

The Use of Forestry and Agricultural Biomass in the Production of Pellets

Steliana RODINO*

Research Institute for Agriculture Economy and Rural Development, Bucharest, Romania

**Corresponding author, steliana.rodino@yahoo.com*

Daniela Nicoleta VOICILĂ

Research Institute for Agriculture Economy and Rural Development, Bucharest, Romania

badan.daniela@iceadr.ro

Cristina Maria STERIE

Research Institute for Agriculture Economy and Rural Development, Bucharest, Romania

sterie.cristina@iceadr.ro

Abstract: The use of forestry and agricultural biomass for pellet production represents a significant opportunity to strengthen a sustainable economy characterized by reducing dependence on fossil fuels and more efficient protection of the environment. The aim of this paper is to improve the understanding of the current state of research on the use of forestry and agricultural biomass for pellets production, fostering awareness of their potential for energy production. In the development of the work, various research stages and techniques were used. These included the analysis of international trade data wood pellets, literature review of research dynamics on agricultural biomass pellet production from last decade, identification of articles from prestigious journals to highlight key trends and concerns in research, analysis of research concentration areas, and investigation and analysis of collaboration networks among researchers and institutions. These methodological approaches have contributed to the creation of a comprehensive and updated work, providing a deeper and clearer understanding of the researched topic. The European Union represents a major force in the global consumption of wood pellets, with demand for this product steadily increasing. Additionally, Romania has significant exports of wood pellets to other European countries, indicating considerable potential for the development of the pellet industry in the country. Furthermore, the literature emphasizes the importance of non-wood biomass, such as agricultural residues, as a crucial source for pellet production. The literature review reveals an increasing focus on biomass pellets in recent years, with research concentrating on various domains such as biotechnology, energy fuels, and sustainable green technology.

Keywords: agricultural biomass, pellets, circular economy, bibliometric analysis, energy production

Introduction

About 80% of the world energy supply is based on fossil fuels which contribute significantly to global warming (Roh, 2016). The need for ambitious climate action to keep temperature increases to no more than 1.5°C, above pre-industrial levels, was demonstrated by numerous reports. Expanding the use of low-carbon renewable energy sources is considered to be an essential part of the solution (Cofas et al., 2023). In addition to the necessary contribution to climate change mitigation, biofuels production can trigger technological innovation and bring multiple socio-economic benefits to local communities (USDA GAIN Report, 2021). In terms of the new political orientations of the European economy, launched through the series of actions included in the

European Green Pact, the Just Transition Strategy and the Recovery and Resilience Plans, the introduction of pellets into consumption, for heating, presents a decisive advantage over other sources, namely they use renewable raw materials.

Biomass is the organic material derived from plants, animals, micro-organisms. Considered a form of energy, in the last decade it has become a topic of global importance in the context of climate issues and sustainable energy sources (Kimming et al., 2011). Biomass from agriculture is derived from organic materials which are considered as waste, including straw, stalks and leaves from crops, crop residues, that might be converted into energy and bio-based products (Saleem, 2022).

Various agricultural and forestry residues and waste streams are currently underutilized, either left on the land or incinerated. In the current context, where concern for sustainability and environmental responsibility is increasing, the circular economy has changed the way people manage production, and on a particular case, the waste from agriculture (Zhang et al., 2021; Balan et al., 2021; Sherwood, 2020).

The aim of this article is to enhance the understanding of the current level of research regarding the utilization of forest and agricultural biomass in pellet manufacturing, facilitating awareness of their potential for energy production. The study is analyzing the process of transforming biomass resources into pellets, considering the importance of transitioning to more sustainable and environmentally friendly energy sources. By highlighting existing information and research, we aim to contribute to accelerating progress in the development and sustainable use of forest and agricultural biomass for energy production.

Literature review

Renewable energy currently accounts for a small share of total global energy consumption, but is expected to reach 30% by 2050 if renewable energy sources are continuously developed (Pradhan et al., 2018, Bajwa et al., 2018). According to the Bioenergy Report released last year, the world production of pellets has registered an increase, to 46 million tons of pellets in 2022 compared to 44.7 million tons in 2021 (Bioenergy Europe, 2023). At EU -27 level, the pellet production increased with 67 thousand tons, from 19.93 million tons in 2021 to 20.5 million tons in 2022. Germany is the country that ranks first as a producer of pellets in the EU-27, with over 3.5 million tons of pellets.

Collaboration between the main pellet producing countries in the EU, represented by Germany, Latvia, Poland, France, Sweden and Austria, make a key contribution to the importance of the EU - 27 region as a key player in the global sector (Bioenergy Europe, 2022).

As pellets are a sustainable and renewable energy source, wood pellet production is developing and growing rapidly worldwide (Garcia et al., 2019). Compact and densified biomass with a low moisture content helps to reduce the technical limitations associated with storage, handling and transportation (Bajwa et al., 2018; Popa et al., 2023). Thus, an immediate solution is the pelletization of raw biomass that increases its energy efficiency and allows biomass to compete with other types of fuels (Smaga et al., 2018).w

Pellets can be obtained from different types of biomass, including waste and by-products from the wood industry, food waste, agricultural residues, energy crops and fruit peels (Kpalo et al., 2020; Aghalari et al., 2021). Among the advantages of pellets is sustainability, so biomass is considered a renewable source option, but also efficient due to its high energy content (Tauro et al., 2018; Cofas et al., 2023).

Methodology

The aim of this paper is to provide an analysis of the current state of research on agricultural biomass pellet production, thus contributing to the understanding of the trends in this field.

Data related to wood pellets international trade were retrieved from Trademap.org based on UN COMTRADE statistics data. Further, the proposed research focuses on conducting an analysis of the dynamics of research on the use of agricultural biomass in pellet production.

The method used in the research involved analyzing bibliographic data and publications in the field, focusing on papers published between 2013-2023 on the Web of Science platform. In parallel, the number of papers published in the 10 most prestigious journals were identified and the tree map was presented to provide a visual perspective on the connections and interdependencies within the most recent research. This method has allowed for a deeper understanding of the evolution of research in the field and the relevance of the papers published in the top journals.

The bibliometric method provides an objective and rigorous framework for examining bibliographic data in a specific research field, facilitating the identification of trends, the evaluation of research impact and relevance, as well as the discovery of collaborations and new research directions.

Results and discussions

The predominant raw material for pellet production is wood and sawdust, as an untreated substrate, the latter being considered ideal, benefiting from the removal of contaminants through processes such as bark removal and log washing before cutting. However, due to the growing demand for wood pellets and the limited resources of sawdust from sawmills, research into pellet production from other sources, including residues from logging or agroforestry plantations has intensified.

Pellet trade

With a consumption of around 29 million tonnes of pellets in 2018, the European Union is the largest consumer of wood pellets in the world. Based on European Commission policies and EU Member State incentives, demand for this product is expected to expand further to 32 million tonnes in 2022 (USDA GAIN Report, 2021; Schipfer et al., 2020). Approximately 40% of the total pellet market is represented by residential use for heating, thus resulting in a relatively stable market compared to industrial heat and power production (Eurostat, 2020). In some EU Member States, households receive subsidies or tax deductions for biomass heating, which is important to keep in mind when targeting strategies for our country.

According to data from 2022, Romania exports significant quantities of wood pellets to countries such as Austria, Italy, Bulgaria, Greece and Slovenia.

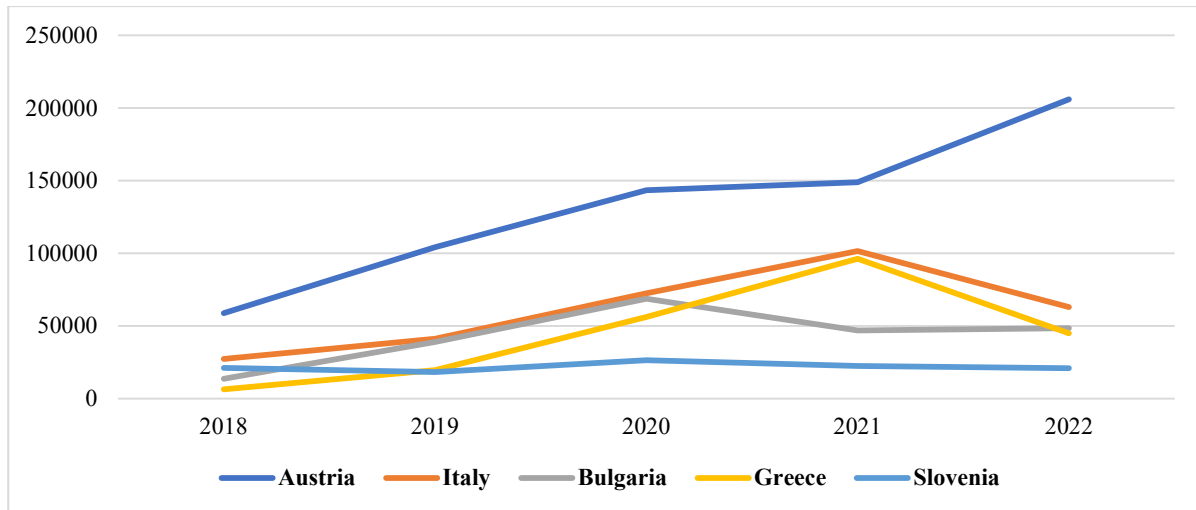


Figure 1. Dynamic of top 5 importing markets for a product exported by Romania, wood pellets, quantities expressed in tons

Source: Processing based on Trademap data.

Analyzing the data on exports of wood pellets from Romania to various countries in the period 2018-2022, it can be seen that Austria was one of the major destinations, with an upward trend, recording a significant increase from almost 60 thousand tons in 2018 to over 200 thousand tons in 2022. Slovenia, although it had a slight fluctuation in export figures, remained one of the important destinations for wood pellets from Romania. Analyzing these data, one can observe a complex dynamics of wood pellets exports from Romania to different European markets in the last five years.

Also, Romania imports significant quantities of pellets from Ukraine, around 50 thousand tons in 2022.

According to the literature, it has been reported that non-wood biomass, such as agricultural residues, is a significant source for pellets due to its high availability, low cost and the importance of reusing agricultural waste in a green and circular economy. Therefore, in the following, this study presents a brief review of the literature in this area.

In 2013, 30 papers were published, and by 2023, the number has increased to 62, registering an increase of more than 106.6%. The highest number of peer-reviewed papers registered in the Web of Science database was 76 in 2021 (Figure 2).

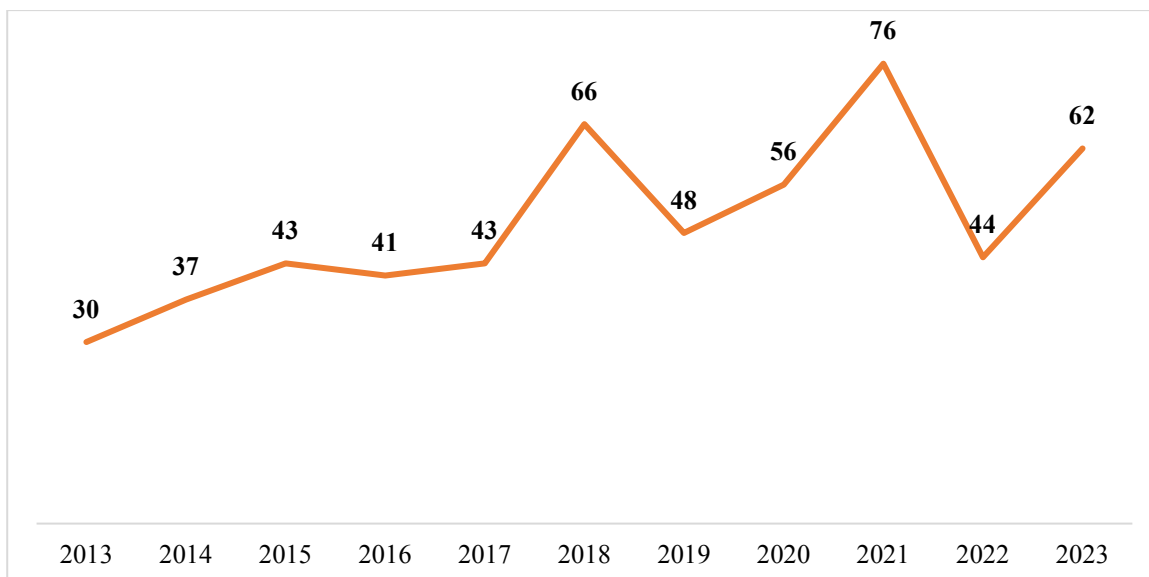


Figure 2. Number of papers published on the topic „Use of Agricultural Biomass in Pellet Production"

Source: Web of Science.

On the topic „Utilization of Agricultural Biomass in Pellet Production", a total of 546 papers published in the Web of Science database during the period 2013-2023 were identified. The researches were included in areas such as: energy fuels (231 researches), environmental sciences (99 researches), green sustainable science technology (84 researches), agricultural engineering (81 researches), chemical engineering (76 researches), biotechnology applied microbiology (60 researches) (Figure 3).



Figure 3. Tree map of research on the topic "Use of Agricultural Biomass in Pellet Production"

Source: Web of Science.

In the period 2020-2024, the United States of America was the leader in research on our topic with a total of 71 studies, followed by China with 68 studies and Poland with 60 studies, indicating an increased interest in the topic. Romania ranks 14th with 16 studies on the subject, with countries such as Lithuania and Malaysia (Table 1).

Table 1. Top 10 Countries with Most Publications Related to „Use of Agricultural Biomass in Pellet Production"

Country	Number
USA	71
CHINA	68
POLAND	60
ITALY	51
CANADA	42
SWEDEN	34
GERMANY	24
BRAZIL	23
SPAIN	23
LATVIA	22

Source: Web of Science.

It should be noted that, in general, the quality of agro- pellets is lower than that of pellets made from forestry material. Assessing and improving pellet quality are fundamental issues in the efficient and sustainable use of biofuels, with significant technical and economic implications.

In the literature, issues related to low density, high ash content and lower calorific value have been highlighted (Gracia et al., 2019; Pradhan et al., 2018; Malik et al., 2016). Blending agricultural biomass with woody, forest-derived biomass is a viable solution for quality improvement (Stasiak et al., 2017; Whittaker & Shield, 2017).

Table 2. Top 4 most cited web of science papers on the use of agricultural biomass in pellet production

Name of publication	Authors	Year	Citation
Pellet Production from Woody and Non-Woody Feedstocks: A Review on Biomass Quality Evaluation	Picchio, R. et al.	2020	49
A review of the mechanism of bonding in densified biomass pellets	Anukam, A. et al.	2021	39
Characteristics of torrefied fuel pellets obtained from co-pelletization of agriculture residues with pyrolysis oil	Sarker, TR et al.	2021	25
Production of sorghum pellets for electricity generation in Indonesia: A life cycle assessment	Wiloso, EI et al.	2020	21

Source: Web of Science.

Pellet quality is influenced by a number of parameters, including raw material properties such as particle size distribution, moisture content and chemical composition. In this respect, recent

studies have focused on improving pellet quality parameters using different organic components, feedstock pretreatment technologies, pellet treatment technologies in the final processing phase, by chemical and physical processes such as steam explosion or torrefaction.

Picchio's 2020 paper examines forest and agricultural biomass as renewable and sustainable fuel sources. The pellet sector has seen a significant increase in production due to global energy growth, but also due to fossil fuel prices. The authors argue that an important element is the quality of pellets, especially when it comes to their production, due to the diversity of biomass feedstock. The research focused on the analysis of pellets of forest and agricultural origin, where literature on the topic of improving pellet quality in the period 2016-2020 was reviewed. The research results focused on the gaps present in current research and on pure feedstocks without biomass binders, the influence of biomass mixed binders affecting pellet quality and pre and post treatments (Picchio et al., 2020).

The second most cited paper was by author Anukam, who discusses the use of sustainable biomass for pellet production. This topic is quite controversial in the literature, being contested because of the mechanism of achievement, namely, the binding resulting from the combination of particles from the pellet press. As a result of the bonding formed, the qualities of the pellets remain unclear, however, it has been observed that although some researchers attempted to explain the mechanism of bonding in densified biomass pellets using different theories, none of their hypotheses support particle bonding from a structural chemistry perspective. There are still no clear explanations that take into account the role of molecular structure and interactions between substances as the ground biomass undergoes pelletization. Therefore, the analysis provides a structural chemistry perspective of the binding mechanism and additive utilization in densified biomass pellets and helps to identify areas of research needed to facilitate a better understanding of binding in densified biomass pellets (Anukam et al., 2021).

Sarker's 2021 paper examines the potential of converting agricultural waste to global energy through pellets, where by-products have low value and conversion to pellets results in high value.

The research focuses on the analysis of co-peeling characteristics with agricultural waste such as rapeseed hulls, oat hulls, barley straw combined with biological pyrolysis oil as a binder. Following co-peeling, it was found that rapeseed husk is a base material due to its low oil content, and after assisting the biomass with water, durability and mechanical strength of the pellets resulted. However, the yield decreased, but 30% co- pelleting of oat hulls, barley straw and rapeseed hulls was optimal. The torrefied pellets exhibited higher heating power, increased energy density, higher carbon content, lower atomic ratio and reduced moisture absorption compared to untreated pellets. Synchrotron computed tomography analysis showed an increase in porosity of up to 39% after torrefaction. In addition, various characterization methods were used to evaluate the mechanical, physical and chemical properties of the pellets (Sarker et al., 2021).

Wiloso's 2020 paper with collaborators examines the use of life-cycle assessment to analyze potential greenhouse gas (GHG) savings in coal-fired power generation by adding 5% sorghum pellets. The study models the use of 100 thousand hectares of marginally underutilized land in Flores, Indonesia for growing sorghum from biomass. It finds that, based on equivalent energy content, 1.12 tonnes of pellets can replace one tonne of coal. Calculation of the pellets' fossil energy ratio indicates a value of 5.8, suggesting the energy viability of pellet production for fuel.

With a biomass yield of 48 tonnes/ha.year, annual pellet production can reach 4.8 million tonnes. Compared to a coal-based system, burning only pellets to generate 8,300 GWh of electricity can reduce the impact of global warming by 7.9 million tonnes of CO₂-eq, representing a significant 85% decrease in GHG emissions. However, the results changed when the model

included the low biomass yield of 24 tonnes/ha.yr, biomass loss, field emissions and incomplete burning. Through sensitivity analysis, it was found that the potential GHG savings could drop from 85%, as originally estimated, to 70%. Overall, the production of sorghum pellets in Flores and their use for electricity generation can make a significant contribution to reducing dependence on fossil fuels and combating climate change. The limitations of these findings are also discussed in the study (Wiloso et al., 2020).

Biomass from woody and agricultural residues, is considered a significant and promising resource for pellet production due to their high availability, low cost, and potential to contribute to a circular and sustainable economy. The study highlights an increasing interest and research in this field in recent years.

Improving the quality of biomass pellets is crucial for their efficient and sustainable use as an energy source, considering challenges related to low density, high ash content, and lower calorific value. The aforementioned studies also emphasize these aspects, highlighting significant issues encountered in biomass pellet production.

Further research is deemed necessary to address these challenges and globally enhance the quality of agricultural biomass pellets. Additionally, the importance of continuing exploration and innovation in pellet production technologies, including investigating the blending of agricultural biomass with woody biomass to improve quality, is emphasized.

A comprehensive approach for advancing biomass pellet technology, will be considering both technical and economic aspects, to develop sustainable energy solutions.

Conclusion

The paper aims to analyze the current research status regarding the production of agricultural biomass pellets, thereby enhancing comprehension of trends within this field

Wood pellet production was identified as a rapidly growing sector, offering a sustainable solution with benefits such as compactness, low moisture content, and improved energy efficiency. Pelletization of diverse biomass types, including wood industry wastes, agricultural residues, and energy crops, holds the potential in meeting energy demands efficiently.

Pellets produced from agricultural biomass are necessary for the transition to a more sustainable energy system and help reduce greenhouse gas emissions. The use of biomass also improves the management of agricultural waste and can be an additional source of income for farmers.

A review of the literature has shown an increasing focus on the study of biomass pellets in recent years worldwide. A total of 546 research papers were identified in this field during the period 2013-2023. The research areas in which the literature is concentrated include: biotechnology applied microbiology, energy fuels, environmental sciences or green sustainable science technology. The study demonstrated the growing interest and research devoted to this field in recent years. There were also highlighted the critical importance of improving the quality of biomass pellets to ensure their efficient and sustainable use as an energy source. Future research on the utilization of forestry and agro biomass for pellet production with practical application for Romania will be focused on conducting a comprehensive technoeconomic study.

Acknowledgment

The present research is part of the Project ADER 22.1.4 "Research on the development of technical-economic solutions for the creation of value chains in the agri-food sector in view of the

transition to the circular bioeconomy" of the Research Institute for Agricultural Economy and Rural Development Bucharest.

References

- Aghalari A., Aladwan B. S., Marufuzzaman M., Tanger S., Da Silva B. K., Gnaneswar Gude V. Optimizing a pellet supply system: Market-specific pellet production with biomass quality considerations. *Computers & Chemical Engineering*. 2021, 153, 107417,
- Anukam, A., Berghel, J., Henrikson, G., Frodeson, S., & Ståhl, M. (2021). A review of the mechanism of bonding in densified biomass pellets. *Renewable and Sustainable Energy Reviews*, 148, 111249. doi:10.1016/j.rser.2021.111249
- Bajwa D.S., Peterson T., Sharma N., Shojaeiarani J., Bajwa S. G. A review of densified solid biomass for energy production. *Renewable and Sustainable Energy Reviews*. 2018, 96, 296-305, <https://doi.org/10.1016/j.rser.2018.07.040>.
- Bălan, E. M., Cismaș, L. M., & Zeldea, C. G. (2021). Agricultural Biomass Production: Implications for Economic Growth and Environment in Central and Eastern European Countries. In *Contemporary Issues in Social Science* (Vol. 106, pp. 263-279). Emerald Publishing Limited.
- Bioenergy Europe | European Bioenergy Outlook – Pellet Report | 2022
- Cofas, E., & Bălăceanu, C. T. (2023). Evaluation of the biomass energy production potential in agricultural holdings in relation to their size. Case study for crop farms in Romania. *Romanian Agricultural Research*, (40).
- European Union: Biofuels Annual, June 22, 2021 | Attaché Report (GAIN) | E42021-0053
- García, R., Gil, M. V., Rubiera, F., & Pevida, C. (2019). Pelletization of wood and alternative residual biomass blends for producing industrial quality pellets. *Fuel*, 251, 739-753
- Kimming, M., Sundberg, C., Nordberg, Å., Baky, A., Bernesson, S., Norén, O., & Hansson, P. A. (2011). Biomass from agriculture in small-scale combined heat and power plants—A comparative life cycle assessment. *Biomass and bioenergy*, 35(4), 1572-1581.
- Kpalo S.Y., Zainuddin M.F., Manaf L.A., Roslan A.M. A Review of Technical and Economic Aspects of Biomass Briquetting. *Sustainability*. 2020, 12(11):4609. <https://doi.org/10.3390/su12114609>
- Malik B., Pirzadah T., Islam S., Tahir I., Kumar M., Rehman R. Biomass Pellet Technology: A Green Approach for Sustainable Development. In: Hakeem K., Jawaid M., Y. Alothman O. (eds) *Agricultural Biomass Based Potential Materials*. Springer, 2015 Cham. https://doi.org/10.1007/978-3-319-13847-3_19
- Picchio, R., Latterini, F., Venanzi, R., Stefanoni, W., Suardi, A., Tocci, D., & Pari, L. (2020). Pellet Production from Woody and Non-Woody Feedstocks: A Review on Biomass Quality Evaluation. *Energies*, 13(11), 2937. doi:10.3390/en13112937
- Popa, L., Trokhaniak, V., Constantin, A. M., Miron, C., Zaica, A., Persu, C., & Pruteanu, A. (2023). Experimental research regarding the achievement of an equipment designed for chopping woody waste. (2023): 757-766.
- Pradhan, P., Arora, A., & Mahajani, S. M. (2018). Pilot scale evaluation of fuel pellets production from garden waste biomass. *Energy for sustainable development*, 43, 1-14.

- Rodino, S., Butu, A., Dragomir, V., & Butu, M. (2019). An analysis regarding the biomass production sector in Romania-a bioeconomy point of view. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, 19(1), 497-502.
- Roh, H. B. Wood Pellets as a Biofuel: Current Status and their Market Potential, 2016. doi:http://dx.doi.org/10.14288/1.0314326
- Saleem, M. (2022). Possibility of utilizing agriculture biomass as a renewable and sustainable future energy source. *Heliyon*.
- Sarker, T. R., Azargohar, R., Dalai, A. K., & Meda, V. (2021). Characteristics of torrefied fuel pellets obtained from co-pelletization of agriculture residues with pyrolysis oil. *Biomass and Bioenergy*, 150, 106139.
- Schipfer, F., Kranzl, L., Olsson, O., & Lamers, P. (2020). The European wood pellets for heating market-Price developments, trade and market efficiency. *Energy*, 212, 118636.
- Sherwood, J. (2020). The significance of biomass in a circular economy. *Bioresource Technology*, 300, 122755.
- Smaga, M., Wielgosiński, G., Kochański, A., & Korczak, K. (2018). Biomass as a major component of pellets. *Acta Innovations*.
- Stasiak, M., Molenda, M., Bańda, M., Wiącek, J., Parafiniuk, P., & Gondek, E. (2017). Mechanical and combustion properties of sawdust—Straw pellets blended in different proportions. *Fuel Processing Technology*, 156, 366-375.
- Tauro, R., García, C. A., Skutsch, M., & Masera, O. (2018). The potential for sustainable biomass pellets in Mexico: An analysis of energy potential, logistic costs and market demand. *Renewable and Sustainable Energy Reviews*, 82, 380-389.
- Whittaker, C., & Shield, I. (2017). Factors affecting wood, energy grass and straw pellet durability—A review. *Renewable and Sustainable Energy Reviews*, 71, 1-11.
- Wiloso, E. I., Setiawan, A. A. R., Prasetya, H., Wiloso, A. R., Sudiana, I., Lestari, R., ... & Heijungs, R. (2020). Production of sorghum pellets for electricity generation in Indonesia: A life cycle assessment. *Biofuel Research Journal*, 7(3), 1178-1194.
- Zhang, Q., Zou, D., Zeng, X., Li, L., Wang, A., Liu, F., ... & Xiao, Z. (2021). Effect of the direct use of biomass in agricultural soil on heavy metals activation or immobilization?. *Environmental Pollution*, 272, 115989.