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PROECOLOGICAL USE OF AGROBIOMASS

Summary

The growing sector of agricultural biogas plants in Poland and Europe is facing a serious problem of managing digestate. In Europe there are currently about 14,500 biogas plants. The fact that both the EU Waste Directive and the Polish Act on Waste qualifying digestate as waste does not make the situation any easier. The simplest method of developing digestate is to directly spread it on fields. The implementation of this method is impeded by limiting the areas of cultivation due to the high content of organic nitrogen and odor emission. The growth in the number of biogas plants will be associated with the increase in the digestate disposal problem. Alternative methods of fertilization involve the separation into solid fractions and liquid fractions. After composting, solid fractions may be used as fertilizer, sometimes as solid granulation. The use of solid fractions of digestate for energy purposes involves using them as feedstock for pellets and briquettes production. The gasification and carbonization are two of several possible methods of thermochemical treatment of biomass.
***Key words**: agricultural biogas plants, managing digestate, agrobiomass, odor emission, thermochemical treatment of biomass*

PROEKOLOGICZNE WYKORZYSTANIE AGROBIOMASY

Streszczenie

Rozwijający się sektor biogazowni rolniczych w Polsce i Europie boryka się z poważnym problemem zagospodarowania pofermentu. W Europie pracuje obecnie ok. 14 500 instalacji biogazowych. Wraz ze wzrostem instalacji biogazowych problem zagospodarowania pofermentu będzie narastał. W świetle unijnej dyrektywy o odpadach oraz polskiej ustawy o odpadach poferment kwalifikowany jest jako odpad. Najprostszą metodą zagospodarowania pofermentu jest bezpośrednie rozprowadzanie go po polach. Przeszkodę w realizacji tej metody aplikacji pofermentu stanowi ograniczenie terenów uprawowych ze względu na dużą zawartość azotu organicznego, ale także emisja odorów. Alternatywnymi metodami zagospodarowania pofermentu jest separacja na frakcję stałą i ciekłą. Frakcja stała po poddaniu do kompostowania materiałów organicznych nadaje się do użycia jako nawóz, czasami stosuje się też granulację osadu. Energetyczne wykorzystanie pofermentu sprowadza się do wykorzystania osadu jako wsadu do produkcji peletów i brykietów. Innymi metodami zagospodarowania pofermentu są gazyfikacja i karbonizacja – wybrane z kilku możliwych sposobów obróbki termochemicznej biomasy.
***Słowa kluczowe**: biogazownie rolnicze, zagospodarowanie pofermentu, agrobiomasa, emisja odorów, obróbka termochemiczna biomasy*

1. Introduction

The market of renewable energy sources is currently stagnating and its development is slow. This is mainly caused by the absence of laws and regulations that may guarantee stable systems enhancing the development of renewable energy sources.

In Poland the agri-food sector is highly developed. Therefore, it enables the development of biogas plants producing energy from renewable sources.

The Polish government schedules to construct approximately two thousand biogas installations in Poland until 2020. Digestate is the main by-product produced by the biogas installation. Taking into account the government's plans, the use of digestate may become a huge problem. According to the data of the Agricultural Market Agency dated 31st December 2014, the number of energy companies registered as biogas plants amounted to 50, whereas the number of biogas plants equaled to 58 [1]. It has been the largest number of biogas plants over the last four years [1].

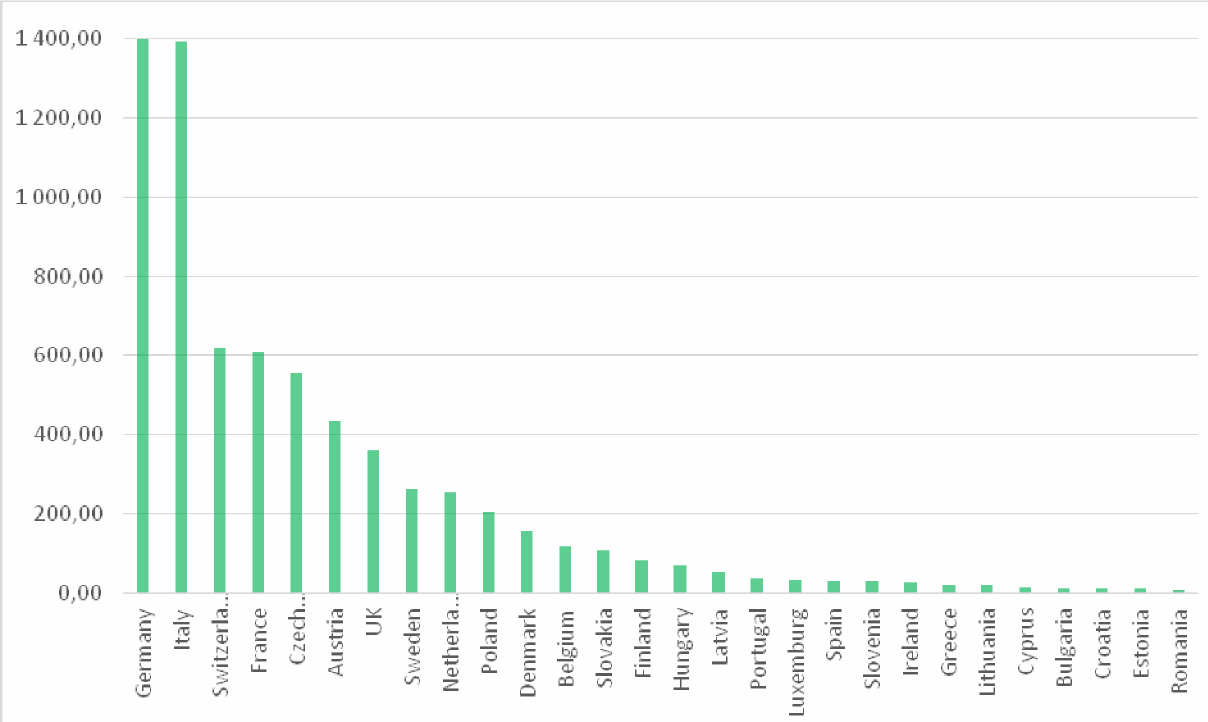
The report of the European Biogas Association [2] dated 27th July 2015 provides that the most biogas plants operate in Germany (9035), then in Italy (1391), Switzerland (620), and France (610). Poland has 206 biogas plants, including 152 agricultural biogas plant installations. The EBA report ranks Poland 9th among 27 European countries. According to the EBA in 2013 Europe had over 14,500 biogas installations and their number is still growing. The below chart shows the EBA data sheet (Fig. 1).

Characteristics of digestate pulp primarily depend on substrates used to produce biogas [4]. According to the 2014 data of the Agricultural Market Agency in Poland [1] the most common substrates used in biogas plats were as follows (Fig. 2):

1. Slurry 574,068.599 Mg -27%,
2. Corn silage 416,683.350 Mg -20%,
3. Residues from fruits and vegetables 355,974.297 Mg -17%,
4. Post-distillers 349,366.450 Mg -16%,
5. Beet cuttings 189,734.900 Mg -7%.

2. Digeste in normative documents

In the domestic law issues pertaining to the production and utilization of digestate are regulated by the Act of 2015 on Fertilizers, the Act on Fertilizers and Fertilizing, and regulations of the Minister of Agriculture[4] and regulations of the Minister of Environment [3]. Digestate is classified as waste and its code is 19 06 06 [3] – digestate from anaerobic treatment of animal and vegetable waste. The composition of digestate depends on a substrate used to prepare biogas at the biogas plant [5]. The main digestate ingredients are compared in Fig. 3.



Source: own work on the basis of the European Biogas Association data
Źródło: opracowanie własne na podstawie danych Europejskiego Stowarzyszenia biogazowni EBA

Fig. 1. The presentation of the number of operating biogas plants in Europe
Rys. 1. Zestawienie liczby pracujących instalacji biogazowych w Europie

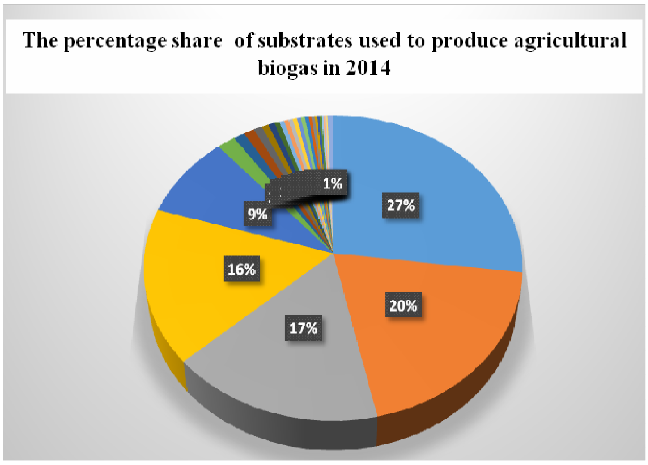


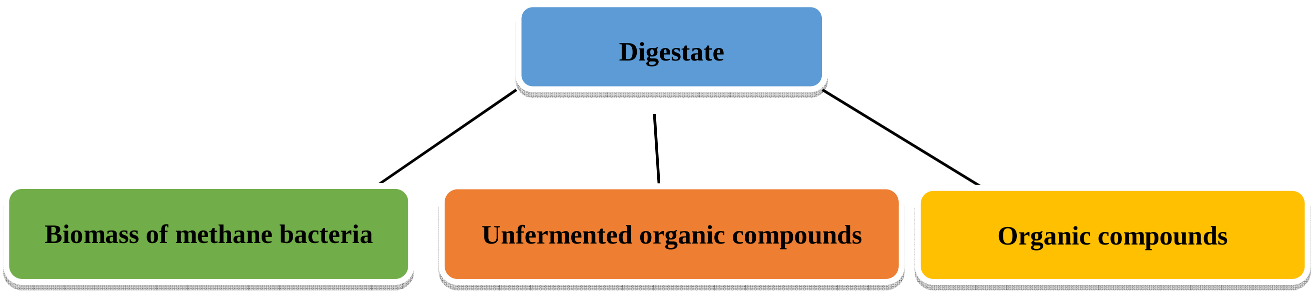
Fig. 2. **P**ercentage share of individual substrates used to produce agricultural biogas on the basis of the ARR data [1]
Rys. 2. Zestawienie procentowego udziału poszczególnych surowców użytych do produkcji biogazu rolniczego opracowane na podstawie danych ARR [1]

As for ecological aspects, one of the methods of managing digestate is its recovery. The most preferable forms of this method are carried out through using the R10 process – spreading over a field or using to enhance soil [6] and R3 process – recycling or recovery of organic substances not used as solvents (including composting and other biological transformation processes [6].

Due to the legal barriers the use of digestate as agricultural fertilizer is not the effective way of its management. Further, when it is necessary to transport digestate to a place located farther than 5-10 km from the biogas plant, fertilization becomes disadvantageous in terms of the profitability of the biogas plant investment. In this case, the energy conversion of digestate is more preferable.

The common digestate management methods are as follows (Fig. 4):

- R10 recovery process,
- separation into solid and liquid fractions,
- R3 slurry recovery process,
- drying and pelletizing,
- thermo-chemical conversion.



Source: own work / Źródło: opracowanie własne

Fig. 3. Basic digestate ingredients
Rys. 3. Podstawowe składniki pofermentu

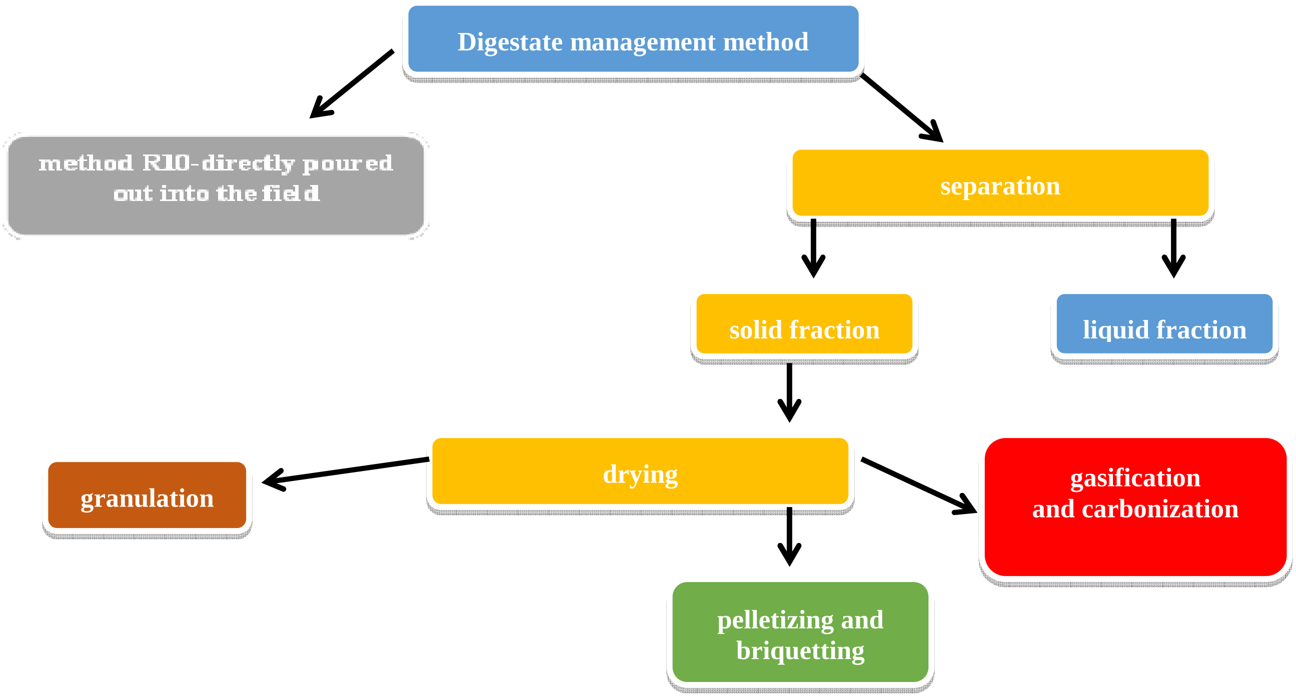


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Fig. 4. Summary of the digestate management methods
Rys. 4. Zestawienie metod zagospodarowania pofermentu

3. The use of digestate as organic fertilizer

Residues from the methane fermentation process have the form of digestate pulp and may be used as fertilizers or substitutes for artificial fertilizers or natural soil fertilizers. When using digestate as fertilizer, it is essential to ensure its proper quality which mostly depends on the quality of substrates used for the biogas production. In order to ensure the relevant quality of substrates, it is necessary to provide some basic information such as the origin of substrates for household waste: its storage location, storage method, methane potential, description of physical properties: color, aroma, texture, description of chemical properties such as pH, density, dry matter content, micro and macro elements, content of chemical impurities, pollution, pathogens, recommendations for safe handling and storage, availability of substrates [7].

The fulfillment of the above requirements for substrates ensures that digestate as by-product is safe, and therefore its use as fertilizer will contribute to the following [7]:

- replacing mineral fertilizers, decreasing their negative impact on the environment;
- increasing the recycling of organic matter and nutrients and the conservation of natural resources;
- providing relevant sanitary conditions for organic waste and animal manures that eliminate the chain of pathogen transmission;
- decreasing costs incurred by farmers through using their own resources and reducing purchases of mineral fertilizers;
- decreasing air pollution through reducing methane and ammonia emissions.

Unwanted digestate impurities that may reduce its usefulness as fertilizer [7]:

- physical impurities, e.g. stones, rubber, glass, wood;
- increased content of heavy metals: iron, cupper, manganese, zinc, mercury;
- organic pollutants: polychlorinated biphenyls, dioxins, furans, polycyclic aromatic hydrocarbons, polybrominated diphenyl ethers
- presence of plant and animal pathogens, e.g. viruses, bacteria, intestinal parasites, weed and crop seeds.

Digestate may be used as fertilizer without any pretreatment[7] or through separation of solid and liquid fractions.

4. Separation into solid and liquid fractions

A large amount of effluents is one of the major problems of the digestate management [8]. In order to reduce its negative feature, the digestate is dewatered i.e.. separated and consequently slurry and effluent are produced [8]. The separation is conducted by separators, sieves, centrifuges, and decanters [8].

The separated solid fraction is enriched with a concentrate from the subsequent purification stages and then certified and sold as fertilizer. The liquid fraction is subject to a series of processes:

- precipitation of dissolved substances units, and hence they may be subject to centrifugation;
- ultrafiltration - the membrane stops any residues of nutrients, colloidal particles, and microorganisms;
- reverse osmosis – it involves the separation of solutes (N, P, K), which - together with the concentrate from ultrafiltration - are used to enrich the solid fraction.

Water of the quality of drinking water is the final product.

In contrast, according to Kolar et al. [9] the liquid fraction is much higher in biodegradable matter. This is confirmed by the results of the authors' research that assessed the content of dry matter, organic nitrogen, P, K, Ca in digestate received under mesophilic fermentation conditions from three substrates: cattle manure, corn silage, and haylage. The authors note that following the fermentation process the content of dry solids and organic nitrogen decreases, whereas the content of P, K and Ca increases. In the experiment carried out by the authors the liquid phase of digestate is enriched with organic and easily degradable substances, at the expense of the solid phase [9].

Due to the higher content of nitrogen - NH_4N concentration in the soil fertilized with digestate is higher than in the conventional fertilizer [10]. In addition, it is necessary to take into account the fact that the annual dose of manure cannot exceed 170 kg of nitrogen in a pure ingredient per 1 ha of the agricultural land [10].

Pontus' study [11] proved that digestate added to the soil did not significantly change the content of the total organic carbon. However, the addition of digestate caused a rapid nitrification of ammonia. Nitrates may directly be obtained by plants and be embedded in their tissue [11].

5. R3 slurry recovery process

The use of digestate pulp as fertilizer can restrict the subsequent effect of fertilizers [4]. This problem may be resolved through recovering and recycling by means of the R3 process. It refers to those organic substances that are not used as solvents.(including composting and other biological transformation processes) [5] or composting digestate pulp containing organic substances with a wide ratio of C: N [5]. In this case, the composting process additionally has the sanitation function.

The composting of digestate pulp increases the content of dry mass to 20% and significantly decreases the general nitrogen and ammonia in dry mas [12].
The most frequently, composting process has the form of heaps and is carried out by tractor aerators [13]. As a result of the thermophile process, organic waste involving microorganisms and oxygen produces young compost which is subsequently transferred to the maturing facility [13].

6. Drying and pelletizing

The process of drying digestate to a moisture below 20% enables digestate to be granulated, stored and used for energy purposes. Only when digestate has an appropriate level of moisture, it may be used to produce pellet. The estimated moisture level can be achieved, using thermal methods [14].

The calorific energy of pellets obtained from the solid fraction of digestate is from 15 MJ kg^{-1} to 17 MJ kg^{-1} [10]. It is similar to the average energy value of pellets produced from different plant materials. In case of pellets made from wheat straw, the calorific value was from 16.1 MJ to 16.5 · kg^{-1} and for pellets made from rape straw, corn, cereal and rapeseed waste - from 16.8 MJ kg^{-1} to 17.5 MJ · kg^{-1} [13]. Pellets made from sludge solids of digestate are characterized by high levels of nitrogen, sulfur and chlorine that exceed the limit values [10].

The content of heavy metals such as mercury, arsenic, cadmium is close to the limit. Exceeding the limit values for nitrogen and sulfur may cause difficulties during combustion and result in emissions of dust, CO and NOx. The content of ash as a residue after burning pellets made from digestate, is greater than in case of non -wood pellet [10]. The high concentration of phosphorus and potassium in ash enables it to be used as fertilizer.

7. Thermo-chemical treatment

Digestate defined as biomass may be used in the thermochemical treatment process [14].
Basic methods of biomass thermochemical processing are as follows:

- combustion;
- carbonization / torrefaction;
- pyrolysis;
- gasification;
- condensation.

Gasification and torrefaction are the most common methods of disposing of digestate. Biomass is slowly heated without access (or minor) of oxygen at a temperature of 200-300 °C. During this process, a change in chemical content of hydrocarbons in the biomass, thus the carbon content increases and the oxygen content decreases. Consequently, the calorific value of biomass and its hygroscopicity increase [14].

The gasification process is carried out at temperatures from 500 to 1300°C and is the conversion of fossil and alternative fuels, e.g. example biomass into the useful synthesis gas and other chemical compounds. To carry out the gasification process the following conditions need to be met: the presence of oxygen or water in the supercritical state [14]. Currently, these processes are widely used for the conversion of fossil fuels, whereas the biomass conversion, due to the different morphology of the batch, is an experimental method that needs to be improved [14].

8. Conclusions

If the government manages to realize till 2020 its plans pertaining to the number of existing biogas plants, then around 10,000 Mg of digestate produced by one biogas plant will be for management. Therefore, it is necessary to currently select the most advantageous digestate development method.

Among the various digestate management methods the cheapest and the most common method is to use digestate, using the R10 process - spreading over a field or using to enhance soil. As for energy, a special attention must be paid to pelletizing, briquetting and thermo-chemical treatment-gasification. These methods are not thoroughly described in the available scientific literature and they may play a key role not only in terms of the digestate management but also in the development of biogas plants.

9. References

[1] www.arr.gov.pl/wytwórcy-biogazu-rolniczego/dane-od-2011.
[2] www.european-biogas.eu/2014/12/16/4331/.
[3] Rozporządzenie Ministra Środowiska z dnia 27 września 2001r. w sprawie katalogu odpadów (Dz.U. 2001 nr 112 pozycja 1206).
[4] Ustawa o nawozach i nawożeniu Dz.U. z 2015 poz. 625.
[5] Pilarska A., Wolna-Murawka A. Piechota T., Pilarski K., Szymańska M., Wolicka D.: Wstępne badania pulpy pofermentacyjnej z biogazowni oraz jej kompostów jako potencjalnych nawozów organicznych. Nauka Przyroda Technologie, 2015, Tom 9, Zeszyt 2, #9, ISSN 1897-7820, 1-10.
[6] Ustawa z dnia 14 grudnia 2012r. o odpadach (Dz.U. 2013 poz. 21).
[7] Al. Sead T. Lukehurst C.: Quality management of digestate from biogas plants used as fertilizer. IEA Bioenergy Task 37-Energy from Biogas, May 2012, edited by Task Leader European Commission, Joint Research Centre.

[8] Czekała W., Pilarski K., Dach J., Jańczak D., Szymańska M.: Analiza możliwości zagospodarowania pofermentu z biogazowni. Technika Rolnicza Ogrodnicza Leśna, 2012, 4.
[9] Kolar L., Kuzel J., Peterka J., Borowa-Balt J.: Agrochemical value of the liquid phase of wastes from fermenters during biogas production. Plant Soil Environ., 2010, 56 (1), 23-27.
[10] Cieślik M., Lewicki A,. Rodriguez Carmona P., Czekała W., Jańczak D., Witaszek K., Dach J.: Research on slurry and digestate pulp separation on the solid and liquid. Archives of Waste Management and Environment Protection, 2014, vol. 16, issue 2, 43-48.
[11] Pontus K.: Osad pofermentacyjny oraz jego wykorzystanie. Badania, technologie, prawo i ekonomika w rejonie Morza Bałtyckiego. [W:] Praca zbiorowa. Redakcja naukowa: Adam Cenian, Janusz Gołaszewski, Tadeusz Noch. Gdańsk: Wydanie w ramach Bałtyckiego Forum Biogazu IV, 2014, 108-117.
[12] Kaparaju P.L.N., Rintala J.A.: Effects of solid-liquid separation on recovering residual methane and nitrogen from digested dairy cow manure. Bioresources Technology, 2008, 99, 120-127.
[13] Niedziółka I., Szpryngiel M.: Ocena cech jakościowych peletów wytworzonych z biomasy roślinnej. Inżynieria Rolnicza, 2012, Z. 2 (136), T. 1, 267-276.
[14] Basu P.: Biomass Gasification, Pyrolysis and Torrefaction: Practical Design and Theory. Second edition, 2013. ISBN 978-0-12-396488.