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UTILIZATION OF POST-FERMENT FROM CO-FERMENTATION METHANE FOR ENERGY PURPOSES

WYKORZYSTANIE POFERMENTU Z KOFERMENTACJI METANOWEJ NA CELE ENERGETYCZNE

Abstract: The main civilization issue of the 21st century is a rapid increase of the waste and pollution amount which influences the natural environment degradation. As early as in the 20th century, the increase in the amount of municipal waste and waste from agri-food industry was reported. Waste chemical composition gives optimal conditions for the development of microorganisms. Under aerobic and non-aerobic conditions bacteria decompose organic compounds which results in gases emission (CH_4, H_2S, CO_2, NO_x), while nitrogen, phosphorus and potassium compounds remain in the post-ferment. These compounds may be diffused into the environment and create a risk of homeostasis corruption. Biogenic elements are transferred to surface water and corrupt the ecosystem balance causing its eutrophication. Various types of fermentation may be distinguished, but the methane fermentation may play a special role with regard to the sustainable energy sources and waste management. This process converts energy included in the biomass into the utility fuel – a source of clean sustainable energy which does not negatively influence the environment. Biogas may be combusted in the boiler in order to obtain thermal energy used for heating rooms or in a gas engine which drives the current generator. It is worth noticing that the above method is a desired one of transforming waste *ie* organic recycling. The research results of biogas production from the organic fraction of municipal waste in co-fermentation with the agricultural mass as well as the suitability of the post-ferment for energy purposes were presented in the paper. In order to image the calorific value of the post-ferment, the tests were carried out on 6 batch mixes where in each one the organic fraction of municipal waste occurred.

Keywords: biogas, organic recycling, waste disposal, renewable energy

In terms of the energy produced, two Mg of biomass are equal to 1 Mg of hard coal. On account of burdening the environment, biomass combustion gives better results,

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which is related to lower SO_2 emission than in the case of coal. Carbon dioxide emission balance is zero since during combustion the same amount of CO_2 as plants previously took is returned to the atmosphere [1–3]. Recently, great hopes are pinned in the use of biogas produced as a result of biomass fermentation, which is a waste itself. Non-areobic fermentation is a complex biochemical process which takes place under non-aerobic conditions. Organic substances are decomposed by bacteria into simple compounds – mainly methane and carbon dioxide. Up to 60% of organic substance is converted into biogas during the non-aerobic fermentation. A decomposition rate depends mainly on the type and mass of raw material and optimally selected duration of the process. Over the increase of the organic mass load in the fermentation chamber to the border value, the biogas production increases. Upon reaching the maximum, the production decreases, since the system gets overloaded. Therefore, it is necessary to recognize the optimal scope of loading the digester. A correct fermentation temperature is 30–35^{o}C for mesophilic bacteria and 50–60 degrees for thermophilic bacteria. Presently: straw, beetroot leaves, potato haulms, maize stalks, clover, grass and sewage sludge are used as biomass for biogas production. These are installations at agricultural farms or sewage treatment plants [3, 4].

The possibility of using biodegradable waste from the stream of municipal waste has almost been ignored, entirely (biogas is recovered from municipal waste only by degassing of post-landfill areas. Methane is a greenhouse gas and it should be combusted as such and not emitted to the atmosphere) [5].

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Research studies carried out by other authors report a considerable, almost 50% share of municipal waste in the whole stream (plant and animal waste 33%, paper 21%) [1–3]. Moreover, the European Council Directive 99/31/WE of 26th April 1999 on storing waste requires limitation of the biodegradable substances content deposited on landfills up to 75% of the initial mass within 5 years from implementation, up to 50% within 8 years, and up to 35% within 15 years. May, 2004, 1st is regarded as the initial moment of implementation and the reference point is the amount of waste produced in 1995. It means that installation neutralizing these wastes in a way different than storing will have to be created within the next years [6].

Biodegradable fractions which are the most popular in municipal waste include: potato waste, cabbage leaves, vegetable peels, citrus fruit and banana peels and animal waste. These substrates occur in rural and urban-rural areas and may be used for energy purposes. So far, there are no solutions for conducting anaerobic fermentation based on the mixture of these organic masses. The optimal model of biogas supply should obtain biomass energy and the same utilize the waste biomass (municipal waste biomass, liquid manure and manure). The determination of biogas profitability of the accepted substrates and parameters of the conducted biogas fermentation in the laboratory chamber allowed determination of biomass usability for gassing purposes during methane fermentation. Selection of these substrates for research is explained by searching for the optimal process of obtaining energy and biomass utilization in rural and urban-rural areas. Agricultural mass is a basic batch in the case of conducting fermentation based on these substrates. Its biochemical variability is low, while municipal biomass constitutes additional batch mass utilized on the spot [1, 2].

Calorific value of biogas depends mainly on the methane content. At the average 0.42 m^3 CH_4 is produced of 1 kg of carbohydrates, 0.47 m^3 CH_4 of 1 kg of apples and 0.75 m^3 CH_4 of fats. Calorific value of methane is 35 $MJ \cdot m^{-3}$. Average calorific value of biogas obtained from municipal biowaste is approx. 21.54 $MJ \cdot m^{-3}$. Energy included in 1 m^3 of such biogas responds to energy included in 0.93 m^3 of natural gas, 1 dm^3 of diesel oil, 1.25 kg of coal and responds to 9.4 kWh of electric energy [7]. However, one should remember that both components of the volatilizing biogas as well as its combustion products get into atmosphere and affect the environment on account of toxics and smell. A lot of them, especially chlorinated carbohydrates show carcinogen activity. Chlorine occurrence in biogas, at disadvantageous conditions of its combustion, may cause emission of dioxines and furans [7].

Material and methods

Renewable energy sources have been amongst the most crucial elements of the European Union policy for a long time. Presently, they have become significant in terms of possibilities of the technology development, which may limit the effects and duration of the economic, energy and climatic crisis. The Directive 2009/28/EC obliges to increase the share of Renewable Energy Sources in the final energy consumption up to 20% (in Poland up to 15%) by 2020.

The program of agricultural biogas plants construction developed by the Ministry of Agriculture and Rural Areas Development assumes that in 2013 the biogas production in Poland will reach the level of 1 billion m^3 annually, and by 2020 this value will have been doubled. The economic situation for biogas plants predicted for the next years [8] forces out development of analytical methods of the biogas composition and parameters assessment [9]. A governmental programme "Biogas plant in each municipality" assumes that by 2020 at least one such an agricultural plant will be operating in each Polish municipality. Each facility will have power of 0.7 to 3.0 MW. According to Gebrezgabher et al [10] profitability of biogas investment is available for the case of the investment of high powers.

Knowledge concerning the biomass use for energy purposes and especially the biogas production is more and more extensive but still inadequate and often inconsistent and inexplicit, both among specialists and advisers as well as farmers. It concerns both batch for fermentation as well as management of the obtained post-fermentation product and the biogas management. Animal waste biogas (from liquid manure and rarely from dung) is in Poland the most frequently produced in agricultural biogas plants. Biogas production especially from the maize silage is the second solution.

The efficient conversion of plant material into biogas is a challenge on account of complex structure of the cell wall of plants. In order to simplify and fasten the efficient hydrolysis of carbohydrates an initial biomass processing is required [11]. The initial processing of lignocellulose materials may be carried out in a physical way (mechanical refining, pyrolysis), chemical (with diluted acid, with the use of alkaline processing), physical and chemical (vapour burst) and biological (fungus producing hydrolytic enzymes) [12]. However, one should remember that such an approach to the management of biomass surplus in a farm leads to a mono-culture cultivation. It concerns the requirements of the standard production balancing according to the rules of the Code of Good Agricultural Practices (Polish: KDPR) and requirements of a lower degree of agriculture chemicalization.

The objective of the research was to develop an optimal biogasing technology so the biogas plant activity would be economically justified and batch to the fermentor could be so varied that it would conform to the good culture in the agricultural production and would use municipal waste biomass that occurs in the area of operation of the biogas plant.

The research was carried out in the biogas laboratory of the University of Agriculture in Krakow placed in the Department of Production Engineering and Energy Power. Material for the research was obtained in 2012 from the individual diary farm in Goleszow municipality. Moreover, the organic fractions of municipal waste were obtained from the area of Krakow municipality. The following fractions were accepted for the research:

– organic plant mass: maize silage, cattle manure,
– organic fraction of municipal waste.

The fractions were fragmented and five samples were collected from each. Samples were weighed in order to determine their weight before drying. The fragmented material was hydrated to approx. 90% moisture forming optimal conditions for development of mesophilic bacteria. Six mixtures of batches of parameters presented in table 1 were accepted for the research. Fermentation was carried out in the digester of 20 dm^3 volume with the regulated temperature environment. The following parameters were controlled in the fermentor used: pH, redox potential and the batch temperature. The produced biogas was collected in the container of a variable volume. A schematic representation of the stand with a digester is presented in Fig. 1.

Table 1

Characteristics of batches for Digesters

Name	Fractions		
	Maize silage [%]	Cattle manure [%]	Fine fraction of municipal waste [%]
Batch 1	65	5	30
Batch 2	100	0	0
Batch 3	0	0	100
Batch 4	50	5	45
Batch 5	20	5	75
Batch 6	75	5	20

Batch 1, accepted as control material is proved and introduced to the digester. Batch 1 is placed in the digester (2) in which by means of sondes (5) fermentation parameters, such as temperature, redox and pH are controlled. These parameters are automatically saved with time interval on the hard disc of a computer of the measuring system. In the digester, the batch is mixed with a mechanical mixer (4) to avoid delamination. The mixer may be smoothly regulated within 0 to 400 rot./min. is equipped with three blades of regulated spacing, which enables the change of intensity of mixing zones in the fermentor.

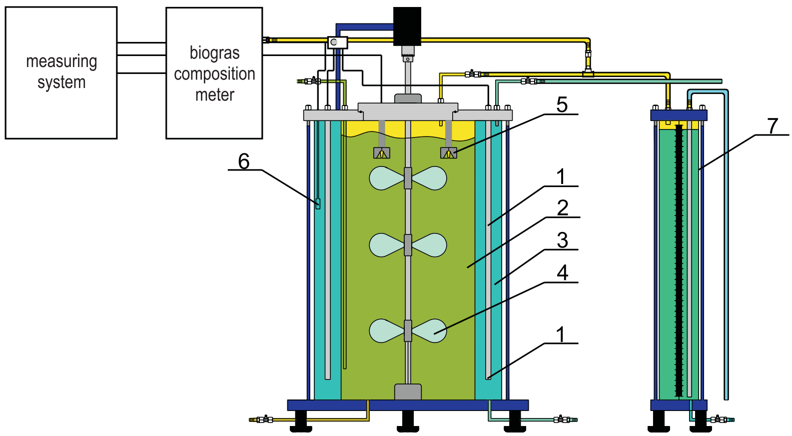

Fig. 1. A schematic representation of the test stand with a 20 litre fermenter: 1 – cartridge heaters, 2 – batch, 3 – water jacket, 4 – mechanical mixer, 5 – sondes, 6 – thermometer, 7 – container

The digester of the fermenter is equipped with a water jacket (3) where three cartridge heaters are placed (1), responsible for heating liquid. The measuring system equipped with a thermometer (6) PT100 is responsible for controlling the process temperature. The produced biogas is collected over the surface of the batch in the fermentor and in the container (7) of variable volume, from which it is sucked in by the biogas composition measuring meter. This meter analyses the following parameters: moisture, temperature, pressure, methane CH_4, oxygen O_2, carbon dioxide CO_2 and hydrogen sulphide H_2S. The measured biogas composition parameters are automatically saved on the computer disc of the measuring system.

Determination of the intensity of the biogas production in the remaining batches was carried out according to standard DIN 38414. Batch mixes were fermented under static conditions consisting in a single introduction of fraction to digesters and conducting the process till the end of fermentation.

Fermentation devices were installed in a container with the regulated temperature forming a part of the test stand, which was additionally composed of a switch panel and the measuring system. A schematic representation of the test stand is presented in Fig. 2. Devices for maintaining a constant temperature environment are mounted to a rack (1) located next to the container (2). Controlling takes place by means of the electronic thermostat ESCO ES-20 (unit switch 16A) with a precision up to ±0.2°C resulting from a sensor hysteresis. Temperature decrease by value exceeding 0.1°C causes switching on a heater of 1500 W (3) power with a simultaneous start of the water pump Hanning DPO 25–205 (4) in order to ensure a uniform distribution of temperature in the whole chamber. After heating water to the temperature exceeding the set temperature by 0.1°C the heater switched off with a 30 seconds delay of the pump.

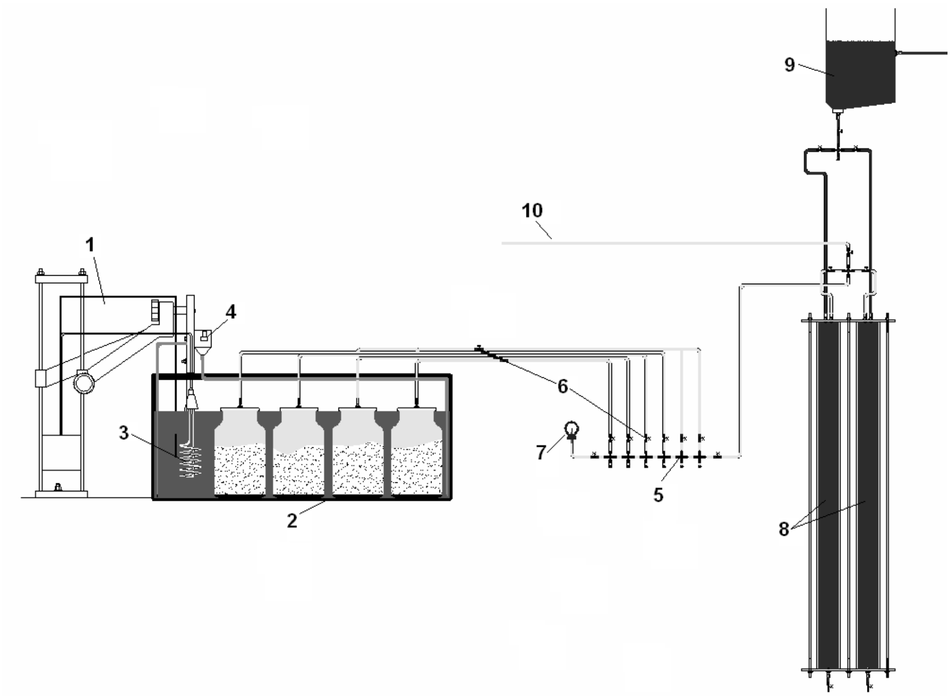

Fig. 2. A schematic representation of the test stand with a 2 litre fermenter: 1 – rack, 2 – container, 3 – heater, 4 – water pump, 5 – switch board, 6 – cut-off valves, 7 – manometer, 8 – system of measuring volume, 9 – columns, 10 – conduit

Separators combined in a row along with cut-off valves (6) and a manometer (7) which measures pressure in particular measuring branches constitute a switch board (5). Due to the use of such system for service of all fermenters, only one measuring system was enough. The system of measuring volume (8) was composed of two columns filled with water with drain valves and a container for filling up the liquid level in columns (9). The measuring system was combined with a switchboard and a biogas composition meter by means of a conduit (10) which was presented in Fig. 1.

A chemical analysis was carried out for all the tested batches before the commencement of fermentation. Dry mass of fraction and reaction were determined. For each batch, fermentation was carried out simultaneously. The amount of the produced gas was read out twice daily at the same time.

Results and a discussion

During planning of the biogas plant construction, standard assumptions of effic iency of the possessed fermentation substrates are accepted for calculation of productivity of installation and determination of economic parameters. Not always, however, these values respond to real biogas yield and its composition; therefore, a detailed research for correct determination of the biogas production value should be carried out in each case. The apparatus presented in Fig. 2 was used in agricultural biogas plants for determination of the biogas yield from an organic fraction of municipal waste as a co-fermentation mass. At the same time, the apparatus with a digester of 20 dm^3 volume was used for determination of energy parameters of a post-ferment. The enlargement of the chamber resulted from the need of obtaining a bigger amount of the post-ferment in order to subject it to pelletization or briquetting.

The research on the fermentation process at laboratory conditions allowed comparison of intensity of biogas emission, following fermentation phases and assessment of susceptibility of the tested batch mixes on biochemical processes of the organic mass decomposition. Parameters of the researched fractions are presented in Table 2 . Figure 3 and 4 present the total amount of the produced biogas and intensity of biogas emission during fermentation. The amount and intensity of biogas emission are parameters which prove the course of the process.

Table 2

Physical and chemical properties of the analyzed components

Item number	Name of the batch component	pH [-]	Dry mass [%]
1	Maize silage	3.8	26.3
2	Cattle manure	7.5	12.0
3	Organic fraction of municipal waste	5.8	54.0

Parameters of the maize silage or the organic fraction of municipal waste did not diverge from the literature value, whereas manure was characterized with a bigger, than presented in literature, content of dry mass, which was within 12%. Such values result from the animal maintenance system applied on the diary cows farm.

The results of the biogas yield analysis in relation to dry mass proved directly the highest batch 1 efficiency, which was 223 $Ndm^3 \cdot kg^{-1}$ (Ndm^3 – biogas volume at atmospheric pressure) of dry mass. Maize silage batch (batch 2) had a slightly lower efficiency, and the value of this parameter was 184 $Ndm^3 \cdot kg^{-1}$ of dry mass. As seen in Fig. 3, in the course of fermentation of batch 2 made of the maize silage only, a visible delay of the increase of biogas volume was observed, which was caused by the batch reaction. The highest inhibition of the increase and delay of biogas production during fermentation was reported for batch 3 which was made only of the organic fraction of municipal waste. A common course of biogas production efficiency was obtained for batch 6, made of 75% maize silage, 5% manure and 20% organic fraction of municipal waste.

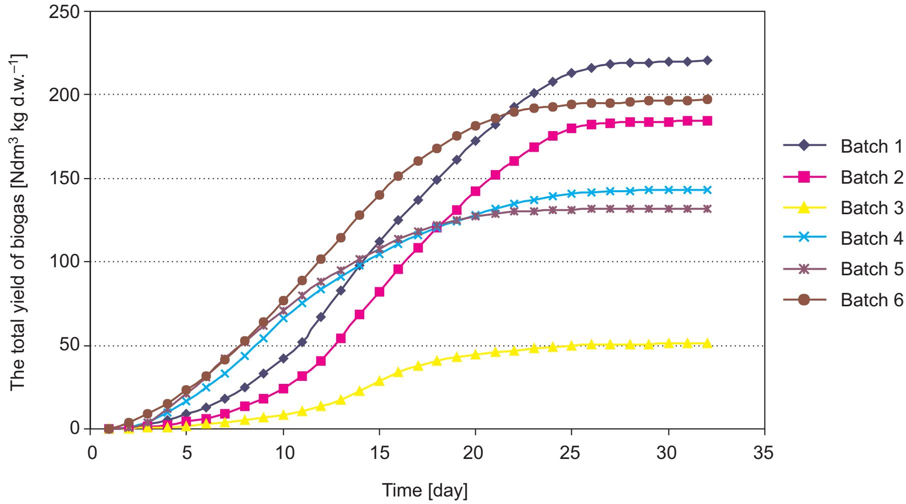

Fig. 3. The total amount of produced biogas

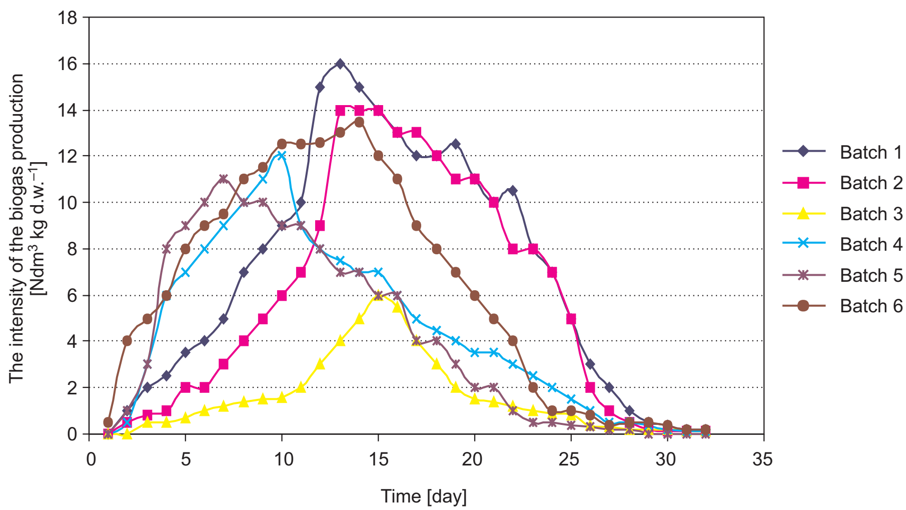

Fig. 4. The intensity of the biogas production

The use of batch made only of the organic fraction of municipal waste for methane fermentation caused a decrease of the biogas yield effect. Such batch may be successfully used for stabilization of waste fractions but not for energy production.

The other apparatus was used for research related to the energy potential of post-fermentation pulp than for batch masses biogas yield. A bioreactor of 20 dm^3 volume was used for the production of briquette from the post-fermentation pulp. From this bioreactor, enough amount of post-fermentation waste could be obtained to subject it to centrifugation, drying and briquetting. A batch for fermentation was disintegrated, therefore the obtained post-ferment was a difficult material for centrifugation. Due to the above reason, during realization of the research, this problem was solved in the following manner: first, the material was compressed on estruders and then subjected to the drying and pellettization process on piston pelleting machines. Then, technological parameters of the material obtained after methane fermentation were determined. Mechanical endurance of briquettes was determined according to the applicable standards [13] in the following way: a prepared sample of briquettes of 1 kg mass was rotated in a drum with rotational speed of 21 rot/min for 5 minutes or for 105 rotations of the drum. Then, a sample remaining on a sieve was weighed and mechanical endurance of briquettes was calculated in percentages depending on:

$$DU = \frac{A}{C} \cdot 100\% \qquad (1)$$

where: DU – mechanical endurance of briquettes,
A – mass of sieved briquettes after processing in the drum in grams,
C – total batch applied to the drum in grams.

The experiment was repeated 3 times and the mean value was calculated with a precision to 0.1 percent.

The obtained results of the research on mechanical endurance of briquettes are shown in Table 3.

Table 3

Technical parameters of energy material made of the batch post-ferment masses

Name	*C* – total batch to the drum [g]	*A* – mass of sieved briquettes after processing in the drum [g]	*DU* – mechanical endurance of briquettes [%]
Batch 1	890	81	9.10
Batch 2	910	75	8.24
Batch 3	1170	78	7.29
Batch 4	1100	91	8.27
Batch 5	1050	79	7.52
Batch 6	905	85	9.39

The obtained material in the form of briquette was characterized with mechanical properties comparable to the wood dust.

Calorific value, which depends on the chemical composition and moisture, constitutes the most important thermophysical parameter of various forms of organic masses. The research aimed at indicating the validity of processing the post-ferment from biogas plants which use co-fermentations of organic municipal waste mixed with agricultural waste masses for energy purposes. Post-fermentation mass was dried to the moisture level within 10–20%, and the results of the obtained calorific values are presented in Table 4.

Table 4

The calorific value of the biomass of the post ferment batch masses

Name	Calorific value in a dry state [MJ · kg^{-1}]
Batch 1	11.36
Batch 2	10.79
Batch 3	9.56
Batch 4	10.86
Batch 5	9.64
Batch 6	11.12

The obtained research results allow assumption that the investigated material may be used as fuel for production of energy at the simultaneous utilization of post-fermentation waste from biogas plants. The obtained material shows properties similar to commonly used briquette and grain straw pellet.

The study proved the improvement of a fermentation ability of batches in co-fermentation. Fraction mixing caused the increase of the intensity of biogas emission during fermentation. In batches based on maize silage in 65% and 75% proportions the highest biogas efficiency was obtained during fermentation. Although there is a possibility of one-component de-fermentation of maize silage, the research proved that de-fermentation of silage as a co-substrate with manure and organic fraction of municipal waste was more efficient. Fermentation using different substrates may significantly increase the efficiency of the process. Fermentation combined with utilization of post-fermentation products for energy purposes seems to be an optimal solution. The replacement of fossil fuels with biogas usually reduces not only emission of greenhouse gases but also nitrogen oxides, hydrocarbons and particles. Due to the high content of nutrients in the waste digestate can be used as a means of improving soil fertility. Use of waste after fermentation as a means to improve the fertility of the soil will reduce the losses of nutrients. Particular importance is the possibility of recycling the elements contained in municipal waste [14].

Conclusions

1. Making batch in proportion 70–30 increases biogas yield; this type of mix may be used for biogas production of energy purposes since the yield from 1 kg of batch was obtained on the level of approx. 200 Ndm^3.

2. Post-ferment obtained from the mix made of organic mass and biofraction of municipal waste upon its preparation may be formed and its calorific value is on the level of the used fuels formed of straw materials.

3. Innovativeness of the presented research and consequently the possibility of applying such activities in economy will allow solution of the issue concerning the post-fermentation waste in the future. In the light of the law on fertilizers, the post-fermentation waste from agricultural biogas plant may be used for fertilization of

fields as a natural fertilizer, whereas it may not be a subject of the trade turnover. When investigating biogas plants of great power (over 600 kW) the post-production waste becomes a considerable issue concerning production profitability. The suggested way of utilization of post-ferment seems to be the most efficient, the least problematic on account of social issues and consequently economically and environmentally justified activity.

References

[1] Sikora J, Szeląg-Sikora A, Cupiał M, Niemiec M, Klimas A. Możliwość wytwarzania biogazu na cele energetyczne w gospodarstwach ekologicznych (Biogas production potential for enegry purposes in ecological farms). Proc ECOpole. 2014;8(1):279-288. DOI: 10.2429/proc.2014.8(1)037.

[2] Madlener R, Antunes C, Dias L.C. Assessing the performance of biogas plants with multi-criteria and data envelopment analysis. Eur J Oper Res. 2009;197(3):1084-1094. DOI: 10.1016/j.ejor.2007.12.051.

[3] Kaltschmitt M, Hartmann H. Energie aus Biomasse – Grundlagen, Techniken und Verfahren; Springer Verlag Berlin, 2001; http://link.springer.com/book/10.1007%2F978-3-540-85095-3.

[4] Chasnyk, O, Sołowski, G, Shkarupa O. Historical, technical and economic aspects of biogas development: Case of Poland and Ukraine. Renew Sust Energ Rev. 2015;52:227-239. DOI:10.1016/j.rser.2015.07.122.

[5] Chamrádová K, Rusín J. Use of biogas biscuit meal EKPO-EB for agricultural biogas plant for substitution of energy crops utilization with organic waste. Pol J Chem Technol. 2015;17(3):40-46. DOI: 10.1515/pjct-2015-0048.

[6] Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Official J L 182, 16/07/1999,1-19. http://eur-lex.europa.eu/legal content/en/ALL/? uri=CELEX:31999 L0031.

[7] Brzuzy LP, Hites RA. Global mass balance for polychlorinated dibenzo-p-dioxins and dibenzofurans. Environ Sci Technol, 1996;30:3646-3648. DOI: 10.1021/es950714n.

[8] Polish Energy Policy until 2030, Ministerstwo Gospodarki, 2009;14-17. http://bip.mg.gov.pl/node/24670.

[9] Zamorska-Wojdyła D, Gaj K, Hołtra A, Sitarska M. Quality Evaluation of Biogas and Selected Methods of its Analysis. Ecol Chem Eng S. 2012;19(1):77-87. DOI: 10.2478/v10216-011-0008-9.

[10] Gebrezgabher AS, Meuwissen PMM, Prins AMB, Oude Lansink GJMA. Economic analysis of anaerobic digestion-A case of Green power biogas plant in the Netherlands. NJAS – Wag J Life Sci. 2010;57(2):109-115. DOI.org/10.1016/j.njas.2009.07.006.

[11] Hong-Wei Y, David EB. Anaerobic co-digestion of algal sludge and waste paper to produce methane. Biores Technol. 2007;98(1):130-134. DOI: 10.1016/j.biortech.2005.11.010.

[12] Bobleter O. Hydrothermal degradation of polymers derived from plants. Prog Polym Sci. 1994;19(5):797-841. DOI: 10.1016/0079-6700(94)90033-7.

[13] PN-G-04650:1997 Formed fuels – Determination of mechanical strength by drumming method ICS: 75.160.10 http://m.freestd.us/soft4/3861352.htm.

[14] Börjesson P, Berglund M. Environmental systems analysis of biogas systems – Part I: Fuel-cycle emissions. Biomass Bioenerg. 2006;30(5):469-485. DOI 10.1016/j.biombioe.2005.11.014.

WYKORZYSTANIE POFERMENTU Z KOFERMENTACJI METANOWEJ NA CELE ENERGETYCZNE

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Abstrakt: Głównym problemem cywilizacyjnym XXI wieku jest gwałtowny wzrost ilości odpadów i zanieczyszczeń przyczyniających się do degradacji środowiska naturalnego. Już w XX wieku dał się zauważyć wzrost ilości odpadów komunalnych i pochodzących z przemysłu rolno-spożywczego. Ich skład chemiczny stwarza optymalne warunki do rozwoju mikroorganizmów. Bakterie w warunkach tlenowych i beztlenowych rozkładają związki organiczne w procesie fermentacji. W wyniku tej przemiany następuje emisja gazów (CH_4, H_2S, CO_2, NO_x) i związków azotowych, fosforowych i potasowych. Związki te przedostają się do atmosfery i wód powierzchniowych, gdzie naruszają równowagę ekosystemu, powodując jego eutrofizację. Wyróżniamy różnego rodzaju fermentacje, jednak to fermentacja metanowa może odgrywać szczególną rolę w kontekście pozyskiwania odnawialnych źródeł energii i gospodarki odpadami. Proces ten przekształca energię zawartą w biomasie w użyteczne paliwo będące źródłem czystej energii odnawialnej, niewpływającej negatywnie na środowisko. Biogaz może być spalany w kotle w celu uzyskania energii cieplnej wykorzystanej do ogrzewania pomieszczeń, lub w silniku gazowym napędzającym generator prądu. Warto zauważyć, że metoda wykorzystująca fermentację metanową należy do pożądanych sposobów przekształcania odpadów, tj. recyklingu organicznego.

W pracy przedstawiono wyniki badań wytwarzania biogazu z organicznej frakcji odpadów komunalnych w kofermentacji z masą pochodzenia rolniczego oraz wykazano przydatność pofermentu na cele energetyczne. Do zobrazowania wartości opałowej pofermentu badania przeprowadzono na sześciu mieszankach wsadowych, gdzie w każdym występowała frakcja organiczna odpadów komunalnych.

Słowa kluczowe: biogaz, recykling organiczny, utylizacja odpadów komunalnych, energia odnawialna