc, arsenic, mercury, cadmium, lead, chromium, copper, nickel and ash melting behavior) and is intended to acquire European quality certificates.

In the research area of liquid biofuel components, the methodology was investigated to separate furfuryl aldehyde from post-hydrolysis solution and to assess the possibility for its catalytic hydrogenation to furfuryl alcohol. Furan derivatives have been rated as prospective biofuels with commercialization status of major biofuel technologies in 2011 Roadmap for Transport Biofuels, developed by International Energy Agency.

The realization of CROPTECH will enable the protection of forest resources and high reduction of CO_2 emissions. Poland will gain competitive advantage in international arena in the field of transport biofuels, precise farming and precisely dedicated products of the wood industry.

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Keywords: *poplar, biofuel, furfural, bioenergy, fuel properties*

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DEGRADATION EFFECTIVENESS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAH) CONTAINED IN CREOSOTE OIL BY WHITE ROT FUNGI AND BACTERIA

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Processes of wood microbiological degradation caused by fungi, bacteria or algae can be inhibited effectively or even eliminated as a result of conservation treatments using various chemical conservation agents. Saturation of tele-technical poles, garden stakes and, in particular, rail sleepers requires the application of wood-preserving and hydrophobizing agents. Despite toxicity of its constituents, creosote oil is still employed on a wide scale in wood conservation practice, especially to treat rail sleepers.

Creosote oil consists of polycyclic aromatic hydrocarbons (PAH) making up ca. 50-70% of the oil constituents and contains among others: naphthalene, anthracene, fenanthrene and chrysene. In addition, creosote oil contains basic and acid constituents – cresols, phenols or purine methyl derivatives. Until now, no alternative conservation agent, which could replace creosote oil on industrial scale has been elaborated. The problem of utilization of the environmentally harmful creosote-containing wastes, due to their high quantities, calls for a scientific investigation with the aim to restrict oil content in the material, once it is out of service. The application of the creosote extraction method (from the impregnated wood) does not guarantee its complete removal from, for example, tele-technical poles or rail sleepers. The process of creosote oil biodegradation in wood following treatment with specific fungal and bacterial species can be used to improve the removal of this dangerous waste from the impregnated wood. Creosote-tolerant fungal and bacterial species are characterized by the ability to decompose polycyclic aromatic hydrocarbons.

In this paper, the biodegradability of creosote oil in the liquid medium and impregnated Scots pine wood (*Pinus sylvestris* L.), by the action of white rot fungi *Phanerochaete chrysosporium*, *Bjerkandera adusta*, *Irpex lacteus* and *Pseudomonas* and *Rahnella* bacterial species was presented. PAH analyses were conducted employing the method of high pressure liquid chromatography (HPLC) equipped with a fluorescent detector (FLD). Following a 16-week incubation of creosote-impregnated pine wood with the *Phanerochaete chrysosporium* fungus, the content of each of the examined polycyclic aromatic hydrocarbons was found to decline. The highest drops were recorded in the case of naphthalene, fenanthrene, acenaphtene, fluorene and pyrene. After 16-week exposure to the action of the *Phanerochaete chrysosporium* fungus, the change in the benzo(α)pyrene content in impregnated wood reached 27.3%. The selected *Pseudomonas* and *Rahnella* bacterial species also demonstrated the ability to decompose polycyclic aromatic hydrocarbons (PAH) contained in the creosote oil.

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Keywords: *creosote oil, polycyclic aromatic hydrocarbons, biodegradation, fungi, bacteria, HPLC*

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Pinus sylvestris L. FROM PUSZCZA NOTECKA: MULTI-ANALYTICAL APPROACH FOR OPTIMAL CONVERSION PATH

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Pinus sylvestris L. is the most popular wooden material used in building constructions and pulp technology. However, it can be also applied in other, more economically beneficial processes like bioethanol production, synthesis of xylose or glucose in commercial quantities and obtaining other substrates for chemical synthesis. The selection of an optimal conversion path of wood should base on knowledge of its chemical composition and physical properties. The overall aim of the research was to determine the chemical composition and characteristic of cellulose and lignin structure on molecular level of *Pinus sylvestris* L. wood from a primeval forest (Puszcza Notecka) in terms of its valorisation. The trees from four stands: two from the primeval forest and two from stands out of the primeval forest (used for comparison) were examined in the research. Percentage of chemical components of wood: holocellulose, cellulose, pentosans and lignin as well as components soluble in ethanol and ash were determined. Chemical analysis provided information on the amount of wood components. Their alteration at molecular level was investigated by Py-GC/MS, highlighting how trees' growth location can affect the formation of wood pyrolysis products. The differences of cellulose and lignin structure between compared feedstocks were also analysed by FTIR. It was shown that chemical composition of material from the stands in the primeval forest is more homogeneous in comparison to material from other investigated stands. Lower content of extractives in trees from the primeval forest facilitates gluing and finishing of wood-based materials. Low content of ash in this material gives possibilities to consider investigated feedstock to be used for energetic purposes. The highest content of holocellulose, 77.5%, was found in the wood gained from the primeval forest and this feedstock was the best for obtaining of carbohydrates derivatives. Both low content of lignin and low content of extractives in trees from Puszcza Notecka let them be applied in the fermentation process. The evaluation of the relative amounts of pyrolysis products deriving from holocellulose and lignin and FTIR analysis highlighted differences between feedstock growing in the compared areas. Obtained results indicated that the trees from Puszcza Notecka are an attractive feedstock for different technological sectors due to its homogenous chemical and physical features and thus it can potentially be used for countless economically-viable applications.

Keywords: *softwood, wood valorisation, wood quality, chemical composition, forest manageme*

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