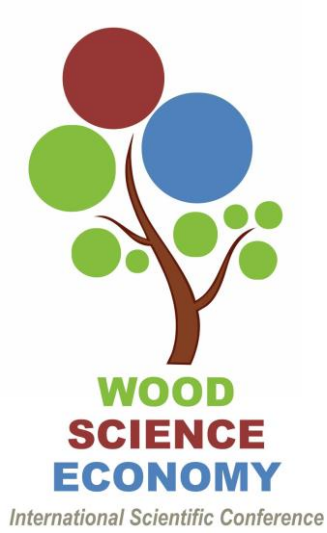
3rd International Scientific Conference

WOOD – SCIENCE – ECONOMY



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Proceedings

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LASY PAŃSTWOWE

Winiarska 1, 60-654 Poznan, Poland
phone: +48 61 849 24 00, fax: +48 61 822 43 72
e-mail: office@itd.poznan.pl, www.itd.poznan.pl

Grójecka 127, 02-124 Warszawa, Poland
phone: +48 22 185 53 53, fax: +48 22 185 53 71
e-mail: cilp@cilp.lasy.gov.pl, www.lasy.gov.pl

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GENERAL AGENDA

Day one (21.10.2019)

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09:50 – 10:00 Welcome

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Changing typologies in Canadian wood construction
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Jarosław Socha, *University of Agriculture in Krakow, Krakow, Poland*
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Martin Amoah, *University of Education Winneba, Kumasi, Ghana*
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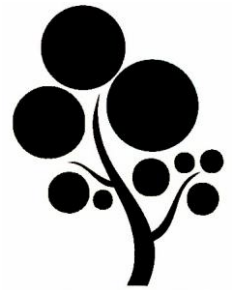
Session V: BIOENERGY – TRENDS AND DEVELOPMENTS

Session VI: WOOD MARKET – ECONOMIC AND SOCIAL ASPECTS

POSTERS

SESSION I
Challenges in forestry



CHANGING TYPOLOGIES IN CANADIAN WOOD CONSTRUCTION

Randall Kober

Laurentian University, McEwen School of Architecture, Sudbury, Ontario, Canada

Canada, the second largest land mass country in the world, is covered from the Atlantic to the Pacific Oceans in forest. Over the past 10,000 years First Nations inhabitants developed building technologies and construction techniques using this abundant natural resource. These timber responses to place varied greatly across vast and diverse areas of inhabitation. Many of these Nations were semi-nomadic, a lifestyle which dictated temporary habitations that could be readily assembled and disassembled. The inhabitations used the forest lightly, allowing its offering to return to the earth, enriching the soil and providing for future growth.

Subsequent European colonization of these lands brought different tools and ideas to the use of forest products. This comparatively brief period, with Viking settlements 1,000 years ago and sustained occupation beginning 500 years ago, saw the introduction of forged metals in tooling, which along with long traditions of hand-crafted joinery changed the ideas of temporality in building. These mass timber buildings firmly grounded themselves in their place and established a land claim.

The industrialization of the forest over the last century has led to another shift in thought and use.

Developments across the country saw the introduction of the 2x framing member and wire nails which made the development of light framing possible. The balloon frame and platform framing became the typical means of wood construction. The platform frame is still the most widely practiced building technique across the country. It is now being used on large scale buildings up to 6 stories in height.

At the moment Canadian forest product research and production is responding to a renewed demand for innovation by the building trades, engineering and architectural professions. New means of production are responding to emerging building typologies. Mass timber products and typologies are being concurrently developed. Many of these products and typologies have been reliant on research and practices undertaken over the past thirty years in central Europe. Canadian designers and builders are currently challenging this European dominance.

Keywords: *wood construction, wood architecture, building typologies, First Nations precedents, colonial precedents, light framing, mass timber*

Corresponding author: rkober@laurentian.ca

ACCURATE VOLUME CALCULATION OF PINE LOGS IN THE FOREST-BASED SECTOR

Zbigniew Karaszewski[1]*, Jarosław Socha[2], Mariusz Bembenek[3], Piotr S. Mederski[3]

[1] Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland
[2] University of Agriculture in Krakow, Krakow, Poland
[3] Poznan University of Life Sciences, Poznan, Poland

Different bark thicknesses affect log volume and, consequently, have an impact (multidirectional) on income throughout the whole forest-wood chain, affecting forest owners, forest entrepreneurs, transport companies, and customers. For forest owners and entrepreneurs, this may result in a decrease in income, if the real roundwood volume is underestimated. Overestimation of the bark content in logs may also affect the weight of transported roundwood. These doubts show the complexity of forest management and the unequal position of some actors in the forest-based industries. Proper wood measurement supports the idea of *sustainable forest operations* as regards three main principles, i.e. economics, optimisation of product quality and production, and people and society.

The volume calculation of pine roundwood (*Pinus sylvestris L.*) is based on the measurements of diameter over bark and log length. To obtain sole timber volume, bark thickness has to be subtracted according to local regulations. These are usually based on the thickness classes of roundwood or on the percentage of bark content in roundwood diameter. The aims of the research were to verify the existing bark allowances with actual pine bark thickness values and to analyse which factors influence variation in pine bark thickness.

The pine timber selected for the study was harvested from trees of different age classes, grown in different soil conditions. In this contribution, the final results, including full range variabilities and a statistical evaluation, will be presented in detail.

Keywords: *sustainable forest operations, roundwood measurement, bark share, under and over bark wood volume*

Corresponding author: z_karaszewski@itd.poznan.pl

THINNING OPERATIONS IN BEECH HIGH FOREST, ASSESSMENT OF IMPACTS ON SOIL AND ITS POTENTIAL FOR SOIL RECOVERY

Rachele Venanzi*, Rodolfo Picchio, Victoria Dayana Pellicori

Tuscia University, Via San Camillo de Lellis, Viterbo, Italy

The aim of this work was to assess the impact on soil according to two different silvicultural treatments applied. This issue was investigated to increase the forest management sustainability and the efficient use of forestry resources. Resulting improvements, if properly applied, in addition to the increase in environmental benefits, could also lead to an important growth of the technological qualities of the "wooden capital". The study area is located in the province of Vibo Valentia (VV), Municipality of Mongiana. The beech high forest has been divided into groups of stands, where two different silvicultural systems were applied: the traditional system and the innovative system. The innovative silvicultural treatment was aimed at diversification of wood production and at an increase in ecosystem services in respect to the traditional one. The differences in terms of silvicultural treatment did not concern logging methodologies. In both systems the work system was the Tree Length System and the extraction was done by winching and skidding. Ground damages were analysed in two different periods using appropriate methodologies (in 2014 and 2017, respectively, one year and three years after logging), considering the following parameters: bulk density, penetration and shear resistance, QBS-ar index, pH, and organic matter percentage. The obtained results showed the possibility to assess the impact of the silvicultural treatment and forest operations carried out in 2014 on soil condition and its recovery achieved until 2017. The choice of the innovative silvicultural system, at least in terms of the impact on soil and the specific characteristics of this forest, did not prove to have been the best choice in the short term, but it has proved to have been a good choice as regards the recovery potential. The choice of the traditional silvicultural system, on the other hand, seemed optimal, but not in terms of the ability of soil to recover from the impacts as well as not for a smaller impacted surface, in comparison to the innovative system. However, in both cases it was possible to notice how the recovery time of the main pedological characteristics can be considered inferior to 5/6 years, for similar forest types, applying sustainable silvicultural treatments and reduced impact logging.

Keywords: *silviculture, logging, sustainability, soil, wood production*

Corresponding author: venanzi@unitus.it

THE IMPACT OF WOOD FUEL PRODUCTION ON FOREST – SAVANNAH TRANSITION ZONES IN GHANA

Addo Koranteng[1]*, Isaac Adu-Poku[2], Tomasz Zawiła-Niedźwiecki[3]

[1] Kumasi Technical University, Kumasi, Ghana
[2] Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[3] Coordination Centre for Environmental Projects, Warsaw, Poland

Charcoal production has been a vital human activity since ancient times. Charcoal production has provided income and energy to the majority of the populace in sub-Saharan Africa, because it is comparatively cheap, reliable in terms of supply, convenient to use and imparts a professed taste to food. Charcoal production has consequently become a means of alleviating the rural and urban poverty and contributed considerably to the Gross Domestic Product (GDP) of developing countries. Ghana ranks among the top ten global charcoal producing countries. The growing trend in charcoal production in the African continent is improbable to change as urban population who are reckoned to be the main consumers of charcoal continues to surge. Notwithstanding the significance of charcoal in the socio-economic development, its production in Africa is being disparaged for its impact on forest loss and resulting woodland degradation. The impacts of charcoal production on woodland were assessed in the Forest-Savannah Transition Zone of Ghana.

The approach used for the study entailed the application of the geographic information system (GIS) and remote sensing techniques, field survey and community interactions. Key outcomes of the study include considerable land use/land cover alteration from one category to another as a result of agricultural expansion, urbanisation, charcoal production and fuel wood harvesting. The charcoal production is intensive and extensive and has contributed to the degradation of the Dense Woodland. The Forest Transitional and Savannah Woodlands are the major sources of fuel wood and mostly preferred. This makes the area very vulnerable to the effects of charcoal production. Wood harvesting for charcoal production has depleted and fragmented the Dense Woodland, changing its original condition and diversity, and contributing significantly to the greenhouse gas emissions, which affect global warming and climate change.

Keywords: *charcoal, dense woodland, forest loss, remote sensing, land use/cover*

**Corresponding author: dr.adokay@gmail.com*

SUPPLEMENTING STEMWOOD IN WOOD PRODUCT MANUFACTURING: THE COMPARISON OF DENSITY AND DECAY RESISTANCE OF A HARDWOOD SPECIES FROM NATURALS FOREST STANDS IN GHANA

Peter Kessels Dadzie[1]*, Paul Inkum[1], Martin Amoah[2], Micheal Acheampong[3]

[1] Kumasi Technical University, Kumasi, Ghana
[2] University of Education Winneba, Kumasi, Ghana
[3] Kumasi Technical Institute, Kumasi, Ghana

There is a global increasing alarm over the trend of tropical forest depletion and degradation rate on account of the multitude of ecosystem services the forests provide and the importance of timber in the construction and housing, and the furniture industries as well as the general developmental agenda of nations (TreePeople 2019; Mark et al 2014). Inefficient logging and extraction of timber in Ghana's tropical forests generate substantial quantities of logging residues/waste including merchantable stem (off-cuts) and branch wood which is left in the forest. This study sought to investigate the possibility of utilizing branch wood of Pterygota macrocarpa to supplement its stemwood for furniture and other wood product manufacturing by comparing their densities and decay resistance.

Stem offcuts and branch wood samples were extracted from a total of 4 felled trees of P. macrocarpa from 2 natural forest sites namely, Aboniyere in the Brong Ahafo Region (Site 1) and Esukawkaw in the Eastern Region (Site 2). ISO 3131 and the European Standard EN 252-1989 were respectively used to estimate density and decay resistance at two moisture levels.

The values of decay resistance of branch wood and stemwood of the species at the same MC were not significantly different at the 5% significance level. This implies that in terms of decay resistance, branch wood of the species could supplement its stemwood. Both moisture level and density affected decay resistance but the influence of density appeared significant (at least $P < 0.05$). Both MC and density appeared to predict the decay resistance of branch wood with relatively higher accuracy than that of stemwood.

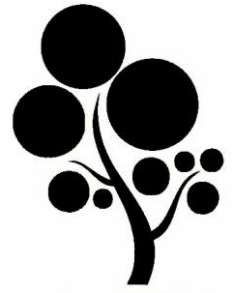
This research appears to provide indications that the influence of density on the durability of wood could largely be attributable to the density rather than MC differentials between the wood types of the species. Branch wood of the species can be used to augment its stemwood to economize the use of wood which will subsequently lead to reducing the deforestation rate.

Keywords: *deforestation; wood durability; Pterygota macrocarpa; branch wood; Ghanaian hardwoods; wood decay*

** Corresponding author: peterdadzie71@gmail.com; pkkdadzie@yahoo.com*

SESSION II

Advancements in wood science



FLAMMABILITY OF CELLULOSE ENCRUSTED WITH EXPANDABLE GRAPHITE

Anyelkis Batista*, Bartłomiej Mazela, Wojciech Grześkowiak

Poznan University of Life Sciences, Poznan, Poland

Constituting parts of plants and microorganism, cellulose is a natural polymer that exists in a large volume on Earth. Due to cellulose sustainability, its use in various applications is increasing rapidly. Cellulose-based fibres (CBF) are largely used in the textile industry, filtration, and also for fibre-reinforced composites. However, its resistance to burning continues to be a challenge to researchers and technologists. Resistance to burning is one of the most useful properties that can be imparted to fibres. Expandable graphite (EG), used in protection methods to improve burning resistance of flammable materials, has been given much attention by researchers over the past decade. New studies indicate that EG is a good source of carbonization agent for the effective and environmentally friendly intumescent systems. However, literature provides only insufficiently detailed reports on the behaviour of EG-IFR systems concerning cellulosic materials. Although EG is used in a growing number of IFR systems as a blowing agent that suppresses flammable gases intensively to 75%, while reducing the flame spread index, its application to cellulosic material is not so popular in today's cellulose industry. Mass loss calorimeter (MLC) is frequently used to investigate the flammability properties of different types of materials, delivering a suitable sort of technical data. Recent analysis of thermal stability of ligno-cellulosic materials under known conditions deliver the decomposition temperatures (Td) of lignin, hemicelluloses and cellulose – the last component with Td =320^{o}C, and char 6% by mass. The current study focuses on flammability concerning solely the cellulose component.

In this study special attention was given to the Cellulose-based Model Material (CMM) encrusted with EG. The general objective of the research was to determine its basic fire resistance properties. The scope of the research involves the measurement of the following parameters: time to ignition (Ti), time to flame out (Tf), heat release rate (HRR), and mass loss (ML).

Samples of cellulose sheets were manufactured with the use of Hydropulper and Rapid-Koethen devices. Two types of EG were encrusted into the cellulose sheet structure at the cellulose pulp preparation stage. The main difference between ES20 C200 and ES100 C10 was that ES20 C200 had a finer particle size (90% <75µm) and thus lower expansion volume (20ml/g). Three variants of cellulose sheets were prepared: control sheets (pure cellulose), sheets with graphite ES200 C20, and sheets with graphite ES100 C10. Sodra Black Cellulose fibres, of the length of 2.05, the width of 30.0µm and the density of 700 kg/m^3, were used in the process of the cellulose sheets manufacture. The cellulose milling time and the drying time was 30 and 40 minutes, respectively. The drying temperature of the final sheets was set to 93oC to avoid graphite activation. The final sheets were conditioned at the room temperature of 20^{o}C and the relative humidity of 60%. All the samples are subjected to MLC measurements. Heat flux at 35kW/m^2 was estimated as a suitable level for all tested samples. This study determined the flammability properties of CMM by measuring the time to ignition (Ti), time to flame out (Tf), heat release rate (HRR), and mass loss (ML).

On average, Ti of ES100C10 was 4s faster than that of control sample, whose registered average was Ti = 23.33s, while the Ti average of 21s was reported for CMM with ES20 C200. The Tf for all three variants was longer in the case of CMM with ES100 C10 whose average was 112.66s, while in the case of pure cellulose and CMM with ES20 C200 the registered average values were 87.66s and 108s, respectively. The average HRR for all three variants was 62.49 kW/m^2 for pure cellulose, 45.12 kW/m^2 for CMM with ES20 C200 and 39.81 kW/m^2 for CMM with ES100 C10. The addition of EG showed an increase in the flame-retardant effectiveness of cellulosic material. Although Ti for all CMM variants was shorter than that of control samples, this fact actually favoured the promotion of char forming. The improved physical characteristics of char were achieved by increasing the amount of the insulated layer and reducing crack formation. The HRR for CMM with bigger encrusted particle had a maximum value of 71.51kW/m^2, which represented 68.81% less heat released to the system compared to pure cellulose with a maximum value of 229.72kW/m^2. CMM with a smaller encrusted particle, however, demonstrated 60% less heat release compared to the reference system. Consequently, CMM with ES100 C10 was the best performing system regarding all three observed parameters.

Keywords: *expandable graphite, mass loss calorimeter, char, cellulose, flammability*

** Corresponding author: anielkis.batista@up.poznan.pl*

FUNCTIONAL POLYMER COMPOSITES FOR THE FURNITURE INDUSTRY

Marta Fiedot-Toboła*, Anna Dmochowska, Wojciech Stawiński, Jacek Marczak

Łukasiewicz Research Network – PORT Polish Centre for Technology Development, Wrocław, Poland

Furniture is used in everyday life and in all branches of industry. It is made of various materials, of which the most popular are products based on wood and wood-like products, e.g. medium density fibreboard (MDF). The wide range of applications of these elements implies the need to give them additional functionalities tailored to their service life conditions. Important features added to wooden products are hydrophobic, antibacterial and antifungal properties. These types of additives allow furniture to be used in places such as healthcare facilities. In addition, they prolong service life of wooden/wood-like elements used in an environment characterized by high humidity and high risk of microbe or fungus development. One of the most common places where such conditions are found is bathroom. It is also preferred that the above-mentioned type of furniture is characterised by reduced flammability. These goals are usually achieved by applying hydrophobic polymeric coatings on wood and wood-like products with the addition of active agents that give them the above-mentioned features.

In the study zinc oxide or layered minerals, like vermiculite and hydrotalcite, were used as functional ingredient in polymer composites. Firstly, methods for synthesizing these compounds were developed, and then a procedure for producing polymer composites. The obtained samples' features were determined by scanning electron microscopy (SEM), infrared spectroscopy (FTIR), X-ray diffraction (XRD), thermogravimetry (TG), and a differential scanning calorimetry analysis (DSC) combined with a mass spectroscopy analysis of the observed gas products (QMS). Additionally, antimicrobial activity and flammability was measured.

The obtained results clearly showed that by adding functional dopants to polymer matrices their functional properties could be controlled. Zinc oxide acted especially as antimicrobial agent against bacteria and fungi. While layered, minerals worked well as flame retardants. Thanks to their high specific surface and water release from their structure in high temperatures, they increased the activation energy of polymer degradation and reduced the amount of produced gases. The obtained polymer composites could be potentially used as outer layers of furniture, especially of those which are to be used in bathrooms, outdoors or in the healthcare sector. To improve these materials, additional research connected with the integration of composites with wood or wood-like elements will be conducted.

This study was financed by the Polish Ministry of Science and Higher Education, statutory grant for supporting the research potential of PORT no. 205719/E-725/S/2018.

Keywords: *polymer composites, zinc oxide, layered minerals, antibacterial, flammability*

** Corresponding author: marta.fiedot-tobola@port.org.pl*

PROPERTIES OF CHIPBOARDS INTENDED FOR CONSTRUCTION PURPOSES SUBJECTED TO AGEING TESTS

Radosław Mirski[1]*, Adam Derkowski[1], Dorota Dziurka[1], Wojciech Bałęczny[2]

[1] Poznan University of Life Sciences, Poznan, Poland
2 Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland

The purpose of the research was to determine the impact of water and air of different humidity on the properties of chipboards made from chips of various quality and intended for use in humid conditions. Chipboards to be used in construction should meet the requirements specified in EN 309 or EN 300 standards. The former concerns boards made from chips smaller than 20-30 mm in length and 6-8 mm in width, which are randomly placed in the board structure, the latter refers to boards produced from chips that are approximately 100-120 mm long and 10-25 mm wide and set in a well-planned manner within the board structure and usually properly directed when forming the mat. The boards used in the research were MFP boards, laboratory chipboards of lowered density and OSB/3 boards that complied with EN 309 and EN 300 standards, respectively.

The laboratory chipboards were formed manually on a metal plate. Two types of boards were produced, differing in density: 500 kg/m^3 and 550 kg/m^3. The pMDI was used to glue the chips. The mat was pressed at 200°C at a pressure of 2.2 MPa for 225 s. After conditioning at 20 ± 2 °C and relative air humidity of 60 ± 5%, the following properties were assessed: modulus of rupture (MOR) and modulus of elasticity (MOE) according to EN 310 standard (1993); internal bonding strength (IB) according to EN 319 standard (1993); thickness swelling (TS) after 24 h according to EN 317 standard (1993); and water absorption (WA). The assessments of MOR, MOE, and IB were conducted on 10-12 samples.

All boards were put to two tests: resistance to humidity in the conditions of cyclic test in accordance with EN 321 standard and determination of dimensional changes resulting from changes in relative humidity according to EN 318 standard. The greatest changes were observed after one test cycle. Moreover, the boards made of fine chips demonstrated slightly higher resistance to the tested factors.

The authors are grateful for the support of the National Centre for Research and Development, grant no. BIOSTRATEG3/344303/14/NCBR/2018.

Keywords: *chipboards, MFP boards, humid conditions, mechanical properties, construction materials*

** Corresponding author: rmirski@up.poznan.pl*

TEST ASSESSMENT OF TIMBER MEMBER COMPRESSION STRENGTH PERPENDICULAR TO THE GRAIN

Janusz Brol*, Marek Węglorz

Silesian University of Technology, Gliwice, Poland

The design compressive stresses in the effective contact area Aef should be taken into account when calculating the load-carrying-capacity due to the compression perpendicular to the grain (bearing strength) according to PN-EN 1995-1-1. They are determined allowing for the effective contact length alongside the grain – contact length l increased by a maximum of 30 mm, but no more than the contact length l, the distance to the cross-member face a, and the clear distance length l1. The research aimed at evaluation of the load-carrying-capacity under the compression perpendicular to the grain of a timber post and the top or sill plates, i.e. the members of a timber frame. The test results were compared with the procedures for determining the load-carrying-capacity of timber members according to Eurocode 5 and PN-EN 408.

The research was carried out on the elements of a timber wall frame: the posts and top or sill plates. These elements were connected with each other by spiral nails. The test samples were made of a solid structural timber of C24 class joined longitudinally by glued finger-joints.

The compression stresses for sill plates of the dimensions of 60 mm × 160 mm, supported continuously, were implemented as follows in individual series:

a) in series 1: two side posts of the dimensions of 40 mm × 160 mm and one middle post of the dimensions of 80 mm × 160 mm at the clear distance length l = 545 mm,

b) in series 2: two side posts of the dimensions of 40 mm × 160 mm at the clear distance length l = 545 mm,

c) in series 3: double legs, two side posts each of the dimensions of 2 × 40 mm × 160 mm and one middle post measuring 40 mm × 160 mm at the clear distance length l = 525 mm,

d) in series 4: double legs, two side posts each with dimensions 2 × 40 mm × 160 mm at the clear distance length l = 1090 mm.

During the tests vertical, uniformly distributed load was applied to the top plate.

Inductive gauges were used to measure local deformations resulting from the compression of the posts to the top and sill plates. Additionally, for selected test samples, displacements were measured using the ARAMIS optical and measurement system.

The load-carrying-capacity of the timber across the grain was determined. The failure modes and deformations of timber grain in top and sill plates loaded perpendicular to the grain by vertical posts were observed. The tests were carried out until the failure of top or sill plate occurred. It was observed that after exceeding the elasticity of timber, clear dents of wood fibres in the top and sill plates were created, and they were limited only to the contact area of the post with the top and sill plates (there was no visible effect on the rest of the effective contact area). In the result of those wooden dents, the cutting of wood fibres in top or sill plates occurred at the side planes of vertical posts.

Thus, the need to modify the current approach of the PN-EN 1995-1-1 standard to determination of the effective contact area at compression perpendicular to the grain was emphasized.

Keywords: *compression perpendicular to the grain, effective contact area, wood, timber construction*

Corresponding author: janusz.brol@polsl.pl

THE HEAT-TREATED HOLM OAK WOOD – TECHNOLOGICAL CHARACTERISTICS AND PROSPECTS OF USE

Angela Lo Monaco*, Francesco Latterini, Rachele Venanzi, P. Rubiu, Rodolfo Picchio

Tuscia University, Via San Camillo de Lellis, Viterbo, Italy

The physical, mechanical and colorimetric characteristics of heat-treated Holm oak (*Quercus ilex L.*) were analysed to improve the valorization of the species widespread in Italy, but little used in the industrial wood sector. Traditionally, holm oak is considered a species suitable for the firewood production and the obtained charcoal is highly appreciated.

The boards were obtained from some holm oaks coppice in conversion located in Sardinia region. These stands represent an important wood resource for the local people and regional economy. Heat treatment was performed using a temperature-controlled laboratory oven, under atmospheric pressure and in the presence of air. Different temperature levels were tested.

The analyses confirmed substantially what had already been reported in literature concerning holm oak. In fact, the samples were characterised by values similar to those reported in literature for holm oak harvested in other areas of Italy.

The results confirmed that heat treatment improved the characteristics of holm oak, except for bending strength. This compromises structural use of heat-treated holm oak. The mass loss was insignificant. Heat treatment increased hardness and darkened the colour of wood, making it more attractive and suitable for use in the production of objects and flooring. Noticeable colour changes were reached at a higher temperature.

Furthermore, it should be emphasized that the potential of wood as regards its contribution to the mechanical stability of buildings is not only limited to structural timber, but the use of wood for flooring, objects, window frames and doors, furniture etc., also positively contributes to the mechanical strength of buildings, as wood is lighter than other materials. New possible applications of holm oak contribute to the improvement of the local economy and reduce the pressure on wood species considered precious, like tropical. The results obtained in this study are very interesting as heat treatment allows improvement of holm oak's characteristics without resorting to the use of polluting additives.

However, further studies are needed to evaluate the possibility of using holm oak wood for strictly structural purposes. These aspects could represent an important wood chain start-up for a new sustainable circular economy based on the green economy principles.

Keywords: *Quercus ilex, density, compression strength, bending strength, hardness, colour, wettability*

** Corresponding author: lomonaco@unitus.it*

VERIFICATION OF THE INFLUENCE OF VISUAL FEATURES ON THE STRENGTH INDICES OF SAWN PINE WOOD

Marek Wieruszewski*, Adam Trociński, Karol Łabęda, Radosław Mirski

Poznan University of Life Sciences, Poznan, Poland

Anatomical features and secondary defects occurring during machining of wood play a significant role in the raw material classification system. The parameters deciding the use of sawnwood for proper applications are, above all, its strength properties. In relation to the applied large-size elements, the effect of scale is becoming more and more important, which translates into an increase in the share of areas with defects.

To assess the suitability of pine wood for structural applications, its characteristics were verified by visual assessment. The scanning system allowing for the identification of these features was verified in the individual measurement of the distribution on and the share of defects within individual planes of wood. The obtained measurement results were referred to the brass of bending springiness which the wood was able to withstand.

In visual tests, the accumulation of features is correlated with the predicted strength indices of the examined types of wood. Proper interpretation of the obtained results allows to optimise the use of available wood resources and, at the same time, guarantees the achievement of the designed strength of the separated structural wood assortments. The broadening of knowledge of raw pine material may be of significant importance for the development of the industry and increase the share of domestic raw material in the construction industry.

A study within the framework of the project entitled "Enhancing the process and material effectiveness in the sawmilling industry", financed by the National Centre for Research and Development within the BIOSTRATEG programme entitled "Natural environment, agriculture and forestry", based on contract no. BIOSTRATEG3/344303/14/NCBR/2018.

Keywords: *pine, visual assessment, construction timber*

Corresponding author: marek.wieruszewski@up.poznan.pl

TECHNOLOGY OF BIOREMEDIATION OF INDUSTRIAL AREA CONTAMINATED WITH CREOSOTE OIL – IDENTIFICATION OF BACTERIA INVOLVED IN BIODEGRADATION OF PAHs

Mateusz Sydow[1]*, Ewa Kaczorek[2], Wojciech Smułek[2], Jadwiga Zabielska-Matejuk[1], Anna Stangierska[1]

[1] Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland
[2] Poznan University of Technology, Poznan, Poland

Contamination of the soil environment with anthropogenic substances has a significant impact on soil organisms (including plants), herbivores, and consequently on humans being the last link in the food chain. The contamination occurs not only during the transport of chemicals, but also during the production and storage of various chemical substances. Creosote oil is one of the most effective and, at the same time, relatively cheap wood preservatives. It is widely used for the protection of wooden railway sleepers, turnout sleepers, bridge posts, teletechnical poles, fence posts, bridge elements, wooden towers etc. There is a number of different bioremediation techniques used in the case of soil contamination with organic substances. The natural process of cleaning the environment without human intervention is relatively ineffective and long-lasting, which is why more and more bioremediation techniques have been explored over the years. One of the most efficient bioremediation techniques is bioaugmentation, i.e. the use of specially selected microbiological strains with high biodegradation potential, which introduced into the contaminated environment support the decomposition of hardly biodegradable compounds. The subject of the study was to identify indigenous bacteria involved in biodegradation of polycyclic aromatic hydrocarbons (PAHs). The research is a preliminary study in developing an original and innovative technology of bioremediation of soil contaminated with creosote oil on the premises of a railway sleeper treating plant.

Soil samples were collected using a mechanical drill from the depth of 0.5 to 4.0 m on the premises of the railway sleeper treating plant located in Koźmin Wielkopolski (Poland). Chemical analyses included determination of PAHs content in soil, content of total nitrogen, phosphorus and organic carbon, moisture content of soil and pH of soil solution. Subsequent activities included the isolation of genetic material from the individual soil samples. The genetic material was then used in metagenomic analyses, which made it possible to identify the naturally occurring bacteria that degrade PAHs.

The highest level of contamination was observed for the sample originating from borehole O7 and the depth of 1.5 m, where the level of PAHs contamination equalled 20 736 [mg kg-1 of dry soil], i.e. was >80 times higher than the permissible PAHs content in that place (i.e. 250 mg kg-1 of dry soil). That high concentration of creosote oil limited the biodiversity of the indigenous microorganisms and promoted the growth of bacteria from the genera *Pseudomonas, Serratia*, and *Sphingomonas*. The total PAHs biodegradation by the isolated consortia ranged between 28-36% during a four-week test.

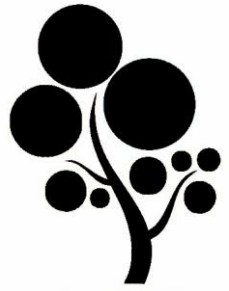
The research was financed as part of the project entitled "Modern technology for bioremediation of soil contaminated with creosote oil on the premises of Sleeper Treating Plant Spółka Akcyjna in Koźmin Wielkopolski", no. POIR.04.01.02-00-0057/17-00, implemented under sub-measure 4.1.2 of the "Regional Science and Research Agendas" and co-financed by the European Regional Development Fund.

Keywords: *creosote oil, impregnated wood, bioremediation, bacteria, PAHs*

** Corresponding author: m_sydow@itd.poznan.pl*

SESSION III

Wood waste management and utilization



WOOD WASTE MANAGEMENT: THE BEST PRACTICES

Ana Luisa Fernando[1]*, Dominique Boulday[2], Paul Antoine[3], Magdalena Borzęcka[4]

[1] MEtRICs/ DCTB, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus de Caparica, Caparica, Portugal
[2] Ceden, Cabinet d'Etudes sur les dechets et l'Energie, France
[3] ARBN, Association Régionale Biomasse Normandie, Caen, France
[4] IUNG - Institute of Soil Science and Plant Cultivation - State Research Institute, Puławy, Poland

With an estimated annual flow of more than 40 million tons at the European level, the mobilisation of end-of-life wood is a major issue, not exclusively in the energy sector. The aim is also to reduce the volume of ultimate waste to be landfilled. But, recycling of wood waste is an issue. In addition to the carbon, oxygen and hydrogen contained in biomass, various components have been added to wood to improve its preservation or for aesthetic reasons (coatings, paints, varnishes, etc.), or for technical reasons, i.e. glues for the manufacture of wood panels. These chemical substances, such as heavy metals, or molecules containing nitrogen or chloride, limit the recycling options. Several of these substances (such as arsenic) have consequently been banned in treatment products, but wood waste recovered today will still contain them, probably for several more decades. Therefore, like any environmentally responsible sector, the wood industry must now integrate the end-of-life of the product already at the manufacturing stage.

Within the EU, the recovery method and industrial ecosystems vary depending on the market opportunities offered in each country. Schematically, the Scandinavian countries and Denmark, major producers of wood waste (linked to a tradition of wood construction), have been developing renewable energies since the early 1980s and naturally encourage energy recovery, while southern and eastern countries have been directing this cheap resource towards panel industry. Absorbing the potential of wood waste in the EU regions and industrial biobased ecosystems is the objective of the BioReg project funded by the European Union. Overall, the project aims to identify, develop and fully unlock the unused wood waste potential at the European level and allow for the implementation of a full range of wood waste valorisation practices among the European regions. Hence, the aim of this work is to present the results obtained within the framework of the BioReg project. Success factors, i.e. factors that have contributed to the development of successful wood waste ecosystems in the model regions, were identified. The analysis shows that all the model regions have common features: a) national legislation and policies push forward the wood waste valorization; b) landfilling with organic waste is prohibited/restricted; c) existence of a good network within the region or in the country to collect, classify and sort wood waste. Based on this, lessons and recommendations for the recipient regions have been proposed and will be presented. The output of the task is a toolbox of the EU success factors which will be available at the BioReg platform.

The studies were carried out within the framework of the BioReg project entitled "Absorbing the Potential of Wood Waste in EU Regions and Industrial Bio-based Ecosystems". This project received funding from the European Union's HORIZON 2020 research and innovative programme under Grant Agreement No. 727958, CallH2020-BB-2016-1, topic: BB-06-2016.

Keywords: *bio-based industries, bio-based products, bioenergy, wood waste, wood waste ecosystems, wood waste valorization*

* *Corresponding author: ala@fct.unl.pt*

EUROPEAN WOOD WASTE PLATFORM

Magdalena Borzęcka[1]*, Ana Luisa Fernando[2], Dominique Boulday[3]

[1] IUNG - Institute of Soil Science and Plant Cultivation - State Research Institute, Puławy, Poland

[2] MEtRICs/ DCTB, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus de Caparica, Caparica, Portugal

[3] Ceden, Cabinet d'Etudes sur les dechets et l'Energie, France

The European Wood Waste Platform was developed within the BioReg Project entitled "Absorbing the Potential of Wood Waste in EU Regions and Industrial Bio-based Ecosystems", executed under Grant Agreement No. 669062. One of the main goals of BioReg is to identify and release the unused wood waste at the European level. The project involves five model regions (which were defined as regions with a well-developed wood waste management) and three recipient regions (where wood waste management is not developed well enough). The platform facilitates the identification and selection of best practices and success factors among the European demonstrator regions which have set up pertinent mechanisms all along the value chain of wood waste management (collection, treatment, valorisation such as: reuse, wood waste to materials, wood waste to energy) and outputs management (gas, ash, other waste from valorisation processes). The forums and working groups will enable the project participants to discuss wood waste management matters. The platform is a tool created for producers, authorities and all those interested in wood waste management. It should help find good practices and enable exchanging experience. All the results were collected and presented as a geoportal, which is a part of the European Wood Waste Platform. The geoportal illustrates how the wood waste ecosystems vary along a number of selected attributes and dimensions and is the tool to present data regarding the wood waste situation in the EU, where the user can display and hide different maps and overlays. It is based on three main maps, namely: theoretical potential of municipal wood waste, theoretical potential of construction and demolition wood, and technical potential of wood waste from the wood industry. In the 28 countries of the European Community and Switzerland the total potential of wood waste from the wood industry, municipal waste as well as from demolition and construction amounted to around 49 million tonnes (Borzęcki et al., 2018). There is also a section presenting the location of different wood waste management facilities, and the amount of collected wood. Wood waste may originate from multiple sources such as the construction, municipal, commercial or other sectors. The map presenting current situation of landfilling organic waste or non-pre-treatment waste is based on data form the EEA. It shows the ecosystems of selected European countries.

The platform has the form of a website to which organizations can subscribe and become members (see the link: http://bioreg.eu/platform/).

The studies were carried out within the framework of the BioReg project entitled "Absorbing the Potential of Wood Waste in EU Regions and Industrial Bio-based Ecosystems". This project received funding from the European Union's HORIZON 2020 research and innovative programme under Grant Agreement No. 727958, CallH2020-BB-2016-1, topic: BB-06-2016.

Keywords: *wood waste, biomass potential, web-platform, geoportal*

* *Corresponding author: mborzecka@iung.pulawy.pl*

ALTERNATIVE LIGNOCELLULOSIC BIOMASS AS A COMPENSATION OF WOOD WASTE POTENTIAL

Anna Jędrejek, Małgorzata Kozak, Magdalena Borzęcka, Rafał Pudełko*

IUNG - Institute of Soil Science and Plant Cultivation - State Research Institute, Puławy, Poland

Wood is perceived to be one of the most important renewable raw materials. Despite its intensive harvesting, forest management in Europe is conducted in a sustainable manner. Since 1995 forest area has been increasing 700,000 ha on average every year. For the bio-economy not only industrial wood, but also wood waste is a valuable raw material. The wood industry produces significant amounts of by-products. Most of them are completely reused, e.g. waste from sawmill production used for the production of slabs, pellets, etc. amounts to 5.6 Mt. There is also potential from other sources such as municipal waste – 24.33 Mt, and demolition and construction – 19.17 Mt) (Borzęcki et al., 2018). As assessed in the BioReg project, the total wood waste potential from the 28 European Union member states accounts for approximately 50.2 Mt. Wood waste can be managed in a variety of ways, depending on the country. We have distinguished three ecosystems: energy recovery, recycling and mixed. Mixed ecosystem means that the two ways of managing wood waste are used, with one of them clearly dominating. Such ecosystem may be oriented towards energy or recycling. The energy recovery ecosystem is very popular in the EU countries, but waste wood itself cannot meet the demand for energy of the EU countries. Therefore, there is a need to reduce this deficiency possibly by cultivating industrial plants on marginal areas. In case of Poland, there are over 2 million of unused agricultural areas (Pudełko at al., 2018). It is a large potential for obtaining biomass by eliminating natural succession and restoring these areas to agricultural production. This process can create a new space for the introduction of lignocellulosic plantations that can be used for industrial purposes, including additional production of wood material.

The studies were carried out within the framework of the BioReg project entitled "Absorbing the Potential of Wood Waste in EU Regions and Industrial Bio-based Ecosystems". This project received funding from the European Union's HORIZON 2020 research and innovative programme under Grant Agreement No. 727958, CallH2020-BB-2016-1, topic: BB-06-2016.

Keywords: *wood waste, modelling, GIS, geographical information system*

* *Corresponding author: rpudelko@iung.pulawy.pl*

GEOPROCESSING AS A TOOL FOR MODELLING WOOD WASTE POTENTIAL

Rafał Pudełko*, Anna Jędrejek, Małgorzata Kozak, Magdalena Borzęcka,

IUNG - Institute of Soil Science and Plant Cultivation - State Research Institute, Puławy, Poland

By geoprocessing we mean various modifications and transformations of geographic data. As a result of such processing, new sets of information collected as a geodatabase can be created based on the existing spatial and statistic data.

The aim of this work was mainly to assess the wood waste potential and regionalization of the municipal wood waste, demolition and wood industry resources. The basic information on these resources are available in Eurostat, but datasets are neither harmonized nor collected frequently and do not cover all the monitored space. Due to the above restrictions, a geographical approach was applied by using auxiliary geo-data which have spatial correlation with the primary statistical data (Eurostat). The following sources were used: Corine Land Cover, Population raster map with resolution of 1x1 km (Geostat), and a municipal waste map according to BioBoost (bioboost.eu).

All data were incorporated into a geographical information system based on ArcGIS. Biomass potential was assessed by applying a geo-processing model based on the developed algorithms for NUTS-2 regions:

- the potential of wood-based fraction from municipal waste was 24.33 million tonnes; the largest potential was found in France (FR10, 609 thousand tonnes), and the highest density was found in the UK (UKH2, 609 t/km^2);
- the potential of demolition and construction waste was 19 million tonnes; the highest value was found in Sweden (SE11, 411 thousand tonnes), while the highest density was recorded in UK (UKI1, 312 t/km^2);
- the estimated potential of waste from the wood industry was 5.6 million tonnes; the largest potential was found in Finland (FI1D, 512 thousand tons), and the highest density was recorded for Belgium (BE34, 5.5 t/km^2).

As a result, a set of maps was obtained visualising differentiation of the chosen biomass types in the scale of NUTS-2. The maps in a digital form are available at the internet geoportal

http://bioreg.eu/Bioreg_Geoportal which allows for interactive work with the data by choosing a map – the option of theoretical potential or biomass density is available. The user can also zoom, move and select a chosen region.

The studies were carried out within the framework of the BioReg project entitled "Absorbing the Potential of Wood Waste in EU Regions and Industrial Bio-based Ecosystems". This project received funding from the European Union's HORIZON 2020 research and innovative programme under Grant Agreement No. 727958, CallH2020-BB-2016-1, topic: BB-06-2016.

Keywords: *wood waste, biomass potential, web-platform, geoportal*

** Corresponding author: rpudelko@iung.pulawy.pl*

PARTICLEBOARDS WITH PARTIALLY LIQUEFIED BARK OF DIFFERENT SIZES

Wen Jiang[1]*, Sergej Medved[2], Stergios Adamopoulos[1]

[1] Linnaeus University, Växjö, Sweden
[2] University of Ljubljana, Ljubljana, Slovenia

Utilizing biomass waste for wood-based composites has been driven by harsh competition for raw materials and environmental concerns for more sustainable products. Bark, as a by-product of the sawmilling and pulping industries, is a lignocellulosic material that is rich in lignin and extractives, and holds potential for producing chemicals and value-added materials. There are many possibilities of using bark in wood-based panel manufacturing such as making adhesives (e.g. bark tannin extractives, liquefied bark) or using it as a furnish in small amounts. Instead of using the completed liquefied bark products in the adhesive mixture, we have been working on a novel method of making particleboards by using partially liquefied bark as a furnish material with binding abilities. Thus, partially liquefied bark was mixed with wood chips with an aim to investigate the effect of different bark sizes on the properties of particleboards.

Maritime pine (*Pinus pinaster Ait.*) bark was partially liquefied in the presence of ethylene glycol as solvent and sulphuric acid (H2SO4) as catalyst in 180˚C for 30 minutes. Four different sizes of bark were used: mix, coarse (> 2 mm), middle (1-2 mm), and fines (< 1 mm). One-layered 8-mm particleboards were prepared by mixing dry wood chips with the partially liquefied bark categories (9.1% or 20% w/w). Melamine-urea-formaldehyde (MUF) resin was 10% of the total weight of the furnish materials (dry wood chips and partially liquefied bark); while boards were also made without adding the resin. Mechanical and physical properties of the particleboards were tested according to the European standards, and ANOVA analysis of the results showed no statistically significant differences between varying bark sizes. Particleboards made with 9.1% of partially liquefied bark and with 10% of MUF resin met all the standard requirements for mechanical strength and thickness swelling. Particleboards made with 20% of partially liquefied bark and without adding MUF resin were inferior to those with MUF resin.

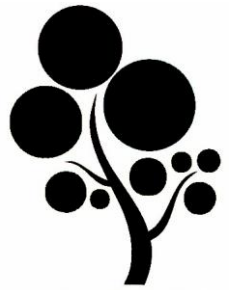
From the current results we can conclude that it is possible to make particleboards from partially liquefied bark with competitive properties, and this supports our original idea of not completing the liquefaction process. In that respect, our work can contribute to energy and material savings when using liquefied products in wood panel manufacturing. More research is needed to optimize the process as well as to evaluate the formaldehyde emission level from this type of panels

Keywords: *bark, ethylene glycol, liquefaction, maritime pine, MUF resin, particleboards*

** Corresponding author: wen.jiang@lnu.se*

SESSION IV

Wood adhesives – innovative bonding approaches



INVESTIGATIONS OF THE ADHESION PROPERTIES OF PINE AND POPLAR WOOD HEAT TREATED IN AIR AND UNDER VACUUM, FINISHED WITH PUR LACQUER

Ahmet Can[1], Tomasz Krystofiak[2]*, Barbara Lis[2]

[1] Bartin University, Bartin, Turkey
[2] Poznan University of Life Sciences, Poznan, Poland

Heat treatment is an eco-friendly and efficient way to improve the properties of wood species. These treatments alter the substrates and could influence the surface properties of lacquer coatings, e.g. roughness, wettability, and adherence of finished surfaces.

In this paper, the effects of heat treatment, in air and under vacuum, of Scots pine (*Pinus sylvestris L.*) and poplar (*Populus euramericana*) wood on the adhesion properties of the PUR lacquer were investigated. Scots pine and poplar samples, of the dimensions of 75 (R) × 15 (T) × 150 (L) mm, were prepared from sapwood blocks. The density of the pine and poplar samples used was 660±20 kg/m^3 and 280±10 kg/m^3, respectively.

Prior to heat treatment, all samples were oven-dried at 103°C to 0% moisture content. The samples, placed in the oven and in the pressure chamber, were subjected to heat treatment for 2 hrs at 180-200°C in the case of poplar and at 190-212°C in the case of Scots pine.

The heat treatment in the air medium (HT) was carried out in an oven and no water vapour or other gases were present in the environment. For the vacuum heat treatment (VHT), the oven-dried samples were place in a vacuum pressure chamber, where a vacuum of 675 mmHg was achieved. The samples were placed in the oven until the target temperature was reached.

For the investigations the PUR lacquer with the trade name L11 Aqua CLOU Holzlack was used. PUR lacquer was applied onto the surfaces acc. to the producer requirements. After application, samples were conditioned in laboratory conditions.

The surface roughness parameters (Ra, Rz, Rmax) in two directions, along and across the grain, were estimated using a Mitutoyo SJ-210 device.

The adherence of coatings was measured in pull-off tests acc. to PN EN ISO 4624 standard. The contact angle was determined acc. to PN-EN 828 standard using a microscope method, and surface free energy, with dispersion and polar shares, was calculated for the tested coatings.

It was observed that the roughness parameters decreased with the increase in the duration of heat treatment in air. The surface roughness parameters of the poplar and Scots pine samples heat treated under vacuum increased with the increase in the heat treatment temperature. Adherence decreased for the poplar and the Scots pine samples alike with the increase in the heat treatment temperature. Heat treatment affected the adherence of the Scots pine samples more than that of the poplar samples.

Keywords: *Scots pine wood, poplar wood, PUR lacquer, modification, roughness, wettability, adherence*

** Corresponding author: tomkrys@up.poznan.pl*

FUNCTIONALISED NANOCELLULOSE AS A PROMISING MATERIAL IN BIOADHESIVE APPLICATION

Patrycja Hochmańska*, Dominika Janiszewska, Wojciech Bałęczny

Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland

Modern bio-based industries are looking for new solutions regarding more sustainable, renewable and safe materials with high performance characteristics. This is in line with the need to gain independence from fossil fuels and improve the environmental protection and human health. Biopolymers of enormous application potential are an excellent choice and an opportunity for the growing bioeconomy. One of the most abundant natural biopolymers on Earth is cellulose derived from plant fibres and tailored to different applications. The paper and packaging industries have been intensively developing products with the use of cellulose. Presently, cellulose is moving into the focus of other industries, including composites, adhesives, coatings, and functional materials. These products need to be biodegradable, lightweight and strong, and nanocellulose with the unique combination of properties like low density, high surface area, high mechanical strength modulus and high tensile strength, can fulfil those requirements.

Researchers and producers have focused their attention on bioadhesives for the wood industry. Potentially, nanocellulose is suitable for the development of a new ecological binder, which would be more environmentally friendly than currently used formaldehyde-based adhesives. Nanocellulose can act as modifying and reinforcing agent of amine resins, improving mechanical performance and reducing formaldehyde emission; however, the hydrophilic nature of nanocellulose can limit its application in wood adhesives and lead to mechanical failure of wood-based panels. To obtain the desirable products quality, it is crucial to modify nanocellulose. Silane compounds, because of their chemical diversity and functionality, can be successfully used for that purpose.

The study focused on the effects of nanocellulose functionalisation with organosilicon compounds on the physical, mechanical and environmental properties of adhesives and wood-based panels. Upon modification with organosilanes, new bands linked to the new functional groups occurred in the modified nanocellulose and the contact angle increased from 27° to 75°. The nanocellulose-reinforced adhesive compositions were characterised by higher viscosity stability. Moreover, particleboards prepared with the resin containing only 1 wt% of silane-modified nanocellulose demonstrated reduced formaldehyde content and improved bending strength compared to standard resin-based boards.

Concluding, silane-modified nanocellulose has proven to be a promising nanobiopolymer in improving adhesive compositions in terms of the particleboard properties.

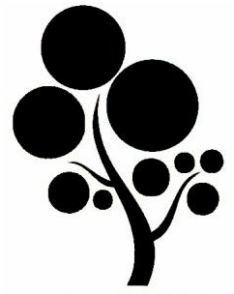
The research was conducted within the framework of the project entitled "New biopolymer adhesives modified with silanes and ionic liquids for application in wood-based materials technology (BioAdSIL)", grant no. LIDER/14/0174/L-7/15/NCBR/2016 (LIDER VII Programme), funded by the National Centre for Research and Development in Poland.

***Keywords:** biopolymers, nanocellulose, silanes, functionalisation, adhesives, wood composites*

** Corresponding author: p_hochmanska@itd.poznan.pl*

SESSION V

Bioenergy – trends and developments



FOREST BIOMASS AS A RENEWABLE ENERGY SOURCE – CONSEQUENCES FOR FORESTRY

Piotr Paschalis Jakubowicz

Warsaw University of Life Sciences – SGGW, Warsaw, Poland

The current provisions in the EU directive, applicable to its signatories, assume obtaining a share of at least 20% of energy coming from renewable sources by 2020. The EU Parliament demands changes to the current directive on forest biomass and its contribution to the use of renewable energy. The Parliament considers it expedient to increase the amount of forest biomass obtained, including wood at various processing states, treating this solution as one of the active methods of replacing the energy derived from fossil fuels. The definition proposed by the EU Parliament states that countries and industrial plants in their areas can receive financial assistance and also be included in the group of consumers of energy 'from renewable sources', if they obtain it from combustion of wood, which is collected only for this purpose. Such position has led to the protest of over 750 scientists from around the world. A letter from researchers to the EU stated that only harvested forest biomass coming exclusively from logging residues and wood waste, and not from wood intended for other use, should be taken into account for the purpose. Signatories of the letter warned that the EU Parliament's proposal put at risk both the global climate goals and maintaining the sustainability of the world's forests.

At the heart of the argument is the conviction of the scientists that the defect of the directive is based on such a construction of regulations that will cause actions which will cause expansive damage to forests in the world and accelerate the occurring climate change. The proposed solution is to limit the obtained amount of forest biomass only to the part that qualifies, according to the directive, as logging residues and wood waste. The real danger, concerning the stability of forests, is the possibility of overestimating the forest's production capacity in supplying forest biomass. This claim is not an expression of academic caution. It is a real threat. The history of overestimation of forest potential is as long as the history of human development, and every time it ended up with a total degradation of the forest and the lack of resources, which forced migration of the population. This risk, both on a global scale and for our country, is high, first of all, because the implementation of the energy policy assumptions, just like agricultural policy, in each case leads to the direct growth of producers' income. It is always higher, as are the profits in other economic sectors, than the income from forest management. In Poland, this income asymmetry may stimulate, as it already has in many countries of the world, changes in forest management leading to the reduction of forest biological diversity, as well as to increased deforestation.

Keywords: *forest biomass, renewable energy, climate change*

** Corresponding author: ppaschalis@wl.sggw.pl*

SOME ASPECTS RELATED TO WOOD PELLET PRODUCTION FROM POPLAR TREES MANAGED AS COPPICES IN THE MEDITERRANEAN AREA

Rodolfo Picchio[1]*, Rachele Venanzi[1], Francesco Latterini[1], Vincenzo Civitarese[2]

[1]Tuscia University, Viterbo, Italy
[2] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria [Crea], Rome, Italy

Agriculture and forestry are an important renewable energy sources in a local context, and contributing to rational use of energy, help mitigate climate change. In this context, there is a need for innovation to achieve energy sustainability.

The research aimed to identify the best raw material suitable for pellet production. The experiments were carried out using wood (whole trees or stems without branches) from poplar plantations at the end of the third, sixth and ninth year of age. The dendrometric characteristics of the trees and the qualitative characteristics of the pellets produced were analysed. Some parameters, such as the calorific value, moisture content, the content of ashes and heavy metals were determined before and after pelleting in order to identify any differences directly related to the transformation process. The wood chips obtained from the Short Rotation Coppice are characterized by a low commercial value and the possibility to convert them into superior merchandise material, in terms of quality, cost and energy, represents an interesting development opportunity for small and medium scale agro-energy chains. Despite the general qualitative improvement that can be achieved through the pelletizing process, the legislation that manages the market is very restrictive, compared to the traditional one concerning wood chips. Other researchers report the difficulty in producing good quality pellets from poplar or willow short rotation coppices, especially using solely this type of material. There are different actions, however, that can be taken to improve the quality of this material, such as preheating the feed material, adding binders, and increasing the pelleting pressure. All types of the pellets made, met the requirements of A1 class as regards diameter, length, moisture content, ash melting point, lower heating value, the content of N, S and heavy metals. None of them met the bulk density parameters; while a great variability as regards ashes and mechanical durability was observed for the different raw materials used. A general improvement of the quality parameters, in terms of heating value, ash content, heavy metals and ash melting point, was observed when poplar wood chips were transformed into pellets. The introduction of specific quality standards could promote and encourage the exploitation of wood biomass produced by dedicated plantations and this could result in creating a potentially interesting market.

Keywords: *chipping, pellet, poplar, SRWC, pelletization, biomass quality, energy quality*

** Corresponding author: r.picchio@unitus.it*

MECHANICAL AND CHEMICAL PROPERTIES OF POPLAR WOOD PELLETS PRODUCED IN INDUSTRIAL CONDITIONS

Wojciech Cichy*, Magdalena Witczak, Małgorzata Walkowiak

Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland

The paper discusses the results of research on wood pellets obtained from 3 to 5-year-old poplar trees from plantation crops. Tests were carried out in industrial conditions on an installation consisting of two granulators with nominal capacity of 4 Mg/h. The attempts to debark harvested roundwood were unsuccessful. For further testing the authors used wood and bark which was ground to wood chips on industrial chippers and then granulated. Pellets were made of 100% poplar wood as well as of a mixture of poplar and pine wood. Variants with an addition of substances improving granulation were prepared as well. The obtained pellets were analysed based on the requirements of EN ISO 17225-2: 2014 standard. Total moisture content, ash content, elemental and trace elements (C, H, N, S, Cl, Hg, As, Cu, Cd, Cr, Ni, Pb, and Zn), gross calorific value, pellet dimensions, bulk density, mechanical strength and ash melting behaviour were determined and the net calorific value was calculated.

It was found that, tested in the same pellet installation, pellets produced from poplar wood from plantation crops had properties similar to those of pine wood pellets obtained in the same conditions. The only factor that definitely influenced the qualitative assessment of polar pellets was the relatively high ash content. Analysis of the results proved that poplar wood from plantation crops can be a complete substitute for softwood in the production of fuel granules (wood pellets).

The study was carried out as part of the project entitled “Intelligent systems for breeding and cultivation of wheat, maize and poplar for optimized biomass production, biofuels and modified wood (CROPTECH)”, executed in the period 2016-2019 and financed by the National Centre for Research and Development.

Keywords: *wood pellets, solid biofuels, poplar wood from plantation*

** Corresponding author: w_cichy@itd.poznan.pl*

CORRELATION BETWEEN THE BIOGAS YIELD AND THE CHEMICAL COMPOSITION OF LIGNOCELLULOSIC MATERIALS

Hanna Waliszewska[1], Magdalena Zborowska[1]*, Agata Stachowiak-Wencek[1], Sławomir Borysiak[2], Czekała Wojciech[1]

[1] Poznan University of Life Sciences, Poznan, Poland
[2] Poznan University of Technology, Poznan, Poland

Lignocellulosic biomass has a huge energy potential, nevertheless, it is used to a rather small extent in the anaerobic digestion in biogas production. The use of lignocellulosic biomass such as annual and perennial plants for energy purposes depends on their chemical composition and physical properties. What limits the use of lignocellulosic biomass for the production of biogas seems to be the share of lignin, which only slightly decomposes in the oxygen-free conditions. This is important because the maintenance of anaerobic conditions is the basis for the operation of a biogas plant. However, lignocellulosic biomass is a biological material consisting of many components, mainly carbohydrates, which are easier biodegradable in anaerobic conditions. Unfortunately, neither the influence of their percentage or structure on the anaerobic digestion nor the importance of extractives in this process is known. This issue, briefly described in the literature, is extremely important as regards the possibility of increasing the efficiency of biogas production from lignocellulosic raw materials.

In the described study, the relationship between the percentage and structure of the selected lignocellulosic components and the efficiency of the anaerobic digestion and the quality of the obtained biogas was analysed. As part of the experiment, the following annual and perennial lignocellulosic raw materials, potentially of great importance in biogas production, were tested: corn straw, miscanthus, sorghum, and poplar wood from plantations. The biogas efficiency and quality tests were carried out according to DIN 38 414 standard in a 21-chamber glass biofermenter. The inoculum came from an active agricultural biogas plant. The TAPPI standards were used to determine the chemical composition of the lignocellulosic materials, and the Seifert method was used to determine the cellulose. The lignin structure was analysed using Fourier Transform Infrared Spectroscopy (FTIR), and Wide-Angle X-Ray Scattering (WAXS) analysis was used to determine the degree of cellulose crystallinity.

Based on the analyses of different lignocellulosic materials it was observed that the components determining the efficiency of the anaerobic digestion were primarily lignin and pentosans. It was revealed, that the biogas yield was negatively correlated with the content of lignin. It was also demonstrated that with the increase in the concentration of pentosans, the amount of biogas increased. However, no relationship was found between the percentage of the crystalline structure of cellulose and the yield of biogas. The results add the knowledge on the impact of the chemical properties of lignocellulosic materials on the biogas yield. They are of great practical importance and are significant for the power industry as well as for the global and national climate policy.

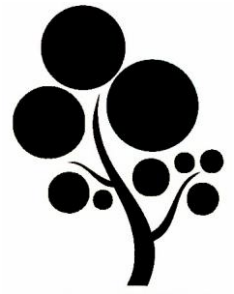
This work was supported by the BIOSTRATEG 2 (298241/10/NCBR/2016) project entitled "Intelligent systems for breeding and cultivation of wheat, maize and poplar for optimized biomass production, biofuels and modified wood (CROPTECH)", financed by the National Centre for Research and Development (NCBR).

Keywords: *lignocellulosic biomass, cellulose, lignin, crystallinity of cellulose, biogas yield, anaerobic digestion, methane production*

** Corresponding author: magdalena.zborowska@up.poznan.pl*

SESSION VI

Wood market – economic and social aspects



BIOECONOMY – QUANTIFICATION, DATA NEEDS AND SUSTAINABILITY

Susanne Iost[1]*, Natalia Geng[1], Naemi Labonte[2], Jörg Schweinle[1], Holger Weimar[1]

[1] Thünen Institute of International Forestry and Forest Economics, Hamburg, Germany
[2] Thünen Institute of Market Analysis, Braunschweig, Germany

The political concept of bioeconomy and its implementation within the European economies is widely discussed within scientific and political communities. Main issues are the definition of the term and its operationalisation in order to quantify the economic effects of bio-based economic activity.

Furthermore, the substitution of fossil resources by bio-based resources is one of the most important objectives of bioeconomy as it is supposed to allow for the reduction of carbon dioxide emissions, higher resource efficiency, and a more sustainable use of resources in general.

The project entitled "Development of a systematic monitoring of the bioeconomy – resource base and sustainability", funded by the German Federal Ministry of Food and Agriculture (BMEL), addresses these issues.

Based on the existing quantifications of bioeconomy, we developed a method for determining the economic impact of bioeconomy as part of a regular monitoring.

Foundation of the method is a comprehensive definition of the term "bioeconomy". Based on that definition, economic activities and goods produced by these activities are classified as fully, partially or not bio-based. This allows for the calculation of bio-based shares of economic activities, which are then applied to official statistical indicators of economic development, i.e. number of jobs, gross added value and turnover. In order to validate and monitor the targeted transition to more bio-based economic activities, we also selected sustainability indicators as listed in the sustainable development goals framework and linked them to the calculated bio-based shares of economic activities. In our calculations, we used official statistics wherever available, as these are collected applying established methods on a regular basis and therefore can be used in a continuous bioeconomy monitoring.

In 2014 the German bioeconomy was characterized by 3.69 million jobs, 452 billion € turnover and 116 billion € gross added value and estimates for further years will be presented. The challenges in estimating bioeconomy are the data availability and the fact that existing statistical economic classifications do not allow for the distinction between fossil-based and bio-based economic activities. For comparison of bioeconomy estimates in different countries, the underlying definition of bioeconomy has to be taken into account. The definition defines which economic activities will be included in economic estimates of bioeconomy. Results are difficult to compare, if some estimates include not only biomass production and bio-based manufacturing, but also bio-based services and research and development related to biotechnology and other natural sciences.

Keywords: *bioeconomy, bio-based materials, bio-based products, Germany, monitoring, sustainability, SDG*

** Corresponding author: susanne.iost@thuenen.de*

SCENARIO ANALYSIS AS A SCIENTIFIC METHOD OF INVESTIGATING COMPLEX SOCIO-ECONOMIC PHENOMENA – THE CASE OF BREXIT AND ITS IMPLICATIONS FOR THE POLISH FURNITURE INDUSTRY

Dobrochna Augustyniak*, Ewa Leszczyszyn, Gabriela Bidzińska

Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland

The withdrawal of the United Kingdom from the European Union is an unprecedented event with potentially far reaching implications for the British and European economies. Although previous analyses suggest that the impacts will be asymmetrical and the UK will bear the greater share of the costs associated with its exit, there are also important risk factors for the European enterprises, especially those connected to the British market through direct or indirect exports, imports and investments. The economic shock caused by Brexit will be transmitted to industries in other countries, including Polish furniture sector, which is highly internationalized and is a vital trade partner for the UK. Therefore, the aim of this research was to identify the consequences of Brexit for Polish furniture industry, which will have to adapt to changing conditions of international activity.

Much of the existing research on Brexit is based on quantitative modelling of its potential effects on trade, economic output or added value. To achieve a greater level of detail and identify possible changes on meso- and microeconomic level, a qualitative scenario analysis method was used, which allowed for considering a wide array of impacts and complex interrelations between various factors. These scenarios were generated according to the General Morphological Analysis technique. Main sources of data were expert opinions, scientific journals, reports, working papers and press releases.

The consequences of Brexit will depend greatly on the institutional arrangements between the UK and the EU. Also, additional areas of uncertainty were addressed such as the economic situation in the United Kingdom and the future of the European integration project. The scenario building process resulted in creating five comprehensive scenarios, i.e.: The Apparent Independence, Escaping from the Sinking Ship, Winning the Game, The Painful Divorce and The Fulfilment of the Worst Fears. For each of them specific consequences for Polish furniture enterprises were identified, which allowed for creating a set of practical recommendations for the furniture companies.

The obtained results suggest the great importance of building sustainable competitive advantages by Polish furniture manufacturers, which would make them more resilient to exogenous shocks and hardly predictable events, like the UK's secession form the EU. In a highly turbulent world, relying only on low production costs is an increasingly risky strategy. The generated scenarios and their consequences illustrate very different visions of the future, which can be a starting point for strategic planning or adaptation of the enterprise to the changing environmental conditions.

Keywords: *scenario analysis, Brexit, furniture industry*

** Corresponding author: d_augustyniak@itd.poznan.pl*

SUPPLY OF WOOD PROCESSING RESIDUES FROM WOOD PACKAGING

Ulrike Saal[1,2]*, Susanne Iost[2]

[1] University of Hamburg, Hamburg, Germany
[2] Thünen Institute of International Forestry and Forest Economics, Hamburg, Germany

Wood processing residues accumulate inevitably in all areas of the manufacture of wood and wood products. They are an important contribution to the overall supply of raw wood materials in times of wood resource scarcity and growing demand for wood for material and energy use. The objectives of waste reduction and recycling within the complex industrial ecology also mean a need to consider more intensively resource recovery and usable residual volumes. Hence, the analysis of the supply structures of wood processing residues helps better understand the material flows and uses within the forest-based sector. It is also needed for constant wood resource monitoring and facilitates bioeconomy monitoring, wood flow analysis or calculation of cascade use. However, data on the supply of wood processing residues from further processing industry branches, e.g. wood packaging, is rare and not monitored regularly. Regarding the production volume and importance of the European wood packaging industry the monitoring of wood use and residue supply is needed. Data on the wood consumption volume of end-use products (e.g. pallets) cannot be taken from official statistics to derive the volumes of wood processing residues. The current study aims at closing the data gap concerning the supplied volume of wood processing residues from a further processing industry sector based on the wood volume contained in wood products. The study focusses on the wood packaging industry of all 28 European Union countries and its standardised products. The classification of wood packaging products includes pallets, cases, boxes and crates, cable drums, lightweight packaging, and barrels. The conceptual framework of the study comprises the detailed analysis of the wood resource mix of standardised wood packaging products. The calculation of the volume of wood contained in wood products is based on a particular product's description of construction, norms and standards. Results are given in m³ of wood volume per product. The results are applied to an annual production dataset given by PRODCOM to calculate the total volume of wood contained. The volume of wood processing residues is then calculated via a residue coefficient, which resulted from the empirical research on wood processing residues in the German wood packaging industry. Earlier calculations from 2010, following a similar approach, resulted in a volume of 2.4 million m³ of wood processing residues from the wood packaging industry on the European level. The current approach however, includes a more detailed differentiation of the production volume. Moreover, the residue coefficient will be verified for its applicability on the EU-level.

Keywords: *wood processing residues, residue coefficient, wood packaging industry, resource mix, European level*

** Corresponding author: ulrike.saal@thuenen.de*

POSTERS

A PHYSICAL INSIGHT INTO A NEW TYPE OF ADHESIVE AND ITS COMPONENTS

1

Natalia Bielejewska[1]*, Dominika Janiszewska[2]

[1] Polish Academy of Sciences, Poznan, Poland
[2] Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland

The main aim of the research is to develop a new type of adhesive based on biopolymers and to optimize its application process into lignocellulosic material. The macroscopic properties of adhesives depend on many parameters and complex physicochemical processes. It is of great importance to understand the processes that occur in the interphase between the lignocellulosic material and the adhesive and to recognize the interactions between various adhesive components. The research aimed to improve this understanding is being carried out at the Institute of Molecular Physics of the Polish Academy of Sciences in Poznan. The detailed analysis, starting from individual components and ending with final product, is crucial to obtain the necessary know-how.

In this study, the analysis of liquified wood, ionic liquids, and modified nanocrystal cellulose composing on the new adhesive is presented. The following experimental methods were used: UV-Vis absorption spectroscopy, differential scanning calorimetry (DSC), and fluorescent scanning confocal microscopy (FSCM).

An important aspect of the study was to investigate the physicochemical properties of the adhesive-lignocellulose contact surface, as it determines the gluing process. The performed microscopic analysis of contact areas allowed determination of the influence of the modifications of the adhesive on the gluing process.

The research was carried out within the framework of the project entitled "New biopolymer adhesives modified with silanes and ionic liquids for application in wood-based materials technology (BioAdSIL)", contract no. LIDER/14/0174/L-7/15/NCBR/2016, funded by the National Centre for Research and Development in Poland under the LIDER VII Programme.

Keywords: *adhesives, biopolymers, nanocellulose, microscopic analysis, gluing process*

** Corresponding author: natalia.bielejewska@ifmpan.poznan.pl*

THE EFFECT OF CONDITIONS IN WHICH FURNITURE IS USED ON THE QUALITY OF INDOOR AIR IN RESIDENTIAL ROOMS

2

Magdalena Czajka*, Aleksandra Dziewanowska-Pudliszak

Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland

The emissions of harmful organic compounds from office, room and upholstered furniture were tested in the course of the study. Tests for the emission of formaldehyde and volatile organic compounds (VOC) were performed using the chamber method in climate conditions set forth in PN-EN 717-1:2006 standard entitled "Wood-based panels - Determination of formaldehyde release - Part 1: Formaldehyde emission by the chamber method". Furniture was tested in large chambers of the volume of 23.6 m^3 and 41 m^3, simulating residential rooms. The following load ratios were used: 1.5 m^2/m^3 (room furniture); 1.6 m^2/m^3 (office furniture); and 0.45 m^2/m^3 (upholstered furniture). The author determined the effect of the number of air exchanges on the concentration of organic compounds in the air of chamber loaded with furniture in an amount that is typical for residential and office rooms.

In the case of office furniture, the gradual reduction of the number of air exchanges from 0.8 to 0.4 h-1 resulted in a slight increase in formaldehyde concentration, which was within the range of 0.031 to 0.039 mg/m^3. Only the reduction of the air exchange rate to 0.05 h-1 caused a fourfold increase in the equilibrium concentration of formaldehyde in the tested air (0.080 mg/m^3). The situation was similar in the case of room furniture, where, at the chamber load of 1.6 m^2/m^3 and the air exchange rate of 1.6 h-1, the determined equilibrium concentration of formaldehyde in the chamber air equalled 0.045 mg/m^3, thus it was within the limits of permissible concentration of this compound (0.05 mg/m^3). Further reduction of the air exchange rate (twofold and fourfold) caused formaldehyde to exceed its permissible concentration by 30% and 100%, and by as much as 500% at the lowest air exchange rate of 0.05 h-1. A similar dynamics of decrease in VOC emission from office and room furniture was observed when the number of air exchanges in the chamber was reduced.

The tests revealed an increase in the concentration of formaldehyde and VOCs in the air of a model room when the amount of air allowed to the chamber was limited. In the light of the common practice of limiting the number of air exchanges in residential rooms, due to economic considerations, it would be advisable to limit the number of air exchanges in the chamber to 0.05$m^3/m^2 \times h$ in tests carried out to assess furniture hygienicity.

It is necessary to introduce standards concerning testing of furniture in the conditions of its practical use, and not in the conditions that are currently used for the assessment of wood-based panels, because the latter conditions do not guarantee an appropriate quality of indoor air in accordance with the Regulation of the Minister of Health and Social Care on permissible concentration and intensity of agents harmful to health released by building materials, appliances and elements of furnishings in rooms intended for stay of people.

Keywords: *furniture, formaldehyde emission, VOC emission*

** Corresponding author: m_czajka@itd.poznan.pl*

BIOPOLYOL-BASED PHENOLIC ADHESIVE

3

Silvia Helena Fuentes da Silva[1]*, Tomasz Krystofiak[2], Jalel Labidi[1]

[1] University of the Basque Country, San Sebastian, Spain
[2] Poznan University of Life Sciences, Poznan, Poland

Resol resins are widely used as wood adhesive for the manufacture of panels due to their excellent properties. This type of resin is synthesized with phenol and formaldehyde, which are toxic chemicals. Lignin has a structure similar to phenol, so much research has been devoted to the possibility of substituting lignin for phenol; however, lignin is less reactive than phenol. The object of many studies is lignin modification by the solvolytic liquefaction using the phenolation method, i.e. using phenol.

In this study, liquefied Kraft lignin was used to replace 60% of phenol in the synthesis of an adhesive phenolic resin. The liquefaction was carried out using polyethylene glycol and glycerol as solvents, without catalyst and under reflux, at 160ºC during 1 h.

Plywood of the dimensions of 300 x 300 x 1.5 mm, made of veneers after thermo-mechanical modification (TM) and of unmodified pine wood, was used in the experiments. Tensile shearing strength acc. to PN-EN 314 standard was estimated.

Plywood made of TM veneers demonstrated higher shearing strength than that made of unmodified pine wood.

Keywords: *Kraft lining, biopolyols, renewable material, phenolic adhesive*

** Corresponding author: silviahfuente@hotmail.com*

HIGHLY EFFICIENT UTILITY FORMS FOR PROTECTION OF HORSE CHESTNUT TREES AGAINST HORSE-CHESTNUT LEAF MINER *CAMERARIA OHRIDELLA*

4

Jacek Grodner*

Łukasiewicz Research Network – Institute of Industrial Organic Chemistry, Warsaw, Poland

Semiochemical compounds, in particular pheromones, are a modern, selective and environmentally-friendly plant protection tool, which is currently commonly used within the framework of the integrated pest management (IPM). A large number of pheromones belong to the group of linear dienes containing a conjugated system of double bonds in opposite configuration (E,Z) or (Z,E). Obtaining such system with high isomeric purity is critically important for well biological activity of the attractant. One of the most important representative of this group of compounds is (8*E*,10*Z*)-tetradeca-8,10-dienal, the sex pheromone of horse-chestnut leaf miner (*Cameraria ohridella*). This tiny moth was first observed 1984 in Macedonia and since then has spread rapidly all-around Europe. Its *larvae* are leaf miners on the common horse chestnut *Aescular hippocastanum*. The continuous epidemic infestation of horse chestnuts by *C. ohridella* is a serious aesthetic and economic problem in urban environments and also forests. Efforts were made at the Institute of Industrial Organic Chemistry (IPO) to obtain the pheromone of *C. ohridella* and then develop utility forms to control population of that pest. The research resulted in the development of an innovative, simple and highly efficient method of obtaining the pheromone of *C. ohridella*, involving high stereo control of creating both double bonds mentioned earlier, and the latest achievements in organic chemistry synthesis. Further modification of the process led to shortening of the synthesis as well as to preparation of pheromone with the isomeric purity exceeding 99%. This method was awarded the golden medal at The Belgian and International Trade *Fair* for Technological Innovation (*Brussels Eureka). The synthesized* pheromone was loaded into a carrier (grey rubber cap) and has been sold in Poland and other European countries for many years under the market name “Pheromone dispenser Cameraria ohridella”. This dispenser, used as a lure in many types of traps, was successfully *used for monitoring and mass trapping* of horse-chestnut leaf miner.

The strategy of obtaining the pheromone of *C. ohridella* was successfully used in synthesis of other attractants of Lepidoptera (e.g. (5*Z*,7*E*)-dodeca-5,7-dienal, a female sex pheromone of pine-tree lappet *Dendrolimus pini* which is an important pest attacking Scots pine *Pinus sylvestris*).

Keywords: *Cameraria ohridella*, sex pheromone, conjugated dienal, dispenser

** Corresponding author: grodner@ipo.waw.pl*

COMPONENT PLYWOOD MADE USING MELAMINE-UREA-FORMALDEHYDE RESIN CONDENSED BY NO-WASTE METHOD AS A BUILDING MATERIALS

5

Mariusz Jóźwiak, Andrzej Fojutowski*

Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland

Plywood as a construction material has many beneficial properties, such as high strength, ease of machining and installation in buildings, good insulating properties, and high aesthetic values. It is classified, as well as other organic materials, as combustible building material, and in terms of its reaction to fire to class D, s1-s3, d0-d2. Thanks to the application of fire-retardant compounds (FRC), which absorb heat, easily carbonise to form a protective layer, emit gaseous products that dilute flammable gases etc., the plywood's reaction to fire class may be improved. The aim of the research was to determine the degree to which the plywood flammability change as a result of incorporating FRC and MUF into its structure.

MUF resins were condensed on the lab scale at the molar ratio: formaldehyde (F): melamine (M): urea (U) equalling 2.8:1.0:1:0. The condensation was a tree-step process carried out using the no-waste method. Beech, alder and pine veneers of the dimensions of 300 × 300 × 1.8; 2.5 and 4.2 ± 0.1 mm, and MC = 6.5 ± 1.0%, were used. They were impregnated with a water-soluble FRC salt using the cold bath method at 22 ± 2°C for 1-4 hours. For the next 24 hours, they were conditioned in the laboratory conditions (22 ± 2°C, RH of 45 ± 5%), and afterwards dried at the temperature of 40°C for 120 minutes, and then again conditioned in the laboratory conditions.

The glue mixture was applied on one side of veneers with an adhesive roller in the amount of 100 g/m^2. After 30 min, 24h or 4 weeks of assembly time, the sets of 3-layer plywood were pressed at 125°C for 5 min under the pressure of 1.4-1.8 MPa.

After 2 weeks of conditioning in normal conditions, the shear strength and wood failure of the glue line was determined acc. to EN-314-1, -2 standards (IF-20, AW-100), formaldehyde release acc. PN-EN 717-3 standard, and the degree of fire protection of the plywood using the radiation method acc. PN-96/B-02874 standard.

The component plywood fulfilled the requirements of EN-314-2 standard in terms of strength and water resistance of the adhesive glue lines, regardless of the resin storage time, the molar ratio, and the applied modifiers. The plywood was characterised by much lower formaldehyde emission compared to control variant (emission was at the level obtained for raw alder wood). Fire protection of the 3-layer component plywood was a fire protection level sufficient for different wood materials. The combustion index ranged from 0.68 to 0.75 and the flammability index oscillated only between 0.06 and 0.07.

Component plywood can be a semi-finished product useful for the production of fireproof wood materials.

Keywords: *plywood, fire, barrier, protection, exterior*

** Corresponding authors: a_fojutowski@itd.poznan.pl*

INFLUENCE OF THE APPLICATION PARAMETERS ON THE ADHERENCE OF PUR LACQUER TO THE MDF VENEERED WITH TM ALDER VENEERS

6

Tomasz Krystofiak[1]*, Pavlo Bekhta[2], Barbara Lis[1], Jurij Maksymiv[2]

[1] Poznan University of Life Sciences, Poznan, Poland
[2] Ukrainian National Forestry University, Lviv, Ukraine

The woodworking industry pays special attention to the quality of finishing. For this purpose, many procedures have been applied in terms of substrate preparation, modification of cladding materials, and the selection of parameters for the application of lacquer products.

Recently, there has been a rapid increase in the application of various modification methods to wood and wood-based materials (in particular, thermal, thermo-mechanical, and thermo-hygro-mechanical treatments) in order to improve their properties. These treatments of wood are ecological methods. Moreover, it was proved that thermo-mechanical compression of veneers before the application of adhesive, in the process of veneer-based product manufacturing, facilitates significant reduction of adhesive consumption. At next step of the technological process, it is very important to select the appropriate lacquer system for finishing. Sometimes, the process of densification weakens the adherence of coating to the substrate. The aim of this study was to estimate the influence of the application parameters on the adherence of PUR lacquer to the MDF veneered with TM alder veneers.

Rotary-peeled alder (*Alnus glutinosa* Gaertn.) wood veneers were used as a cladding material. Commercially manufactured MDF was the substrate material. Single-component waterborne Jowacoll 124.00 (based on PVAC) and Jowacoll 148.00 (based on EVA) adhesives were used for veneering of the MDF panels.

Veneer sheets were compressed using an automatically controlled single-opening hot press at the temperature of 150, 180, or 210°C. The densified veneers were conditioned in laboratory (temp. 20±2°C and RH=65±5%). Panels were veneered with non-compressed (control) and compressed veneer sheets using Jowacoll 124.00 and Jowacoll 148.00 adhesives. The adhesives were applied on the MDF surface with a glue roller.

After 168 hrs, veneered MDF surfaces were finished using 2C PUR lacquer in the laboratory conditions of REMMERS Comp. 1 and 2 layers were applied, with and without interlayer sanding. The test for coating adherence was carried out using the pull-off method acc. to PN EN ISO 4624 standard.

It was observed that PUR lacquer demonstrated very good adherence to the substrate. Surface preparation and densification parameters significantly influenced the adherence of PUR lacquer to the substrate. Interlayer sanding improved the adherence. An increase in the densification temperature caused an increase in mixed delamination.

Keywords: *alder wood, veneer, PUR lacquer, MDF, adherence, delamination*

** Corresponding author: tomkrys@up.poznan.pl*

THE BIOLOGICAL ACTIVITY OF CAFFEINE-CHITOSAN FORMULATION TOWARDS MOULD ATTACK

7

Patrycja Kwaśniewska-Sip[1]*, Magdalena Woźniak[2], Anna Szulc[2], Grzegorz Cofta[2], Izabela Ratajczak[2]

[1]Łukasiewicz Research Network – Wood Technology Institute, Poznan, Poland
[2] Poznan University of Life Sciences, Poznan, Poland

The increasing range of wood application and growing requirements as to its service life have prompted the search for new wood preservatives that would be more effective and environmentally friendly. Various natural products are potentially suitable for wood protection. Caffeine (1,3,7-trimethylxanthine) is a naturally occurring alkaloid found mainly in tea, coffee, kola nuts, and cocoa. Caffeine, which is considered an attractive alternative to traditional wood preservatives, exhibits a wide range of biological activity, including fungistatic properties against decay fungi and moulds. Another interesting substance is chitosan. It is a polymer derived from chitin and consisting of β-1,4-linked glucosamine (deacetylated units) and N-acetyl-D-glusoamine (acetylated units). Due to its properties, such as biodegradability, non-toxicity and antimicrobial effect, it is widely used in numerous applications, including waste management, medicine, food, agriculture, and also the protection and modification of wood.

The aim of the research was to determine the biological activity of caffeine-chitosan solution against mould attack. Tests were carried out for caffeine and caffeine-chitosan solutions in which the caffeine concentration was in the range 1% - 1×10^{-7}%, while the concentration of chitosan in the tested solutions was constant and amounted to 0.4%. Additionally, tests were carried out for chitosan and the solvent, which was 2% acetic acid. The following fungi strains were used: *Aspergillus niger* van Tiegen, *Paecilomyces variotii, Penicillium funiculosum, and Trichoderma virens*. The bioassay of the examined solutions was prepared in 96-microdilution tray using the broth microdilution method. MIC value was defined as the lowest concentration of the antifungal agent at which container was optically clear. The most promising results were obtained for two strains of fungi (*P.funiculosum* and *T.virens*), where the caffeine-chitosan solution inhibited the growth of fungi in a caffeine concentration of 1×10^{-7} %. Caffeine inhibited the tested fungi in the range of 0.1% to 0.2%. The results indicate that the addition of chitosan to the caffeine solution resulted in a reduction in the caffeine concentration needed to inhibit the mould growth.

The obtained results of the preliminary study allow conclusion that the fungistatic activity of the new formulation based on caffeine and chitosan may be potentially useful for controlling the growth of moulds attacking wood. Furthermore, the results of our research indicate that the caffeine-chitosan solution can be an interesting agent to apply in research of eco-friendly wood preservatives.

Keywords: *caffeine, chitosan, moulds, wood preservatives*

** Corresponding author: p_kwasniewska@itd.poznan.pl*

KERATIN AS ENVIRONMENTALLY FRIENDLY NATURAL POLYMER FOR ANTIMICROBIAL CONSERVATION OF AND REDUCING FORMALDEHYDE EMISSIONS FROM WOOD-BASED PANELS

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Ján Matyašovský[1], Ján Sedliačik[2]*, Pavlo Bekhta[3], Peter Duchovič[1], Peter Jurkovič[1]

[1] VIPO, a.s., Partizánske, Slovakia
[2] Technical University, Zvolen, Slovakia
[3] Ukrainian National Forestry University, Lviv, Ukraine

Keratins belong to a large group of fibrous proteins which form part of the skin layer and associated structures such as hair, nails, horn, and feathers. The research was focused on the biopolymer keratin, because the main characteristic of the keratin protein is the high content of thio-amino acids – methionine and cysteine. Keratin hydrolysates were prepared using sheep wool "Merino" of the composition: nitrogen 12.15 %, ash 2.53 %, sulphur 2.21 %, fat 7.16 %. They were analysed and parametrized using X-Ray photoelectron spectroscopy (XPS) and ATR-FTIR spectroscopy measurements. Changes in the spectra of keratin hydrolysates were mainly demonstrated in the content of sulphur, in the proportion between the reduced C-S form (S2p signal at ~163 eV) and SO_3 oxidized form (S2p signal at ~ 168 eV). The proposal to test the disinfecting activity of the keratin hydrolysates on the selected bacteria strains was based on the chemical composition of keratin. The tested keratin samples fulfilled the requirements of PhEur.7.0.5.1.3-2. Technical applications were also directed to the application of keratin hydrolysates in modification of urea-formaldehyde (UF) resin mixtures in order to reduce the release of formaldehyde from bonded wood-based panels. Formaldehyde emissions were assessed from five-layer plywood according to JIS A 1460 (2001) "Building boards. Desiccator method". The quality of gluing was tested according to EN 314-1 and EN 314-2 standards. The tested plywood fulfilled the requirements of the standard for class of gluing 1 – they were suitable for application in normal interior environment. The measured values of extinctions of the tested samples confirmed the reduction of formaldehyde emissions for each concentration of keratin hydrolysate, compared to the reference sample. The most significant decrease in formaldehyde, up to 37%, was obtained for a 5% dosage of keratin with the highest sulphur and sulphide bonds content.

This research investigated the modifications of natural keratin polymer and its hydrolytic treatment directed mainly at cleavage of the disulphide bond to the S–H thiol groups (O–SO_3 bond, respectively). Moreover, the influence of these changes on the antioxidant properties, the antimicrobial conservation and the reduction of formaldehyde emissions was also studied. This allowed the transferred of the glued wood products to a qualitatively higher emission class.

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

** Corresponding author: sedliacik@tuzvo.sk*

INVESTIGATION OF METALLOCENE POLYOLEFIN-BASED HOT-MELT ADHESIVES

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Igor Novák[1]*, Juraj Pavlinec[1], Ivan Chodák[1], Jozef Preťo[2], Vladimír Vanko[2]

[1]Slovak Academy of Sciences, Bratislava, Slovakia
[2] VIPO, a.s., Partizánske, Slovakia

Metallocene polyolefin-based hot-melt adhesives (HMA) typically have lower density and higher adhesive strength compared to the other HMA. Therefore, it is possible to use less adhesive without compromising the strength. Currently, metallocene polyolefin polymers and copolymers are frequently used as a base that imparts excellent performance to the HMA. In many cases, the strength of nonpolar HMA adhesion to cellulose-based materials such as paper, cardboard or cotton is satisfactory. The simplest approach to obtain higher adhesion is to increase their polarity by applying controlled oxidation to a certain extent. In addition, an increase in the metallocene polyolefin-based HMA's polarity is frequently achieved by adding polar components to the adhesive polymer composition. Alternatively, the basic polymer component can be modified by grafting the polar polymer moieties. Treating the polymer powder, films, or fabrics with a polar vinyl monomer along with a free radical initiator is a convenient method of modifying the metallocene polyolefin macromolecules by free radical grafting. The initiation of the graft polymer chains' growth on the modified polymer is the most important reaction for the effective binding of polymer branches to basic polymer. An alternative procedure for modifying the activated RXP powder was carried out in a Brabender Plasticorder kneading machine (Germany) in a 30 ml chamber at 110 °C for 30 min. Filling the chamber with polymer and the homogenization of the polymer melt with NaLS (wetting agent) took approximately 5 min at 80 °C. The peel strength of the adhesive joints was evaluated according to ASTM D 1876 standard. In these experiments, BOPP-laminated cardboard was used as a substrate for testing peel adhesion. Kneading molten RXP with reaction components in the polymer melt without a solvent proved to have been the most effective procedure for RXP grafting with AA. Considering that grafting proceeds in a high viscosity medium (102-105 Pa) that is several orders of magnitude higher than that in solution, the reaction medium affects the individual polymerization steps involved in grafting. The determined grafting efficiency was high and varied between 0.77 and 0.97. The polarity of virgin RXP after grafting increased as indicated by the water contact angle on the RXP surface grafted with AA that decreased 15% or more and the surface energy and its polar component which increased 1.1-1.7 times compared to virgin RXP. The peel temperature resistance of RXP grafted with AA increased more than 10 °C. Peel adhesion strength increased 1.2. During the peel tests, the adhesive joints of the system: cardboard-unmodified RXP demonstrated adhesive failure, but the joints of the system: cardboard-grafted RXP showed cohesive destruction.

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Keywords: *hot-melt adhesives, cellulose-based materials, peel strength, adhesive properties*

** Corresponding author: igor.novak@savba.sk*

MODIFICATION OF METALLOCENE COPOLYMERS IN SOLUTION FOR HOT-MELT ADHESIVES PREPARATION

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Igor Novák[1]*, Juraj Pavlinec[1], Ivan Chodák[1], Jozef Preťo[2], Vladimír Vanko[2]

[1]Slovak Academy of Sciences, Bratislava, Slovakia
[2] VIPO, a.s., Partizánske, Slovakia

Metallocene polyolefins are frequently used for hot-melt adhesives. Therefore, the investigation of relations between the polymer structure and the ultimate properties of adhesive is necessary. The basic experiments consist in developing material composition from commercially available components, and basic components are so modified to enhance certain parameters of the adhesive. The metallocene polyolefin has been frequently modified by polar polymer grafting to increase the adhesive properties. The polyolefin copolymer Resinex PE, RXP 1502 (RXP) is a metallocene copolymer of ethylene with octene. The incorporation of octene into the polyethylene chain, compared to the PE homopolymer, results in the reduction of melting temperature of the polymer to 70 °C. The RXP is partially soluble in toluene at RT, which also indicates to reduce the polymer crystallinity. This fact significantly affects the approach to the RXP modification by radical polymerization using acrylic acid (AA). The selection of suitable process for initiating the growth of PAA chains bound to macromolecules RXP (RXP-g-AA) is particularly importance and so is the grafting technique of the polymer. Based on previous experience with the activation of polyolefins for vinyl monomer grafting with gaseous O_2 + O_3 mixture, we used this method to accumulate peroxides also on RXP molecules. The polymer powder was exposed to a flow of reaction gas produced in an atmospheric plasma generator. The activation time was 3, 2, and 1 hour. The presence of grafted PAA in RXP-g-AA was proved by FTIR analysis. FTIR spectra were measured with a FTIR spectrometer Nicolet 8700TM. The good solubility of both RXP and AA in toluene at elevated temperatures and the boiling temperature of toluene of 141 °C allowed us to carry out the reaction at 90-110 °C, i.e. the temperature that is sufficient for peroxide groups of the activated RXP to decompose. The advantage was also that poly(acrylic acid) (PAA) homo-polymer is not soluble in toluene, which facilitated its separation from RXP-g-AA. In a solution the amount of grafted AA increased, however the efficiency of grafting remined low and reached the value of 0.25-0.5. The modification efficiency increased as the AA concentration in the feedstock increased. FTIR absorbance for the acid carbonyl compounds at approximately 1715 cm^{-1} and the reference band at 1464 cm^{-1} showed the proliferation of the PAA graft quantity, depending on the amount of AA in the feedstock. However, the more effective method of RXP grafting with AA was kneading the reaction components without solvent in a Brabender Plasticoder in molten RXP.

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Keywords: *hot-melt adhesives, cellulose-based materials, adhesive properties, FTIR analysis*

** Corresponding author: igor.novak@savba.sk*

ANTIBACTERIAL PRE-TREATMENT OF POLYAMIDE 12 VENEERS BY DCBD PLASMA AND POLYSACCHARIDE IMMOBILIZATION

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Igor Novák[1], Ján Sedliačik[2]*, Ivan Chodák[1], Ján Matyašovský[3], Peter Jurkovič[3]

[1] Slovak Academy of Sciences, Bratislava, Slovakia
[2] Technical University, Zvolen, Slovakia
[3] VIPO, a.s., Partizánske, Slovakia

Antibacterial agents based on biopolymers are important alternatives to low molecular weight biocides, as they are usually non-toxic and can be used as effective surface coatings inhibiting the bacterial proliferation. Alginic acid (ALGA) is a carbohydrate polymer of great potential and a naturally occurring hydrophilic colloidal polysaccharide consisting mainly of residues of D-mannuronic acid and L-glucuronic acid obtained from various species of brown seaweed. It is an effective polyanion, as it is readily associable with many molecules through ionic interactions or covalent bonds. Polyamide 12 (PA12) veneer was studied in terms of increasing its bacteriostatic properties against the selected bacterial strains, i.e. *Escherichia coli* and *Staphylococcus aureus*. The diffuse coplanar barrier discharge (DCBD) plasma modification was followed with grafting of selected precursors (allylalcohol, allylamine, hydroxyethyl methacrylate), and then ALGA was deposited on the polymer. The polyanionic character of ALGA as a carbohydrate polymer compound plays the main role in the antibacterial activity. The cell wall composition of the tested bacterial strains, *Escherichia coli* and *Staphylococcus aureus*, have various levels of efficiency due to the different levels of bacteriostatic performance. The surface analysis confirmed that ALGA was immobilized onto the surface of PA12 veneers. The wettability changes of the PA12 surface after the polysaccharides immobilization by the multistep process were evaluated by the contact angle measurements. The surface energy measurement (SEE) system was used for experiments and the adhesion between two materials was characterized by the 90° peel strength test. The antibacterial activity of the prepared samples was tested against both bacterial strains by the inhibition zone method (diffusion test) on agar. The samples were incubated for 24 h at 37 °C and the diameter of the inhibition zone was measured. FTIR measurements showed that in PA12 the characteristic peaks intensities were reduced, besides, the signal at approximately 1100 cm^{-1} strengthened in magnitude, which was attributed to C–O bond stretching in alcohols. According to FTIR results, two broad peaks of minor magnitude, one at 1600 cm^{-1} and another at approximately 1100 cm^{-1}, assigned to N–H bending and C–N stretching in amines, respectively, increased in magnitude. The broad peak at 1700 cm^{-1}, associated with C=O group, was present together with a signal at approximately 1100 cm^{-1} due to C–O bond and an increase in C=O and C–O peaks intensity was noticeable.

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Keywords: *diffuse coplanar barrier discharge plasma, polyamide 12 veneer, bacteriostatic performance, 90° peel strength test*

** Corresponding author: sedliacik@tuzvo.sk*

MODIFICATION OF VARIOUS WOOD SPECIES BY BARRIER DISCHARGE PLASMA

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Igor Novák[1], Ján Sedliačik[2]*, Ivan Chodák[1], Tomasz Krystofiak[3], Ján Matyašovský[4]

[1]Slovak Academy of Sciences, Bratislava, Slovakia
[2]Technical University, Zvolen, Slovakia
[3]Poznan University of Life Sciences, Poznan, Poland
[4]VIPO, a.s., Partizánske, Slovakia

The plasma discharge was used to modify the wood surface properties such as wettability and adhesion. The transposition to wood is expected with a good result for the application in adhesive bonding, printing and extrusion coating. Plasma is generated by a discharge, it is an excited gas that consists of atoms, ions, molecules, free radicals, electrons, and metastable species. Their interactions with the solid surface placed in the plasma lead to the desired surface properties, depending on the nature of the gas used. The barrier discharge plasma (BP) modification was suggested as an appropriate method for increasing the polarity of the wood surface. The surface properties of various wood species (beech (*Fagus*), maple (*Acer*), and birch (*Betula*)) were pre-treated using BP plasma at atmospheric pressure in the air. The properties of the treated wood surface were measured using a contact angle meter with a set of testing liquids of various polarity. An increase in the polar component of the surface energy of the plasma-modified wood surface was observed. The water contact angle on the investigated wood surfaces diminished with the increase in modification time from 56° (pristine beech wood) up to 22° after activation of beech wood with BP in the air for 20 s. The decrease in the water contact angle during aging is explained by the increase in the hydrophilicity of wood surface after pre-treatment with BC plasma in the air. The hydrophilicity of wood surface depends on the formation of polar oxygenic functional groups during BP modification. At saturation of the wood surface with polar groups, the hydrophilicity was stabilized. In the course of aging, the water contact angle of the modified wood surfaces increased rapidly for two days, after which the aging process was slower. The increase in the water contact angle during aging was smaller in the case of birch wood than in the case of beech and maple wood. The FTIR spectrum of the three tested species of wood was a mixed spectrum (composition) of cellulose and lignin with characteristic peaks corresponding to –OH bonds (with a maximum at about 3400 cm^{-1}) and fingerprints assigned to the –CO, –COO and $–CH_2–$ bonds typical for polysaccharides. The peak in the FTIR spectrum at 898 cm^{-1}, corresponding to glycosidic linkages, appeared as a typical spectral band of wood. The shear strength of the adhesive joints of wood, using overlapped plasma modified adhesive joints, was also measured and the results were in good correlation with the results of the surface energy measurements.

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Keywords: *barrier discharge plasma, contact angle, beech, maple, birch wood, shear strength*

** Corresponding author: sedliacik@tuzvo.sk*

TERMINOLOGY OF WOOD PROCESSING RESIDUES

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Ulrike Saal[1,2]

[1] *University of Hamburg, Hamburg, Germany*
[2] *Thünen Institute of International Forestry and Forest Economics, Hamburg, Germany*

Residues from the wood processing industry are a by-product of all wood working and manufacturing processes. This raw wood material is important by volume within the circle of forest industry production, energy use and new bioeconomy applications. Data on wood processing residues are relevant for current research on the supply of total wood resources, and so is their collection and comparison on the international level. So far, there is no common terminology on the international level. The English language terminology of a particular wood resource is used inconsistently. Available data on wood assortments are reported variously under different terms and conceptions. This "random" use of terminology is misleading and complicates the necessary comparison of data. The systematic approach to terminology includes reproducibility of science. Harmonised terminology is the basis for standardised collection and comparison of data, especially for the efficient multilingual documentation and reporting in the international context. This study aims at recommending an unambiguous term and definition of a given wood resource in the English language for mutual recognition. The conceptual description of the term is based on the given system of wood processing facilitates, the understanding of a wood resource, and its common classification. The combination of terminology and the content analysis is set as the methodological approach. Based on the concept of terminology analysis, a variety of terms already used within the scientific context and a defined research area are listed. The terms are pre-evaluated based on the prerequisites of terminology. The concept of content analysis is applied in order to further analyse, qualitatively and quantitatively, the actual use of the various terms in the scientific context. The list of the terms is then applied for a keyword search within the Web of Science research database focussing on the abstracts of scientific articles. Based on the earlier set definition of the analysed assortment and further categorising variables, the abstracts are analysed as to whether they match the used term and assortment. Also, a preliminary list of 22 different terms describing the assortment of wood processing residues is applied for content analysis. First results showed that many of the applied terms did not fulfil the prerequisites of the terminology. The refined keyword search resulted in a total of 1,248 abstracts which were analysed as regards matching the terms and assortments. Clarification and shaping of terminology and definition is always a starting point for the improvement of data. Hence, this study contributes to the improvement of data quality and comparability, e.g. the data on bioeconomy monitoring and circular economy on the international level, their common terminology, and definitions.

Keywords: *wood processing residues, terminology, standardisation, definition, content analysis*

** Corresponding author: ulrike.saal@thuenen.de*