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Abstracts of the
International Scientific Conference

SUSTAINABLE USE OF PLANT BIOMASS. TECHNICAL, TECHNOLOGICAL, ENVIRONMENTAL, AND LEGAL PROBLEMS

Krynica Zdrój 2026

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THE PROCESS OF BURNING WOOD CHIPS IN A DUAL-COMBUSTION AUTOMATIC HEATING BOILER

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Currently, there is a growing trend, driven by legal regulations (in Europe, this is known as the ‘Green Deal’, which aims to make Europe climate neutral by 2050), and one of its objectives is to replace fossil fuels with fuels derived from renewable sources. These efforts are also strongly motivated by a general concern for the state of the natural environment on our planet. This motivation is driven by rapid climate change, which is often unfavorable in a broader temporal and social context for the planet and the people living on it. In response to these challenges, joint research with Inventor from Mokobody resulted in the development of a prototype dual-combustion, multi-fuel, automatic boiler for burning wood chips K40. The device consists of four separate combustion chambers, a wood chip feed chamber, a first combustion channel and a second combustion channel. The fuel (wood chips) is automatically fed into the furnace. The tests carried out on the boiler prototype were aimed at determining its technical characteristics and specifying the boiler's power and efficiency. The purpose of the tests conducted on the heating boiler prototype was to determine its technical characteristics and to measure the boiler's power and efficiency. The boiler tests were carried out in accordance with the requirements of the PN-EN 303-5+A1:2023-05 standard. The laboratory tests mainly used wood (branches and twigs) from birch (*Betula* L.), pine (*Pinus* L.) and spruce (*Picea* A. Dietr.), with small amounts of branches from European larch (*Larix decidua* Mill.) and small-leaved lime (*Tilia cordata* Mill.) additionally shredded. The quality of the wood chips produced was tested on the basis of fraction analysis in accordance with the PN-91/D-95009 standard. The results of thermal tests of the wood chip boiler confirmed the assumed thermal power, efficiency and pollutant emissions. A nominal useful power of 30 kW was achieved, compared to the assumed 40 kW. Thermal efficiency at nominal power was 90%, allowing a central heating water temperature of 60÷90°C to be achieved at an operating pressure of 0.15 MPa. The measured CO content in the exhaust gases was 2.0% and CO_2 was 0.01%. The tests carried out showed that the boiler prototype met the assumed specifications and can be submitted for further implementation activities.

Keywords: *heating boiler, wood chips, combustion, combustion parameters, boiler heat output*

CLASSIFICATION OF WASTE MATERIALS FOR ENERGETIC PRODUCTION AND USED DISINTEGRATION TECHNOLOGY

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Relatively large number of waste types can be used for energy production by direct combustion, gasification or specific anaerobic fermentation etc., but their total amount in market is much smaller than it could be expected. From relatively wide range of waste materials, the waste paper component appears to be relatively available after re-sorting, i.e. paper egg packaging, cardboard-type paper packaging, especially devalued from food products, pharmaceuticals, and small to medium-sized packaging from suction cardboard for various technical products which cannot be used in other applications. Biogas production technology is often highlighted as a sustainable alternative to fossil fuels. In biogas stations there is possible to process this waste paper types as unused material, which would in the best case end up in municipal waste incinerators. However, biochemical transformation methods for such wastes in their natural state are very inefficient due to their composite structure. Particles of lignocellulosic materials in the fermenter either sediment to the bottom of the reactor vessel or rise towards the surface, where they float and form a compact, dense layer. Sufficient pre-treatment of such wastes in the first phase of disintegration is one of the key steps to achieve maximum efficiency of waste material transformation. By combining various methods of mechanical disintegration, i.e. breaking, crushing or grinding, the resulting particle size can be achieved, where when breaking, the size of the part ranges from 10-30 mm and when grinding, disintegration can be effective down to 0.2-2 mm.

Keywords: *waste paper, biogas production, disintegration process.*

The study was supported by the internal grant agency of the Faculty of Engineering at the Czech University of Life Sciences (IGA TF) and through Visegrad Grants from International Visegrad Fund.

ASSESSMENT OF GRAPEVINE CUTTINGS AS A RENEWABLE FEEDSTOCK FOR BIOENERGY AND PELLET PRODUCTION

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This study explores the potential for valorizing wood waste derived from grapevine cultivation of the Pesecká leánka (white graft) and Frankovka modrá (red graft) for pellets production. The chemical composition of the samples was analyzed using two extraction methods (water and ethanol) to determine extractives, acid-insoluble (Klason) lignin, and structural carbohydrates. Mechanical properties, including compressive strength parallel to the grain, and morphological characteristics (fiber length, width, and shape factor determined using a Fiber Tester) were evaluated. In addition, the energy potential of grapevine wood was assessed by determining its calorific value. The results revealed a relatively high carbohydrate content (54.19–55.27%), indicating good potential for acid or enzymatic hydrolysis to produce monosaccharides or second-generation bioethanol. The compressive strength of grapevine wood (37.34 MPa for red; 32.34 MPa for white) was comparable to that of softwood species, suggesting its suitability for particleboard or fiberboard production. The average fiber length was similar to that of non-wood materials, implying that grapevine cuttings could also be utilized in pulp and paper manufacturing. The calorific value of grapevine wood ranged from 18.68 $MJ \cdot kg^{-1}$ (white) to 18.91 $MJ \cdot kg^{-1}$ (red), while pellets exhibited a value of 16.96 $MJ \cdot kg^{-1}$. Although the energy potential of grapevine cuttings is comparable to other woody materials, the high ash content of pellets (10.54%) significantly exceeds the EN ISO 17225-1 standard limit, representing a major drawback for their use as biofuel.

Keywords: *Grapevine pruning residue, Energy valorization, Pellet production, Biomass characterization, Renewable energy*

This paper was prepared as part of the Visegrad Fund no. 22420094 „Logging Residue Torrefaction and Pressure Agglomeration as a Method to Conserve Fossil Fuels"and the Slovak Research and Development Agency under Contract no. APVV-21-0180.

CHEMICAL COMPONENTS AND ENERGY POTENTIAL IN STORED SPRUCE WOOD AND BARK

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The objective of this study was to examine the chemical composition and energy potential of spruce wood during a six-month storage period in an open forest woodshed. The analysis focused on determining the contents of extractives, cellulose, holocellulose, and lignin, as well as evaluating the energy potential through calorific value measurements. Samples were taken from different parts of the harvested trees, including trunk and crown wood, bark, and wood chips. After six months of storage, the extractive content decreased in all wood and bark samples. Lignin content remained relatively stable in wood samples but increased in bark and chip samples. The most pronounced changes were observed in the hemicellulose fraction, which showed the largest reduction—up to 25%—in separately stored bark samples. The calorific value of all samples declined by approximately 7–10% over the storage period. These results indicate that significant chemical and energetic changes occurred in the stored wood, potentially affecting the quality of downstream products such as wood chips, pulp, paper, pellets and particleboards.

Keywords: *Spruce wood, Chemical composition, Wood storage, Calorific value, Lignocellulosic changes*

This paper was prepared as part of the Visegrad Fund no. 22420094 „Logging Residue Torrefaction and Pressure Agglomeration as a Method to Conserve Fossil Fuels", the Slovak Research and Development Agency under Contract no. APVV-21-0180 and APVV-22-0034 and by the Ministry of Education, Research, Development and Youth of the Slovak Republic under the Contract no. VEGA 1/0027/24.

DEVELOPMENT OF THE BIOGAS MARKET IN UKRAINE AND THE EU

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The development of the biogas sector has acquired strategic importance in Europe, becoming a cornerstone of decarbonization policies and increasing energy sustainability. In the context of the European Green Deal and the REPowerEU program, the European Union has set an extremely ambitious goal - to increase biomethane production to 35 billion cubic meters by 2030. For Ukraine, which is striving for European integration, biogas and biomethane are not only an environmental solution, but also a critically important element of green reconstruction, decentralization of energy infrastructure, in particular, replacing destroyed centralized supply facilities, and strengthening the sustainability of the national energy system. The biogas market in the EU is highly developed and is characterized by a strong, dynamic regulatory framework, embodied in the Renewable Energy Directives. The EU strategy clearly shifts the focus from biogas production for cogeneration of electricity to the production of highly purified biomethane. Biomethane allows for the effective decarbonization of hard-to-reach sectors, such as gas distribution and gas transportation networks, industry and heavy transport. The main incentive mechanisms are Guarantees of Origin, which ensure transparency and traceability of the "green" origin of gas, as well as direct investment subsidies and premium gas prices formed through auctions or bilateral contracts. At the same time, Ukraine has one of the largest biomethane production potentials in Europe, estimated at up to 10 billion m³ per year, mainly through the processing of agricultural, livestock and food waste (manure, silage, post-harvest residues). This allows not only to produce energy, but also to solve environmental problems associated with the disposal of organic residues. Interest in the sector has increased significantly after the adoption of key legislation on biomethane in 2021-2022, which provided a regulatory framework for its physical injection into the gas transportation system and trade. However, key challenges in a full-scale war environment remain high investment risks, the need for war risk insurance, the high cost of credit resources, as well as logistical problems and the need to demine significant areas of potentially fertile land suitable for a raw material base. The

strategic perspective is to form a full-fledged "biomethane corridor" between Ukraine and the EU, which involves the export of Ukrainian biomethane to European consumers. Ensuring the certification of Ukrainian biomethane according to recognized European standards is critically important for the implementation of this scenario. Ukrainian biomethane, integrated into the European market, should become a powerful source of substitution for Russian fossil gas, directly contributing to the achievement of the REPowerEU goals and strengthening the overall energy sustainability and sovereignty of the entire European continent.

Keywords: *biogas, biomethane, energy security, decarbonization, green recovery, agricultural waste, ISCC EU, KZR INiG.*

LOCAL BIOMASS CENTERS AS A WAY TO SOLVE THE ENERGY PROBLEMS OF RESIDENTS OF SMALL TOWNS

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The presentation presented the idea of protecting residents of rural areas and small towns from threats leading to energy poverty. Local Biomass Centers aim to utilize local plant biomass resources and process them into solid biofuels. The immediate goal of establishing Local Biomass Centers is to create opportunities for biomass fuel production on farms that cannot afford the complete technical equipment necessary to produce solid biofuels.

The Local Biomass Center is to be an organization operating within the municipality, possessing information on residents' energy needs, the potential of local energy carriers, and the potential of technical equipment for energy and fuel production. The LBC organizes contacts between suppliers of technical equipment and interested residents of the municipality and has a set of basic technical equipment enabling the production of biomass fuels from locally available raw materials. The LBC organizes contacts between suppliers of technical equipment and interested residents of the municipality (e.g., boiler equipment). The produced solid biofuels will be assessed in specialized (accredited) laboratories. It is also possible to obtain a relevant quality certificate. The benefits of establishing Local Biomass Centers include: managing agricultural and orchard waste, preventing the waste of plant biomass residues, and combating energy poverty among residents of rural and small towns.

The idea (project) is aimed at local governments, technical equipment manufacturers, and Agricultural Advisory Centers.

Keywords: *plant biomass; solid biofuels; local biomass resources; logistics for obtaining solid biofuels.*

FROM RAW BIOMASS TO HIGH-QUALITY PELLETS: TECHNICAL CHALLENGES AND SUSTAINABLE SOLUTIONS

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The transition from raw plant biomass to high-quality pellets involves a series of technical processes that strongly influence the final fuel's performance, environmental impact, and market value. This presentation explores key properties of biomass relevant to pellet production, including moisture content, particle size, and chemical composition, and highlights the challenges associated with feedstock variability, drying efficiency, equipment wear, and quality control. It also discusses critical pellet quality parameters such as density, durability, ash content, and calorific value. Emphasis is placed on sustainable solutions that enhance process efficiency and reduce environmental impacts, including the use of waste biomass streams, energy-efficient drying technologies, natural binders, and improved automation. By integrating technical optimization with sustainability principles, high-quality pellet production can significantly support the development of low-carbon, circular bioenergy systems.

Keywords: *biomass pellets; pellet quality; sustainable bioenergy; feedstock properties; agglomeration*

EVALUATION OF TECHNIQUES FOR MEASURING SMALL WOOD CHIP HEAPS VIA LASER SCANNING

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Accurate quantification of forest biomass is essential for optimizing logistics, ensuring supply efficiency, and supporting sustainable resource management. Traditional methods for monitoring biomass stockpiles—especially in large-scale operations—are often irregular and rely on manual measurements or cargo tracking. This study investigates the feasibility and accuracy of smart laser scanning technologies for measuring small piles of chipped forest biomass, focusing on cost-effective and user-friendly solutions. The experiment was conducted in central Slovakia using 50 m³ of chipped beech wood distributed into four piles. Two scanning devices were evaluated: the Stonex Geoslam X120 GO handheld laser scanner and the iPhone 14 Pro Max equipped with a LiDAR sensor. Scans were processed using CloudCompare, GOpost, and the 3D Scanner App. Conversion coefficients from Slovak and Austrian technical standards were applied to translate stacked volumes into solid cubic meters. Terrain irregularities and scattered biomass fragments were accounted for during volume calculations. Both scanning methods produced comparable results, with the smallest deviation from the reference volume being 6%. The mobile phone solution demonstrated significant advantages in speed, ease of use, and affordability, completing scans and evaluations in under 30 minutes. In contrast, the handheld scanner required more time and technical expertise but offered slightly more detailed data processing. The findings confirm that smart LiDAR-based solutions—particularly those integrated into mobile devices—can deliver sufficiently accurate volume estimates for small biomass piles. These methods are practical for field conditions and offer a promising alternative to traditional techniques, especially for rapid inventorying and operational decision-making in forestry logistics.

Keywords: *forest biomass, LiDAR, laser scanning, mobile scanning, chip pile volume, smart forestry*

The research was carried out within the framework of the projects: nr. APVV-22–0001; KEGA 004TU Z-4/2023. The study was co-funded by the European Commission within the LignoSilva project [Grant Agreement #101,059,552] under the Horizon Europe Teaming for Excellence action, and the Visegrad Fund no. 22420094 „Logging Residue Torrefaction and Pressure Agglomeration as a Method to Conserve Fossil Fuels".

LOGGING RESIDUE TORREFACTION AND PRESSURE AGGLOMERATION AS A METHOD TO CONSERVE FOSSIL FUELS

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The problem under consideration concerned the technical possibilities and limitations associated with the use of torrefaction technology for forest logging residues and the subsequent processing of the torrefied material into solid fuels (pellet production). The production and use of these biomass-based fuels aims to reduce the use of fossil fuels and their adverse environmental impact. As part of the research, the following were determined in the Visegrad Group countries: a) the available raw material base that can be used for torrefaction and subsequently for pellet production from the obtained torrefied material; b) the quality parameters of the input products to torrefaction; c) the limiting parameters of the torrefaction process and the quality parameters of the obtained torrefied material; d) the parameters of the torrefaction product densification process. The final result of the research was the identification of material and process parameters that enabled the production of pellets of satisfactory quality. The test results obtained for torrefied pine and spruce logging residues allowed us to conclude that pellets of sufficient quality can be obtained at a torrefaction temperature of 250°C, an agglomeration temperature of 120°C, and a compaction pressure of 180 MPa. Pellets have a specific density of approximately 1.1 $g \cdot cm^{-3}$, radial compressive strength of 3-3.5 MPa, modulus of elasticity of 60-80 MPa, and calorific value of 20.3-23.8 $MJ \cdot kg^{-1}$.

Keywords: *logging residues; pellet; torrefaction; compressive strength; elemental composition; calorific value*

The project ID 22420094 is co-financed by the Governments of the Czechia, Hungary, Poland and Slovakia through Visegrad Grants from International Visegrad Fund. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe.

DEVELOPMENT OF A MULTIFUNCTIONAL OPTIMIZATION MODEL, ALGORITHM AND SOFTWARE FOR RESOURCE RECOVERY FROM AGRICULTURAL WASTE

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The aim of the research is to develop a multifunctional optimization model, algorithm and software for resource recovery from agricultural waste based on evolutionary computing. This toolkit allows to increase the efficiency of waste processing in agricultural enterprises, reduce environmental impact and maximize economic benefits. To achieve this goal, a model was proposed that optimizes several objective functions, such as minimizing processing costs, maximizing energy efficiency, reducing greenhouse gas emissions and increasing the overall suitability of the process. The research methods included the use of evolutionary computing, which implements multi-criteria optimization by generating initial solutions, assessing their suitability, selecting the best solutions, crossing and mutation to create new generations. The developed software provides modeling of various scenarios of agricultural waste processing, which provides justification for economically oriented strategies with maximizing energy efficiency, minimizing CO_2 emissions and using a comprehensive assessment of agricultural waste processing systems. The results of the study showed that the optimal solutions for different scenarios for the development of agricultural waste processing systems depend significantly on the selected priorities. It was found that for cost-minimization scenarios, high suitability indicators are achieved at low costs and moderate levels of CO_2 emissions. In scenarios of maximizing energy efficiency, an increase in suitability is observed at higher costs for waste processing. The results also confirmed that a combined approach taking into account both economic and environmental components ensures balanced performance indicators that meet the principles of sustainable development of agricultural enterprises. Based on the obtained results of the study, recommendations were substantiated for the selection of optimal waste processing strategies depending on the specific conditions and goals of agricultural enterprises. The obtained results have practical value due to the

possibility of implementation in the field of agricultural waste processing, contributing to increasing the efficiency of resource conservation and reducing the negative impact on the environment.

Keywords: *multifunctional optimization, agricultural waste, evolutionary computing, energy efficiency, recycling costs, greenhouse gas emissions, sustainable development, environmental efficiency.*

THE EFFECTIVE METHOD OF DECOMPOSITION OF PURPOSE-GROWN ENERGY BIOMASS

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The aim of this contribution is comprehensive evaluation of suitable technology for the decomposition of purpose-grown energy biomass on reclamation areas to ensure year-round raw material availability for biogas production from biomass sources at any given time. This involves verifying the appropriate technological treatment of selected biodegradable raw materials using surplus electrical energy from already installed and newly built photovoltaic systems. The energy intensity of selected energy transformation and storage processes will be taken into account, including assessment of environmental and socio-economic benefits. Treated biomass can be simply stored for later energy use (biogas – heat, biomethane, biogas cogeneration to electricity) throughout the year and utilized during periods of energy shortage. Excess energy can be used for drying of the by-products, e.g. of digestate for use as organic fertilizer, thereby reducing the costs of its treatment. This involves advanced technologies for processing into an environmentally positive material – hydrosorbent.

Keywords: *Decomposition of biomass, surplus electrical and thermal energy, photovoltaic power plant.*

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MODELS FOR SUSTAINABLE MANAGEMENT OF LIVESTOCK WASTE BASED ON NEURAL NETWORK ARCHITECTURES

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This study addresses the problem of minimizing the environmental impact of livestock production while improving the efficiency of livestock waste-to-energy conversion. A sustainable management approach based on neural network models is proposed and substantiated, focusing on predicting livestock waste generation and optimizing farm configurations. The novelty of this work lies in the development and validation of a multilayer perceptron (MLP) neural network model tailored to regional and production characteristics of cattle farms in western Ukraine. The approach includes 11 stages, from data preprocessing and feature selection to multiobjective optimization and emission assessment. The optimized MLP model demonstrated high predictive performance, achieving a mean squared error (MSE) of 0.0005 and a mean absolute percentage error (MAPE) of 6.51%, compared to 8.01% for the baseline model. The study confirms that feeding rations significantly affect both waste generation and greenhouse gas emissions. Farms using protein-rich or concentrated diets show increased biogas production potential but also higher CO_2-equivalent emissions (kg/year), while roughage-based diets reduce methane (CH_4) and nitrous oxide (N_2O) emissions, lowering environmental impact. Optimization results reveal a non-linear relationship between herd size and sustainability indicators. The most effective emission reduction was achieved on farms with 900 cattle, where CO_2-equivalent emissions decreased from 4,560,590 kg/year to 3,830,100 kg/year. Simultaneously, biogas production increased by 7–16%, exceeding 1,100,002 m³/year on large farms. These findings support the use of anaerobic digestion technologies and intelligent modelling for planning farm modernization. The proposed approach can inform decision-making at the farm and policy levels, contributing to climate resilience and the sustainable development of livestock farming.

Keywords: *sustainable management, waste, animal husbandry, neural network model, biogas, energy supply, emissions, environmental sustainability.*

SPECIFIC FEATURES OF BIOFUEL PRODUCTION FROM BIOMASS IN AGRICULTURE

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Agricultural production generates a significant amount of lignocellulosic and organic biomass, which represents a valuable resource for sustainable biofuel production. However, the energy conversion of agricultural biomass is limited by numerous technical, environmental, and economic factors. This study synthesizes the specific features of biomass-to-biofuel pathways in agriculture based on an analysis of biomass potential, conversion technologies, and systemic constraints identified in recent scientific research. The results show that the availability of crop residues, oil-crop by-products, and livestock waste is highly variable and region-dependent, while their conversion requires balancing energy, environmental, and economic criteria. Determining the real biomass potential remains a critically important prerequisite for managerial decisions regarding the selection of biomass types, conversion technologies, and the scale of implementation. Crop residues possess substantial potential for generating thermal and electrical energy, and livestock waste provides an additional resource for biomethane and biohydrogen production, although logistical limitations and declining biomass availability in some regions constrain the overall production potential.

The study emphasizes that biofuel production in agriculture must ensure soil fertility preservation, food security, and adherence to ecological restrictions, since excessive removal of biomass or inefficient conversion processes may negatively affect agroecosystem sustainability. Technical barriers—including high energy and water requirements, transportation costs, and equipment investment—further influence the feasibility and rationality of biofuel production systems. Therefore, optimized managerial decision-making algorithms that integrate biomass availability, technological efficiency, and ecological criteria are essential for identifying optimal biofuel production pathways and strengthening regional energy independence. The findings confirm the need to develop rational, region-specific bioenergy strategies that maximize economic and environmental benefits while minimizing risks associated with the energy conversion of agricultural biomass.

Keywords: *biomass potential, agricultural residues, biofuel production, biomethane, biohydrogen, bioenergy conversion, sustainable agriculture*

ANALYSIS OF WORK EFFICIENCY WHEN CHIPPING FOREST RESIDUES WITH THE ALBACH DIAMANT 2000 CHIPPER

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Due to Poland's climatic and geographical conditions, biomass, which is still considered a renewable energy source, is believed to be one of the important sources of energy in Poland. One source of biomass can be wood residues. When harvesting wood residues, there are three basic models of machine technology for harvesting energy raw materials: 1- production of energy chips on the forest surface; 2- production of chips from material collected at the haul road; 3- packaging of logging residues. Depending on the technology used, the energy raw material reaches the recipient in various forms, such as wood chips or bales. Due to the fact that specialised machines for processing wood from material collected at the haul road, such as the Albach Diamant 2000, are becoming increasingly common on the domestic market, it was interesting to see what real efficiency can be achieved using this type of machine. The research was carried out during the processing of wood residues in the Rudy Raciborskie Forest District in the Lubieszów and Nędza forest ranges. The machine was owned by the company ‘P.P.H.U SKALEC’ from Koniecpol. The piles (Fig. 2) were prepared with a forwarder on paved roads. Albach Diamant 2000 chipped the material directly into containers. The main species chipped were Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and silver birch (*Betula pendula*). The research methodology was based on timing the working day. Based on the analysis of the results, it was concluded that: 1- appropriate stacking of material in large piles (up to 90 m³) on a hardened surface had a positive impact on the efficiency and organisation of the machine's operation; 2- on the day of operation, the Albach Diament 2000 chipped over 161.50 m³ of wood residues, which resulted in nine full truckloads with a load capacity of 18.10 m³ to 22.20 m³; 3- the productivity in the W_{08} work shift was low and amounted to 12.48 m³/h (the operator's working day is 12 hours, and the chipper worked for 4 hours and 30 minutes); 4- the effective productivity of W_1 was only 35.51 m³/h, which may have been influenced by the material prepared for chipping - often crooked and containing large amounts of roots;

Keywords: *logging residues, wood chips, self-propelled wood chipper, work efficiency.*

THE USAGE OF ALTERNATIVE BIOMASS MATERIALS FOR BIOGAS PRODUCTION WITH REGARDS TO ENERGY YIELD

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If we compare lignocellulosic biomass materials as a feedstock for biogas production with typical agricultural materials which are widely used in biogas plants, these lignocellulosic materials produce slightly less biogas, resp. methane. However, with appropriate mixtures, these shortcomings could be largely remedied. Another option is to treat these materials with a hydrolysis process, which can again improve their suitability for anaerobic fermentation. Hydrolytic pretreatment of such lignocellulosic materials is one of the most universal steps to achieve maximum efficiency of material transformation. For example, corn and straw residues, sugarcane processing waste, rice straw and other by-products from the agricultural sector are the most accessible waste lignocellulosic raw materials. They are usually used directly for animal feed or remain on the fields for the purpose of plowing and increasing the carbon content in the soil, in other cases they are, for example, burned without further treatment.

Keywords: Biogas production, lignocellulosic agriculture materials, hydrolysis process.

The study was supported by the internal grant agency of the Faculty of Engineering at the Czech University of Life Sciences (IGA TF) and through Visegrad Grants from International Visegrad Fund.

SPLITTING PROCESS OF EUROPEAN BEECH USING A CLASSIC SPLITTING WEDGE

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This study investigates the splitting process of European beech (*Fagus sylvatica*) using a classic splitting wedge under controlled laboratory conditions. The main objective was to determine the splitting force required for logs of different diameters and to evaluate the influence of wood size on the splitting process. Two log diameters, 30 cm and 15 cm, were tested at a moisture content of 28%. The moisture content was determined gravimetrically according to the relevant standard. The measurements were carried out on a horizontal hydraulic log splitter in the laboratories of the Technical University in Zvolen. The splitting force was measured using strain gauges mounted on the piston rod and a pressure sensor installed in the hydraulic circuit, with the actual splitting force calculated from the measured pressure values. The results revealed a significant difference in the required splitting force between the tested diameters, with larger diameters exhibiting notably higher force demands due to increased wood volume and internal resistance. The study provides relevant data for optimizing the design and operation of log splitters and contributes to a better understanding of the mechanical behavior of beech wood during the splitting process.

Keywords: *European beech, splitting force, splitting wedge, moisture content, wood splitting process*

This paper was prepared as part of the Visegrad Fund no. 22420094 „Logging Residue Torrefaction and Pressure Agglomeration as a Method to Conserve Fossil Fuels, and APVV-21-0180 "Innovative approaches to increase the lifetime and reduce the energy consumption of cutting tools in wood processing in forestry"

COMPARISON OF ENERGY PROPERTIES OF AGRICULTURAL AND FORESTRY BIOMASS AS A RENEWABLE ENERGY SOURCE

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The paper focuses on the analysis and comparison of the energy properties of selected agricultural and forestry biomass species to assess their potential for effective energy use. The research evaluated key physico-chemical parameters, such as combustion heat, calorific value, relative humidity, and ash content. Additionally, the dry matter yield was monitored, as it significantly influences the total productive capacity of biomass.

The samples included twelve species of energy herbs and grasses and four species of fast-growing woody plants cultivated under Slovak conditions. The results showed that fast-growing trees, particularly willows and poplars, achieved higher combustion heat values (18.4–19.8 $MJ \cdot kg^{-1}$) compared to energy herbs and grasses (17.2–18.4 $MJ \cdot kg^{-1}$). Nevertheless, herbs and grasses represent a promising biomass source due to their low cultivation requirements and ability to grow on marginal soils.

The findings confirm that combining agricultural and forestry biomass can contribute to the diversification of the fuel base and enhance the energy self-sufficiency of rural regions. The paper also highlights the need to optimize cultivation systems and processing technologies with an emphasis on environmental sustainability and economic efficiency.

Keywords: *biomass, energy crops, fast-growing woody plants, calorific value, combustion heat, biofuels, energy self-sufficiency*

The research was carried out within the framework of the projects: nr. APVV-22–0001;APVV-22-0030.

EVALUATION OF SELECTED PROPERTIES IN WOOD CHIPPING

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The work deals with the evaluation of selected properties during wood chipping, namely measuring tool wear using the weighing method, measuring fuel consumption and sieve analysis of the chips formed after chipping. The aim of the work is to research the service life of wood-chipping tools with different surface finishes. Chipping was carried out on a Pezzolato H 780/200 chipping device, where 5 m^3 of beech logs with an average diameter of 18 cm and a length of 2 m were processed. 3 knives with PVD coating were used for chopping (polished, ground from right to left, ground from left to right). The wear measurement showed that the weight of the polished tool increased by 0.19 g and ground tool from right to left increased by 0.08 g, due to material burning. The weight of the ground tool from left to right decreased by 0.15 g due to material removal. The fuel consumption measurement showed an average consumption per 1 cubic meter of 1.645 l. Sieve analysis showed that the largest fraction in the chips was from 2 to 5 mm. The above evaluation of selected properties will help further research into tools suitable for chipping, in terms of increasing their service life.

Keywords: *wood chipping, tool wear, fuel consumption, sieve analysis, service life*

This paper was prepared as part of the Visegrad Fund no. 22420094 „Logging Residue Torrefaction and Pressure Agglomeration as a Method to Conserve Fossil Fuels" and the Slovak Research and Development Agency under Contract no. APVV-21-0180.

UTILIZATION OF AGRO-FOOD RESIDUES IN THE PRODUCTION OF HIGH-QUALITY SOLID BIOFUELS

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The issue of solid biofuel quality is gaining increasing importance in the context of energy sector decarbonization, improving fuel logistics efficiency, and valorizing agricultural and food-processing residues. This study analysed the possibility of using waste orange peel—rich in pectins—as a natural additive enhancing intermolecular bonding forces in pellets produced from softwood sawdust. The main objective was to determine whether this additive could improve mechanical and operational properties of pellets without significantly compromising their energy quality.

The research was carried out at the accredited Laboratory of Biofuel Production Technology and Quality Assessment, using measurement equipment such as a pelletizer, muffle furnace, calorimeter, pycnometer, durability tester, and drying oven. Five samples with a constant base mass (3 kg) were prepared, containing respectively: 0%, 1%, 3%, 6%, and 9% dried and ground orange peel. For each sample, moisture content, bulk and particle density, mechanical durability, ash content, and calorific value were determined.

The results showed that:

- Mechanical durability increased with the proportion of peel – from 97.1% (0%) to 98.8% (9%),
- Bulk density decreased – from 0.629 to 0.552 g/cm³,
- Particle density also slightly declined at higher additive levels,
- Ash content increased from 0.51% to 0.70%,
- Calorific value remained at a satisfactory level.

Conclusions: The use of waste orange peel as an additive to woody biomass in pellet production is technologically and environmentally justified. Improved pellet durability can reduce losses during logistics and storage, while the valorization of food-processing waste alleviates environmental pressure. The applied proportions (up to 9%) do not significantly deteriorate key pellet quality parameters, confirming the potential for scaling up this solution. Future research should focus on assessing the impact of pectin-based additives on emission performance during combustion and their influence on long-term boiler operation

Keywords: *solid biofuels, pellets, food waste, pectins, orange peel, pellet quality, fuel logistics*

BRINELL HARDNESS TESTING OF WILLOW (*SALIX VIMINALIS*) INTENDED FOR BIOMASS

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Under the EU climate and energy policy, Member States, including Poland, are required by the provisions of the Regulation of the European Parliament and of the Council to take long-term action on energy and climate change with a view to achieving the complete decarbonisation of the energy sector by 2050.

Willow (*Salix viminalis*) is widely used for the production of biomass from plantations. In order to design machines and working units that can process this type of wood efficiently without unnecessary energy expenditure, it is necessary to understand its physical and mechanical properties. An important feature is hardness, which is why tests were carried out to examine this parameter.

Hardness measurements were performed using the Brinell method with a SHIMADZU AGX-V strength testing machine. Thirty shoots were tested in the basal part and at heights of 1 to 3–4 metres, every metre. The tests were performed immediately after cutting (moisture content 50%). Research has shown that the hardness of willow shoots varies slightly depending on their location (section). Averaging the hardness of all samples tested, it can be concluded that the average hardness of fresh energy willow is 1.92787 N/mm² ≈ 0.19659 kg/mm². Taking into account Mörhat's classification of wood hardness, it can be concluded that energy willow wood is very soft. The statistical tests performed, i.e. Pearson's linear correlation and Kruskal-Wallis analysis of variance, did not show a clear trend that would characterise the variability of willow shoot hardness when divided into sections.

On the other hand, it is puzzling why the hardness of the basal parts of the shoots is lower than that of the upper parts. It seems that the relationship should be the opposite, as the parts of the trees that are close to the ground should have a higher hardness because they support the entire mass above them. Therefore, it would be necessary to investigate to what extent the hardness of wood is influenced by the growth of annual rings. This is because the lower part has wider annual rings and is characterised by lower hardness than the upper sections, where the rings are narrower. The difference in hardness between the samples may also be due to the difference in density between the samples from different sections; therefore, it would be appropriate to conduct research on the density of this wood species.

Keywords: *willow, hardness*

LOGGING FROM FORESTS AND ENVIRONMENTAL PROTECTION: A CASE STUDY OF GERMAN BEECH FORESTS

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Germany's plan to suspend timber harvesting in ~170,000 ha of public old-growth beech (Fagus sylvatica) forests is framed as climate mitigation by conserving forest carbon stocks. This paper evaluates whether setting aside highly stocked, mature stands can deliver durable net removals under accelerating climate-driven disturbances. We synthesize evidence on beech stand dynamics, mortality and decay processes, and compare the climate outcomes of (i) passive protection and (ii) Climate-Smart Forestry (CSF) that combines adaptive silviculture with cascading wood use. Current set-aside areas average ~425–444 $m^3\ ha^{-1}$ of timber volume; projections of increasing stocks to 575–736 $m^3\ ha^{-1}$ by 2050 rely on stable growth that is increasingly uncertain. Rising drought stress, pests and fungal attacks increase tree and crown mortality, shifting mature stands toward carbon neutrality and, eventually, net emissions as deadwood decomposes. If stands approach ~700 $m^3\ ha^{-1}$ and lose ~50% during the decay phase, uncontrolled releases could reach ~60 Mt CO_2 from the set-aside area (excluding soil losses). In contrast, managed stands maintained in a younger age structure can sustain higher net uptake, while harvested wood stored in long-lived products and used to substitute steel, concrete and fossil energy yields additional, cumulative emission reductions. A domestic logging ban also risks leakage by displacing harvest to regions with lower environmental standards. We conclude that climate policy should prioritize CSF: active stand conversion and sustainable harvest coupled with material substitution, rather than treating old beech reserves as stable, long-term carbon sinks.

***Keywords**: Climate-Smart Forestry (CSF); beech forests; forest carbon balance; wood product substitution; sustainable forest management; leakage.*

A comparison of bricketed biofuels for a combustion equipment with a power output up to 10 kW

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An emission problem is so important and wide, that mostly is problem concerned to the ideal combusting of fuels. There are certain ways to decrease these emissions. Such as continuous dosing of fuel, enough high level of temperature in a combustion chamber input of secondary, even terciary air, choice of an optimal fuel humidity. A work is concerned of an actual topic, an energetically use of briquette solid phytomass for combustion equipment with a power output limitation 10 kW. In order to get a valid and reliable judgment it is necessary to base work on stechiometry equations, elements composition of biomass and working parameters of combustion equipment. Solving of given problem contributes to the emission limitation and to the decreasing air pollution level.

A measurement is focused for emission concentrations` observing produced by combusting of mixed briquette phytomass. There are also checked carbon`s oxides (Carbon Dioxide CO_2 a Carbon Oxide CO), Nitrogen's oxides (Carbon Nitrogen NO a Carbon Nitrogen NO2), Sulphur's oxides (SO_2) and Hydrogen Chloride (HCl). The air excess n is very important working parameter, which influences emissions as well as heating system efficiency. It also determines amount of oxiding parts and a furnace temperature. Optimal working temperature is possible to set in the case of consumers of this class in a power range $1{,}4 \leq n \leq 2{,}6$.

Values determined by this interval were obtained by burning of briquette Canary Grass, briquette mix Power Sorrel and Canary Grass in ratio 3 : 2 a Soft Coal 10% m/m, briquette mix Canary Grass and Gold-of-pleasure in ratio 1 : 1 a Soft Coal 15% m/m, briquette mix Canary Grass a Wood ships of Poplar in ratio 1 : 1 and with additional 10 % m/m Soft Coal, and briquette mix Canary Grass a Poplar Bark 1 : 1 with additional 10 % m/m Soft Coal.

Keywords: *Phytomass, briquette, stechiometry, combusting, fireplace.*

The study was supported by the internal grant agency of the Faculty of Engineering at the Czech University of Life Sciences (IGA TF) and through Visegrad Grants from International Visegrad Fund.

ESTIMATION METHODS OF DENDROMASS ON FAST-GROWING TREE PLANTATIONS

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Short-rotation woody crop (SRWC) plantations play a crucial role in addressing the current energy and climate crisis. Their dendromass production potential represents a strategic source of renewable energy and an effective means of carbon sequestration, while also contributing to the energy self-sufficiency of rural regions. Efficient monitoring of production characteristics—particularly the estimation of dry biomass—is essential for optimizing the management and productivity of these plantations. This study focused on estimating both dry and fresh biomass in a coppiced poplar plantation using three scanning technologies: terrestrial laser scanning (TLS), mobile laser scanning (MLS), and a low-cost MLS prototype. Volume models were generated from point cloud data, with the low-cost MLS prototype demonstrating the highest performance, achieving correlation coefficients up to 0.84 (R^2) and root mean square error (RMSE) values below 0.75 kg. Predictive models were developed to estimate not only dry biomass but also fresh biomass. The highest accuracy in dry biomass estimation was achieved using the MLS prototype with a voxel size of 5 cm, yielding $R^2 = 0.89$ and RMSE = 0.75 kg. The results confirm that both

TLS and MLS technologies are effective tools for dendromass quantification under Central European conditions. Moreover, the low-cost MLS prototype offers excellent performance at minimal operational cost, making it a promising solution for large-scale biomass monitoring. This approach demonstrates high potential for precise tracking of dendromass dynamics in SRWC plantation environments and supports the development of sustainable biomass production systems.

Keywords: *Terrestrial Laser Scanning; mobile laser scanning; short-rotation woody crop plantations; dry biomass estimation*

This research was funded by Scientific Grant Agency VEGA, grant numbers VEGA 1/0177/24 and VEGA 1/0604/24.

APPLICATION OF HYDROSORBENTS INCREASES THE GROWTH OF FAST-GROWING POPLARS

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Wood is an ecological and sustainable source of energy compared to coal. However, in forestry, industrial logging is only possible in stands older than 80 years (rarely from 20 to 40 years old). One option to compensate for the demand for wood biomass is to use fast-growing trees. The growth rate of biomass is crucial in this case, and fast-growing poplar species are most often used for this purpose. The quantity of biomass can be positively influenced by planting trees using hydrosorbent materials that are able to retain water. In 2020, an experiment with fast-growing poplars of the J105 clone was established on arable land in Prague-Ruzyně to determine the effect of various hydrosorbents on poplar growth.

The following materials were added to the planting hole (Ø of 50 cm) during planting: (1) biochar; (2) hydrogel; (3) pellets (Ø of 10 mm, length 3-4 cm) with a combination of post-harvest agricultural residue materials (wheat straw, chaff) and dried digestate. All materials were applied in an amount of 1 kg, except for hydrogel in an amount of 65 g. Tree height and trunk width at a height of 1.3 m were measured over 3 years. Tree height increases in the variants with pellets were significantly higher than in the control, by an average of 85 cm. The application of biochar had a similar effect as the application of pellets. The application of pellets and biochar had the same effect on trunk width, which was on average 1,5 cm higher than on the control. On the other hand, the variant with hydrogel showed similar increases as the control. The yield of above-ground biomass in dry matter, based on estimates from allometric equations (Fajman, Palát, Sedlák 2009), was two times higher with the application of biochar and granulated materials.

Granulated materials in the form of pellets, unlike hydrogels, are a natural, sustainable material of non-chemical origin. They also have better applications and lower logistics due to their higher bulk density (40-60 % higher) and form compared to biochar. The production of biochar in the kiln has significant carbon emissions. The application of natural organic materials to the soil leads to an increase in water retention and promotes biomass growth.

Keywords: *Sustainbility; water retention;post-harvest agricultural residues;biochar*

This study was supported by the Ministry of Agriculture of the Czech Republic, institutional support MZE-RO0426

VALORIZATION OF FRUIT TREE WOOD FOR RENEWABLE ENERGY AND BIOCHAR

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Wood from fruit trees represents an underutilized but highly promising biomass resource for sustainable energy production and biochar generation. Regular pruning and tree replacement in orchards produce substantial amounts of woody residues that are often inefficiently used or left unvalorized. Owing to their high density, elevated lignin content, and favorable ash characteristics, species such as apple, cherry, and walnut provide suitable feedstocks for thermochemical conversion processes.

This study investigates the energetic and physicochemical properties of fruit tree biomass and the characteristics of biochar produced through torrefaction and pyrolysis. Biomass samples collected from productive orchards in the Central Bohemian Region (Czech Republic) were subjected to thermal treatment at 250–550°C under an inert nitrogen atmosphere in a laboratory fixed-bed reactor, with a residence time of 30 minutes at each target temperature. Proximate analysis was performed using a LECO TGA 701, elemental composition (C, H, N, S) was determined using a LECO CHN628 + S analyzer, and the higher heating value (HHV) was measured with a LECO AC-600 isoperibol calorimeter.

To express the influence of the torrefaction and pyrolysis treatments on combustion behavior, stoichiometric combustion calculations were conducted. These calculations enabled the evaluation of changes in theoretical oxygen demand, formation of combustion gases, and the energy release potential of the biomass and resulting biochars.

The results confirm the high calorific value of fruitwood (18–21 MJ/kg) and demonstrate that increasing pyrolysis temperature enhances biochar carbonization, aromaticity, and stability. Overall, the study contributes to a deeper understanding of orchard-derived woody biomass as a renewable energy source and as a valuable feedstock for biochar production, supporting sustainable resource management and circular bioeconomy pathways.

***Keywords**: Fruit tree biomass, torrefaction, pyrolysis, biochar, heating value*

THE ENHANCEMENT OF BIOMASS BY THERMAL TREATMENT WITH REGARDS TO MEETING BIOFUEL TECHNICAL STANDARDS

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Thermal treatment of biomass in the absence of air may be called pyrolysis or torrefaction, depending on the process conditions. Torrefaction is usually reserved for low temperature treatment under 350°C, while pyrolysis normally applies for higher temperature treatment. In general, both types of treatment change biomass feedstocks through thermal decomposition into darkened material, biochar, with higher content of carbon and lower contents of hydrogen and oxygen. Other biogenic elements, like nitrogen and sulphur, may sometimes concentrate in the biochar. Biochar may be used for various environmental applications, however, thanks to high carbon content its calorific value is also very often significantly increased compared to the feedstock. The thermal treatment has some other positive impacts on fuel properties, such as decreased biodegradability and better grindability. On the other hand, biochar is typically harder to process into densified fuels. Since 2023 there is a technical standard (*ISO 17225-8*) which puts requirements on fuels made from thermally treated biomass. The present contribution discusses the influence of thermal treatment of biomass of varying quality and ash content on the expected quality of biochar and its applicability as a standalone fuel in regards to meeting requirements of *ISO 17225-8* and the strategy of using it in fuel mixtures.

Keywords: *Torrefaction; Pyrolysis; ISO standards; Energy content; Fuel quality*.

The study was supported by the internal grant agency of the Faculty of Engineering at the Czech University of Life Sciences (IGA TF) and through Visegrad Grants from International Visegrad Fund.

CARBONIZATION OF RESIDUES FROM THE WOOD-BASED PANEL INDUSTRY FOR PRODUCING SOLID BIOFUELS FOR INDUSTRIAL APPLICATIONS

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The increasingly limited supply of wood in the domestic energy market necessitates the search for alternative raw materials, including wood-based panel waste. However, these materials contain synthetic resins, which limit their potential use as an energy carrier in Poland. One way to mitigate the unfavourable properties of this biomass as a fuel could be through thermal pre-treatment. This study aimed to produce solid biofuels from wood-based waste panels loaded with synthetic chemicals with improved functional properties obtained through thermal treatment.

The study included residues from the wood-based panel industry (particleboard, MDF). The basic fuel properties of the tested raw materials were determined, and thermogravimetric analysis was performed under dynamic conditions. The thermal modification process was carried out using variable temperature parameters. The percentage mass loss relative to the dry mass of the raw material was determined in the resulting chars, and the elemental composition was analysed.

The conducted research confirms the feasibility of using thermal processing to obtain solid biofuels from wood-based panel waste loaded with synthetic chemicals with improved performance properties. Thermal processing of wood-based materials bonded with urea adhesives in an anaerobic environment results in partial destruction of the adhesive bonds, which is reflected in changes in the nitrogen content of the treated samples.

Keywords: *biofuels, waste wood, carbonization, torrefaction*

ASSESSMENT OF THE ENERGY PARAMETERS OF VARIOUS LIGNOCELLULOSIC FEEDSTOCKS USED IN BIOFUEL PRODUCTION

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Biomass as a biofuel has become a sustainable alternative in the global energy landscape. This study evaluates the fundamental energetic properties of solid biofuels formed into pellets and briquettes, produced from a various lignocellulosic materials, including wood as: broad-leaf and coniferous, agricultural biomass such as straw from wheat, rapeseed, hops, hemp, olive cakes, sunflower husks, oil palm shell, torrefied materials or paper. The analysed physicochemical parameters comprised moisture and ash content, elemental composition (carbon, hydrogen, nitrogen, sulphur, chlorine), gross and net calorific value and mechanical durability. Quality assessment was performed in accordance with European standards with emphasis on requirements for domestic-scale applications. The results of the study indicate that, for producers, the key parameter determining the classification of pelletized biofuel is its mechanical durability. The results highlight notable variability in non-woody biomass, yet indicate that most producers are capable of manufacturing high-quality pellets and briquettes suitable for small-scale combustion systems. The study reinforces the importance of standardized quality monitoring to ensure efficient and environmentally compliant use of solid biofuels.

Keywords: *biofuels, pellets, briquets, wood, biomass, agricultural*

MATERIAL PROPERTIES CHANGES CAUSED BY HIGH TEMPERATURE DRYING – WALNUT SHELLS CASE STUDY

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Biomass is an energy source with variable physico-chemical properties. Thermal treatments lower moisture and volatile matter contents. They also raise the high heating value. This is especially desirable for agro-residues with energy potential, like walnut shells. To make pellets from biomass, it is important to keep the lignin intact which is responsible for particle adhesion. This paper presents a study focused on high-temperature drying of walnuts shells. The process temperatures were selected from a range between 60 and 220°C. The upper temperature limit prevents significant lignin breakdown. We also do not exceed the self-ignition temperature of the raw material. The study analyzed changes in basic technical parameters. These include moisture content, ash content and high heating value. We tested the grinding and densification process. We measured the raw material's particle size distribution (PSD), specific density, and the mechanical durability (DU) of the agglomerates. The study showed a positive effect of high-temperature drying on the technical parameters.

Keywords: *biomass drying; grindability; pellets; solid density; mechanical durability*.

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