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Sustainable development of environment and energy aspects of methane fermentation on family farms in Poland

© 2022. Jan Barwicki[1], Andrzej Marczuk[2] ✉, Dariusz Góral[2], Małgorzata Góral-Kowalczyk[2], Sybilla Nazarewicz[2]
[1]Institute of Technology and Life Sciences, Branch in Warsaw, Poland,
[2]University of Life Sciences in Lublin, Poland

The goal of these study was to present results of investigation concerning possibilities of utilization of harmful wastes in countryside area to produce ecological energy. Biogas production can be important from the point of view of environment protection especially in case of overproduction of animal wastes. Production and utilization of energy from agriculture residues gives a great chance for diversification and grows of income for family farms. Besides energetic and environment gains, we can obtain very valuable fertilizer, which is easy absorbed by plants in field crop production. The experimental study was conducted to investigate the effect of mixing process on the parameters of methane fermentation process. Temperature inside fermentation chamber, pH of fermented material, redox potential and carbon to nitrogen ratio (C:N) were investigated. Utilize wastes from pig and poultry houses were used for the study. Digestion in a chamber was provided at constant temperature of 37 °C. After adding fresh substrate to the digester, the temperature of the raw material decreased by 1,0-1.5 °C depending on the location in the tank. Also, it was observed that biogas production decreased. The mixing process had a positive effect on the homogeneity of the material throughout the digester volume. The best results for biogas production were obtained when the pH value was 7.0. Research results obtained from tested biogas installation show, that from two bio reactors at total capacity of 410 m³ we can get electrical energy at cost of 34,52 € MWh⁻¹ and thermal energy at cost of 62,54 €·MWh⁻¹. While the cost of producing electricity in a professional power plant based on lignite was 76.23 €MWh⁻¹. The energy produced was used for the operational activities of the farm.

Key words: *biogas, renewable energy, manure, environment protection, economy*

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Устойчивое развитие экологических и энергетических аспектов ферментации метана на семейных фермах в Польше

© 2022. Я. Барвицкий[1], А. Марчук[2] ✉, Д. Гураль[2], М. Гураль-Ковальчик[2], С. Назаревич[2]
[1]Институт технологии и наук о жизни, филиал в Варшаве, Польша
[2]Университет естественных наук в Люблине, Польша

Цель работы – изучить возможность утилизации вредных отходов в сельской местности для получения экологической энергии. Производство биогаза актуально с точки зрения охраны окружающей среды, особенно в случае перепроизводства отходов животноводства. Использование энергии, полученной из сельскохозяйственных отходов, приводит к диверсификации и росту доходов семейных ферм. Помимо энергетических и экологических выгод при утилизации отходов можно получить очень ценное удобрение, которое легко усваивается растениями. Экспериментальные исследования проводили с целью изучения влияния процесса перемешивания отходов свинарников и птичников на параметры ферментации метана: температуру внутри ферментационной камеры, pH ферментированного материала, окислительно-восстановительный потенциал и соотношение углерода к азоту (C:N). Для ферментации отходов в камере обеспечивали постоянную температуру 37 °C. После добавления свежего субстрата в реактор температура сырья снижалась на 1,0-1,5 °C в зависимости от расположения в резервуаре, и производство биогаза сокращалось. Процесс перемешивания положительно влиял на однородность распределения материала по всему объему реактора, при этом увеличивалось производство биогаза. Наилучшие результаты получены при значении pH 7,0. Результаты исследований, полученные при испытании биогазовой установки,

состоящей из двух биореакторов общим объемом 410 м^3, показали, что можно получить электрическую энергию стоимостью 34,52 € МВт-ч$^{-1}$ и тепловую энергию стоимостью 62,54 € МВт-ч$^{-1}$. При этом стоимость производства электроэнергии на профессиональной электростанции на основе бурого угля составляет 76,23 €МВт-ч$^{-1}$. Произведенная энергия использовалась для деятельности фермы.

Ключевые слова: *биогаз, возобновляемая энергетика, навоз, охрана окружающей среды, экономика*

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Global change in the environment, caused by the overexploitation of natural resources and the burning of fossil fuels, has a number of negative effects on human health and the functioning of ecosystems. Waste production is increasing rapidly as a result of industrialization, global urbanization and economic development [1].

With growing requirement of meat and milk consumption, animal production become one of the most harmful sector for environment protection phenomena. Emission to the atmosphere methane, carbon dioxide, carbon oxide, ammonia and hydrogen sulphide is very high and especially it happens during summer period, what has negative influence on environment and in case of higher concentrations, it gives poisonous reaction on neighborhood [2, 3].

The idea of sustainable development can be presented as an evolution of the idea of progress, from technocratic conceived economic growth (production, consumption, technical progress), through sustainable development (development planned and implemented taking into account the possibilities and environmental effects), to contemporary multidisciplinary and humanitarian concept (Universal Declaration of Human Rights), where the subject is the human person, and especially his right to a healthy and productive life in harmony with nature, the well-being of the global community of people of intergenerational justice, self-realization. Sustainable development can be seen as an alternative to globalization[1] [4, 5, 6].

The concept of sustainable development was first used during the Stockholm Conference in 1972, where the goals and tasks of global environmental protection were discussed [7]. In Poland, the principle of sustainable development was given the rank of a fundamental right resulting from the provisions of the Constitution of the Republic of Poland of 1997 (the Constitution of the Republic of Poland of April 2, 1997)[2]. Sustainable development is most broadly defined in environmental protection acts. The most important of them is the Environmental Protection Law of April 27, 2001[3], which comprehensively regulates the principles of environmental protection and the conditions for using its resources. Promoting renewable forms of energy is one of the objectives of the EU's energy policy. Increased use of energy from renewable sources is an important part of the package of measures needed to reduce greenhouse gas emissions and meet the provisions of the Paris Climate Agreement and the EU's 2020-2030 climate and energy policy framework. As part of the European Green Deal, in September 2020, the Commission proposed to increase the GHG reduction target, including emissions and removals, to at least 55 %. by 2030 compared to 1990 levels.

One of the most important goals is to provide at least 32 percent. share of renewable energy in total energy consumption[4].

Liquid manure have in it content huge amount of microorganisms, which in certain condition could be illness factors for human beans and animals. Big doses of liquid manure which is not fully fermented and cleaned has negative influence on biological soil properties, what can lead to considerable and final degradation of natural environment. Fertilization by using of high doses of non-fermented liquid manure, can lead to stoppage of biological life and loss of soil ability

[1]Polish Ministry of Agriculture (MRiRW) data 2019. URL: https://www.gov.pl/web/agriculture

[2]Konstytucja Rzeczypospolitej Polskiej z dnia 2 kwietnia 1997 r. Dz. U. Nr 78, poz. 483 ze zm.; dalej: konstytucja RP. URL: https://docplayer.pl/24729240-Konstytucja-rp-z-2-kwietnia-1997-r.html

[3]Environmental Protection Law, 2001. [PL: Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska. Dz.U. 2001 Nr 62 poz. 627.]

[4]Eurostat 2019. URL: https://ec.europa.eu/clima/policies/strategies/2030_en,

to self-cleaning [8, 9, 10]. In such conditions it provides to the grows of carbon dioxide (CO_2) concentration in soil air, where it is present oxygen free distribution with emitting of hydrogen sulphide (H_2S), methane (CH_4), ethylene, nitrite and other poisonous compounds for existed plants. Huge amount of animal manure is well enough signal for looking for rational methods of processing and it utilization with special attention to liquid manure. Production of liquid manure is considerable higher then crops requirement for fertilizer, therefore it is important to provide its effective processing. One of methods of liquid manure processing is providing methane fermentation. Methane fermentation is complex biochemical process, which is provided in oxygen free conditions. Multi molecules organic substances are distributed on simple stabilize chemical compounds – but mainly on methane (CH_4) and carbon dioxide (CO_2) [11, 12].

At the end of 2018, Directive (EU) 2018/2001[5] of the European Parliament and of the Council of December 11, 2018 on the promotion of the use of energy from renewable sources, commonly known as RED II (Renewable Energy Directive II), entered into force. The directive sets targets for the consumption of renewable energy sources in 2021-2030. It also introduces many changes in the area of certification of sustainable biofuel production, which will apply from 2021.

Biogas can be produced from a variety of feedstock and used for different purposes: electricity, heat and transport [13]. Thus, the sustainability schemes for biomass and the GHG calculation of biogas pathways would need to take these into consideration. For instance, anaerobic digestion of manure greatly reduces the amount of methane that would otherwise be released in the atmosphere and enable therefore significant GHG savings. Biogas production also closes the nutrient cycle when the produced digestate, an excellent bio-fertiliser, replaces and thereby prevents the CO2 emissions from the production and use of mineral fertilizer [14]. As for biofuels, the co-digestion of energy crops and manure has proved to be the most energy -efficient: one hectare of land used for biomethane production allows a longer running distance than with any other biofuel [15].

Yearly amount of natural manure provided from cattle and pig farms according to Romaniuk et al. [16] is equal about 58 million tons of solid manure and about 73 million m3 of liquid manure. According to the Register of agricultural biogas producers provided by the General Director of the National Center for Agricultural Support[6] (Status as of: June 15, 2021) taking into account all wastes from animal production, it is possible to obtain 494 023 199 m3 of biogas per year. According to the same source of statistics actually there are 104 biogas installations in Poland and total yearly electrical output of these stations is equal 121.396 MW. The size of power production from one biogas installation varies from 0.080 MW to 2.400 MW[7].

The aim of the study was to investigate the possibility of continuous feeding of the biogas plant with slurry and waste from pig sites and poultry farms, and to examine the profitability of this type of installation.

Material and methods. During experimental tests of biogas station all most important parameters, which have influence on fermentation process were taking into consideration and they are as follows: temperature inside fermentation chamber, pH of fermented material, redox potential and carbon to nitrogen ratio (C:N). Influence of mixing process on general state of observed parameters of methane fermentation process were provided. When adding fresh substrate to fermentation chamber, temperature of the material decreased by 1,0-1.5 °C depending on the location in a tank and biogas production slightly decreased also. All parameters were measured using ITP laboratory validated instrumentation and there were taken 3 repetitions of all measurements. As a final result of all measurements always the average values were taken into consideration.

After 15 minutes of mixing process biogas production obtained its previous value. After one hour of mixing all material in a chamber also temperature reached a state as it was before adding a substrate. Mixing process has also positive influence on uniformity of all material in the whole volume of a fermentation chamber.

On figure 1 it is presented biogas installation in Poland, which utilize wastes from pig and poultry houses. Besides that, corn silage substrates were utilized in mesophilic digestion process.

[5]Eurostat 2018. URL: https://eur-lex.europa.eu/legal-content/PL/TXT/?uri=CELEX%3A32018L2001
[6]Rejestr wytwórców biogazu rolniczego. URL: https://www.kowr.gov.pl/odnawialne-zrodla-energii/biogaz-rolniczy/wytworcy-biogazu-rolniczego/rejestr-wytworcow-biogazu-rolniczego
[7]KOWR-Polish Agency of EU Payment 2019. URL: https://www.kowr.gov.pl/odnawialne-zrodla-energii/biogaz-rolniczy/wytworcy-biogazu-rolniczego/rejestr-wytworcow-biogazu-rolniczego

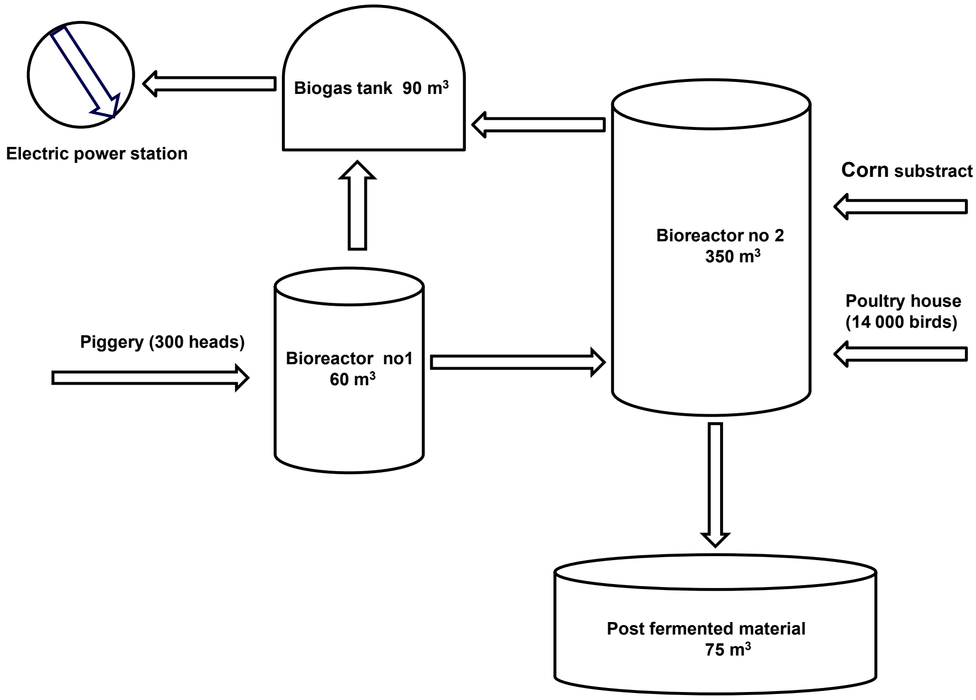

Fig. 1. **Scheme of biogas installation used in described study (Source: Own study based on research Romaniuk et al.) [17] /**

Рис. 1. **Схема биогазовой установки, использованная в описанном исследовании (Источник: Собственное исследование, основанное на исследовании Романюка и др.) [17]**

Liquid manure in piggery house heaving 300 heads of animals, was collected under slotted floor and then transported to digester three times a day at total capacity of 1 m^3 each time. Digestion in a chamber was provided at constant temperature of 37 °C. Also three times a day mechanical mixing of the whole capacity of the digester was provided. The same amount of liquid manure it was added to bioreactor no 1 automatically was pumped to bioreactor no 2. Bioreactor no 2 was also fed by solid manure from poultry house with capacity of 14 000 birds.

Periodically bioreactor no 2 was loaded by corn silage or green fodder at quantity of 300 kg. As an effect of that operation, it was observed growth by about 15% of biogas production. Post fermented material from bioreactor no 2 was transported to the tank of capacity 75 m^3. Generated by condensation water vapour was collected in deodorizers. Produced biogas was collected in elastic container at capacity of 90 m^3. Biogas was utilized to supply co-generation unit which converted it into electrical energy. During tests hydrogen sulphide content in biogas were measured. Results of that were as follows: range from 600 to 700 ppm. These values are high, but still below safe limit of working conditions for aggregate engine Podkówka [18]. Produced energy were utilized for on farm operational activity.

Results and discussion. Methane fermentation is provided in oxygen free conditions Biogas installations can be a real alternative to traditional energy production especially for countryside population, which still have limited other local energy sources. Energetic characteristic of tested biogas installation is presented in table 1.

For bacteria which cause methane fermentation, the process requires keeping neutral pH content, because when pH value is below 6.0 and over 8.0 fermentation process is stopped at all. The best results for biogas production obtained in case when pH value was equal 7.0 [19]. pH value which characterizes fermentation chamber content, is a function of very complex parameter called alkalinity, and is described by concentration of volatile fatty acids, as well as presence of bicarbonate HCO_3. If concentration of volatile fatty acids is growing too fast, buffer potential of bicarbonate anions becomes not enough to keep pH level at value of 7,0. However in normal circumstances bicarbonate concentration between 2,5-6.0 g guarantee sufficient buffer potential. Bacteria which are present during methane fermentation process requires very low redox potential at value 250 mV or lower [20].

Chemical composition and energetic value of biogas is presented in table 2.

Table 1 – **Energetic characteristic of biogas installation /**
Таблица 1 – **Энергетическая характеристика биогазовой установки**

Parameters / Параметры	*Unit / Ед. изм.*	*Period / Период*			
		11.05.2012-31.05.2012		*5.09.2012-25.09.2012*	
		bioreactor 1 / биореактор 1	*bioreactor 2 / биореактор 2*	*bioreactor 1 / биореактор 1*	*bioreactor 2 / биореактор 2*
Biogas production during 21 days / Производство биогаза в течение 21 дня	m³	2 616	3 012	2 720	3 421
Average daily biogas production / Среднесуточное производство биогаза	m³	123	147	132	166
Biogas caloric value / Калорийность (теплотворность) биогаза	$MJ \cdot m^{-3}$	20.72	20.71	22.19	22.24
Energy generated in tested biogas station / Энергия, вырабатываемая на испытанной биогазовой станции	MJ	54468.71	62742	60 633.38	75 764.59
Amount of energy utilized to maintain constant temperature in the fermentation chamber / Количество энергии, затрачиваемой на поддержание постоянной температуры в камере брожения	MJ	15251.82	19451.35	16972.14	23092.12

Table 2 – **Chemical composition and energetic value of biogas /**
Таблица 2 – **Химический состав и энергетическая ценность биогаза**

Period of biogas production / Период производства биогаза	*Chemical composition, % / Химический состав, %*					*Heat of combustion, $MJ \cdot m^{-3}$ / Теплота сгорания, $МДж \cdot м^3$*	*Caloric value, $MJ \cdot m^{-3}$ / Калорийность, $МДж \cdot м^{-3}$*
	CH_4	*CO_2*	*N_2*	*O_2*	*other / другой*		
11.05-31.05.2012	62.18	34.36	2.61	0.74	0.11	25.13	22.64
05.09-25.09.2012	58.09	38.52	2.42	0.83	0.14	23.19	21.16

It is interesting how big difference is between manure characteristic before and after methane fermentation process. The results of research work are presented in table 3.

Table 3 – **Liquid manure characteristic before and after methane fermentation /**
Таблица 3 – **Характеристика жидкого навоза до и после метановой ферментации**

Parameters / Параметры	*Unit / Ед. изм.*	*Average data for liquid manure / Средние данные по жидкому навозу*		*Reduction, % / Сокращение, %*
		raw / необработанный	*digested / переваренный (сброженный)*	
CHZT	$g\ O_2 \cdot l^{-1}$	25.2	6.2	74.1
BZT_5	$g\ O_2 \cdot l^{-1}$	16.1	1.3	92.4
Dry residue / Сухой остаток	$g\ O_2 \cdot l^{-1}$	17.8	7.4	41.8
Oxygen consumption / Потребление кислорода	$g\ O_2 \cdot l^{-1}$	3.8	2.5	31.2
Suspension / Суспензия	$g\ O_2 \cdot l^{-1}$	17.9	7.5	41.7

The results of experiment concerning relationships between temperature in fermentation chamber and biogas production capacity are presented on figure 2.

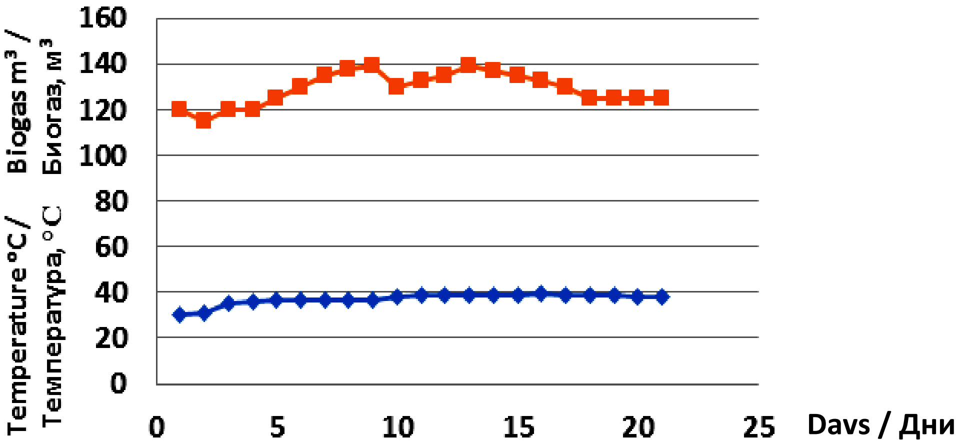

Fig 2. **Biogas production depending on temperature of fermentation material at capacity of 350 m^{-3}, in a period of 11-31 may 2012 Source: Romaniuk et al [21] and own study /**

Рис. 2. **Производство биогаза в зависимости от температуры ферментируемого материала при мощности 350 м^3, в период с 11 по 31 мая 2012 г. Источник: Романюк и др. [21] и собственное исследование**

Bacteria production In methane fermentation process requires sufficient amount of nutrient medium, to grows and reproduction. In spite of that C:N ratio should not exceed ratio 100:3, what was confirmed while providing this experiment. We can see from a graph that in spite of quite stable temperature in fermentation chamber, biogas production capacity is changing from day to day Calculated research results which we have got from tested biogas station show, that from two bio reactors at total capacity of 410 m^3 we can get electrical energy at cost of 34.52 € MWh^{-1} and thermal energy at cost of 62.54 €·MWh^{-1}. While the cost of producing electricity in a professional power plant based on lignite was 76.23 €MWh^{-1}.

Conclusions. Biogas production can be a way for diversification and grows of income for family farms, especially in case of overproduction of animal wastes.

Usage of agricultural biogas is dependent on many factors specific to location of each installation (distance from the grid, general and local demand for a particular source of energy).

Biogas plants are the objects of stable energy generation, which when properly used with the technological regime, have a constant electrical performance and can be built to meet the demand for electricity.

In Poland, it is possible to build both agricultural biogas plants, 0.1 MW as well as much larger installations. The final investment decision should result from a comprehensive account of the opportunities and needs.

Presented results from tested biogas installation show, that from two bio reactors at total capacity of 410 m3 we can get electrical energy at cost of 34.52 € MWh^{-1} and thermal energy at cost of 62.54 €·MWh^{-1}.

References

1. Czatzkowska M., Harnisz M., Korzeniewska E., Koniuszewska I. Inhibitors of the methane fermentation process with particular emphasis on the microbiological aspect: A review. Energy Science and Engineering. 2020;8(5):1880-1897. DOI: https://doi.org/10.1002/ese3.609

2. Koryś K. A., Latawiec A. E., Grotkiewicz K., Kuboń M. The review of biomass potential for agricultural biogas production in Poland. Sustainability. 2019;11(22):6515. DOI: https://doi.org/10.3390/su11226515

3. Matos J. S., Barberino A. T. M. S., de Araujo L. P., Lôbo I. P., de Almeida Neto J. A. Potentials and Limitations of the Bioconversion of Animal Manure Using Fly Larvae. Waste and Biomass Valorization. 2021;12:3497-3520. DOI: https://doi.org/10.1007/s12649-020-01141-y

4. Kostecka J., Koc-Jurczyk J., Brudzisz K. Waste management in Poland and European Union. Waste management. 2014;16(1):1-10. URL: https://www.researchgate.net/publication/311233169_Waste_management_in_Poland_and_European_Union

5. Silvestre B. S., Ţîrcă D. M. Innovations for sustainable development: Moving toward a sustainable future. Journal of Cleaner Production. 2019;208:325-332. DOI: https://doi.org/10.1016/J.JCLEPRO.2018.09.244

6. Kumar G., Lay C. H., Kim S. H., Ponnusamy V. K. Recent developments on alternative fuels, energy and environment for sustainability. Bioresource Technology. 2020;317:124010. DOI: https://doi.org/10.1016/j.biortech.2020.124010

7. Kruk H., Waldziński D. Rozwój zrównoważony i konkurencyjność regionów-rozważania teoretyczne. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu. 2010;(110 Problemy rozwoju regionalnego):87-96.

8. Pandey P., Chiu C., Miao M., Wang Y., Settles M., Del Rio N. S., Castillo A., Souza A., Pereira R., Jeannotte R. 16S rRNA analysis of diversity of manure microbial community in dairy farm environment. PloS one. 2018;13(1):e0190126. DOI: https://doi.org/10.1371/journal.pone.0190126

9. Kazimierowicz J. Depletion efficiency of selected expired food products in the process of methane fermentation. Journal of Ecological Engineering. 2019;20(1):132-137. DOI: https://doi.org/10.12911/22998993/93865

10. Zubair M., Wang S., Zhang P., Ye J., Liang J., Nabi M., Zhau Z., Tao X., Chen N., Sun R., Xiao Ju., Cai Y. Biological nutrient removal and recovery from solid and liquid livestock manure: Recent advance and perspective. Bioresource technology. 2020;301:122823. DOI: https://doi.org/10.1016/j.biortech.2020.122823

11. Owen J. J., Silver W. L. Greenhouse gas emissions from dairy manure management in a Mediterranean environment. Ecological applications. 2017;27(2):545-559. DOI: https://doi.org/10.1002/eap.1465

12. Broucek J. Nitrous oxide production from cattle and swine manure. Journal of Animal Behaviour and Biometeorology. 2016;5(1):13-19. DOI: https://doi.org/10.14269/2318-1265/jabb.v5n1p13-19

13. Yevstafiieva Y., Levytska V., Terenov D. Biogas Production as a Component of Green Energy Generation. In: Mudryk K., Werle S. (eds) Renewable Energy Sources: Engineering, Technology, Innovation. Springer Proceedings in Energy. Springer, Cham. 2018. pp. 755-764. DOI: https://doi.org/10.1007/978-3-319-72371-6_74

14. Apdini T., Al Zahra W., Oosting S. J., de Boer I. J., de Vries M., Engel B., van Middelaar C. E. Understanding variability in greenhouse gas emission estimates of smallholder dairy farms in Indonesia. The International Journal of Life Cycle Assessment. 2021;26:1160-1176. DOI: https://doi.org/10.1007/s11367-021-01923-z

15. Scarlat N., Dallemand J. F., Fahl F. Biogas: Developments and perspectives in Europe. Renewable energy. 2018;129(Part A):457-472. DOI: https://doi.org/10.1016/j.renene.2018.03.006

16. Romaniuk W., Głaszczka A., Domasiewicz T., Biskupska K., Barwicki J. Method of evaluation of biogas stations. Problems of animals production in the view of farm structure, environment protection and EU standards: monograph. Falenty: ITP, 2011. pp. 108–114.

17. Romaniuk W., Biskupska K. Tests results of biogas stations below 100 kW. Problems of intensification of animal production taking into account environment protection, EU standards and biogas production: monograph. Red. Romaniuk W., Falenty: ITP, 2012. pp. 132-143.

18. Podkówka W. Biogas from agriculture as renewable source of energy. Theory and practice. Warsaw: PWRiL, 2012. pp. 263.

19. Jankowska E., Chwialkowska J., Stodolny M., Oleskowicz-Popiel P. Volatile fatty acids production during mixed culture fermentation – The impact of substrate complexity and pH. Chemical Engineering Journal. 2017;326:901-910. DOI: https://doi.org/10.1016/J.CEJ.2017.06.021

20. Myczko A., Myczko R., Kołodziejczyk T., Golimowska R., Lenarczyk J., Janas Z., Kliber A., Karłowski J., Dolska M. Construction and exploitation of agriculture biogas stations. Handbook for investors. Wydawnictwo ITP Falenty, 2011. 142 p.

21. Romaniuk W., Głaszczka A., Biskupska K. Analysis of the biogas installation solutions for the family farms and farming enterprises: monograph. Engineering in Agriculture. Falenty: ITP, 2012. No 9. pp.94

Information about the authors

Jan Barwicki, PhD in Engineering, professor, Institute of Technology and Life Sciences in Falenty, Branch in Warsaw, Rakowiecka 32, Warszawa, Poland, 02-532

✉ **Andrzej Marczuk**, DSc in Engineering, full professor, vice-rector, head of the Department, Department of Agricultural, Forestry and Transport Machines, Faculty of Production Engineering, University of Life Sciences in Lublin, Głęboka 28, Lublin, Poland, 20-950, e-mail: andrzej.marczuk@up.lublin.pl

Dariusz Góral, PhD in Engineering, associate professor, Department of Biological Bases of Food and Feed Technologies, Faculty of Production Engineering, University of Life Sciences in Lublin, Głęboka 28, Lublin, Poland, 20-950

Małgorzata Góral-Kowalczyk, PhD in Engineering, Department of Agricultural, Forestry and Transport Machines, Faculty of Production Engineering, University of Life Sciences in Lublin, Głęboka 28, Lublin, Poland, 20-950

Sybilla Nazarewicz, MSc, Department of Agricultural, Forestry and Transport Machines, Faculty of Production Engineering, University of Life Sciences in Lublin, Głęboka 28, Lublin, Poland, 20-950

Сведения об авторах

Ян Барвицкий, кандидат техн. наук, профессор, Институт технологии и наук о жизни в Фалентах, филиал в Варшаве, Раковецка 32, Варшава, Польша, 02-532

✉ **Анджей Марчук**, доктор техн. наук, профессор, проректор, заведующий кафедрой сельскохозяйственных, лесных и транспортных машин, факультет техники производства, Университет естественных наук в Люблине, Głęboka 28, Люблин, Польша, 20-950, e-mail: andrzej.marczuk@up.lublin.pl

Дариуш Гураль, доктор техн. наук, кафедра биологических основ пищевых и кормовых технологий, факультет техники производства, Университет естественных наук в Люблине, Głęboka 28, Люблин, Польша, 20-950

Малгожата Гураль-Ковальчик, кандидат техн. наук, кафедра сельскохозяйственных, лесных и транспортных машин, факультет техники производства, Университет естественных наук в Люблине, Głęboka 28, Люблин, Польша, 20-950

Сибилла Назаревич, магистр наук, кафедра сельскохозяйственных, лесных и транспортных машин, факультет техники производства, Университет естественных наук в Люблине, Głęboka 28, Люблин, Польша, 20-950

✉ – Для контактов / Corresponding author