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THE EFFECT OF SUBSTRATE ON THE AMOUNT AND COMPOSITION OF BIOGAS IN AGRICULTURAL BIOGAS PLANT

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Summary

Construction of biogas plants processing agricultural waste enables to reduce waste, limit emission of gases and odors in rural areas as well as gives the possibility to ensure self-sufficiency of energy. The amount of generated electricity and heat depends on the quantity and quality of biogas. The aim of this work was to show how the substrate affects the amount and composition of the biogas in agricultural biogas plants. The most commonly applied types of substrates in agricultural biogas plants in 2011-2012 and in the first half of 2013 were indicated due to the Agricultural Market Agency data. The research also showed the amount of agricultural biogas produced as well as the amount of electricity and heat generated from agricultural biogas during the time period mentioned above.

Key words: biogas, alternative energy, agricultural biogas plant, substrates

INTRODUCTION

The obligation of EU countries to obtain energy from unconventional sources has created a situation in which a food producer may become an important energy producer. The effects of deliberate strategy, which provides the economy and farmers involved in the production of electricity with benefits, are observed in the Western countries. To fulfill the commitment Poland needs to introduce cultivation of energy crops together with the maximum use

of agricultural and food industry waste (Eder B., Schulz H. 2007; Pilarski K., Adamski M. 2009)

Agricultural biogas plants are becoming more popular among agricultural producers mainly due to easy access to information about the agricultural uses of biogas plants, pressure from suppliers, changes in energy law and the need for proper utilization of manure and slurry. Biogas plant is also an excellent source of income diversification owing to rising production costs and decreasing profitability of crops and livestock production (Gniazdowski J. 2009).

To produce biogas, more commonly are used materials which differ from traditional natural fertilizers – manure and slurry, municipal waste and sewage sludge. For example, corn intended for the production of biogas enables to produce around ten times greater amount of methane than slurry (Eder B., Schulz H. 2007). The effectiveness of methane production from arable crops depends not only on their species but also upon other cultivation factors, such as dry matter content, plant maturity or harvest date (Amon T., Kryvoruchko V., Bodiroza V., Amon B. 2005). These factors depend on climate, soil factors and region (regional diversity of crops).

AGRICULTURAL BIOGAS PLANT PRINCIPLE OF OPERATION

Agricultural biogas plants are used for the production of biogas whose main component is methane. The starting materials are dosed to the fermentation chamber. Here the biomass is mixed, which allows to distribute evenly next portions of substrate and to maintain proper parameters, including pH and the temperature. The fermented substrate is used as a liquid fertilizer. Produced biogas is stored in a tank, dried and after being disposed of hydrogen sulfide it is received by the CHP aggregate or module (http://biogazownie.pl/fermentacja-metanowa.html). As a consequence, electricity and heat are created..

Cycle of anaerobic biochemical reactions occurring in fermentation chambers is composed of four stages, such as (Dudek J., Zaleska-Bartosz J. 2010):

- hydrolysis – polymers: hydrocarbons, fats and proteins are decomposed to monomers: sugars, glycerine, amino acids, fatty acids,
- acidogenesis – monomers are converted to short-chain fatty acids, alcohols, hydrogen, carbon dioxide and methane,
- acetogenesis – fatty acids are converted to acetic acid, hydrogen and carbon dioxide,
- methanogenesis – from acetic acid and hydrogen arises a mixture of methane and carbon dioxide, the final product.

Depending on the starting materials and the process conditions, the composition of biogas can vary considerably. Table 1 shows the chemical composition of biogas (Steppa M. 1988). Proper preparation of the substrate has a significant

impact on the speed of the process of biological waste treatment as well as on the composition of the biogas.

Table 1. The chemical composition of biogas from agricultural biogas plant

Component of biogas	Concentration [%]
CH_4	52 – 85
CO_2	14 – 48
H_2S	0.08 – 5.5
H_2	0 – 5.5
CO	0 – 2.1
N_2	0.6 – 7.5
O_2	0 – 1.0

Source: (Steppa M. 1988)

ADVANTAGES OF AGRICULTURAL BIOGAS PLANT

Biogas plants which are based on waste from animal husbandry, slaughterhouse waste, distilleries or meat processing plants allow to obtain biogas which is renewable energy carrier as well as fermented mass, i.e. useful technological waste, bacteriologically safe. Such use of waste is considered appropriate mainly for liquid waste from animal husbandry. Biochemical transformation of farmed waste has other benefits, namely: minimized emissions of odorous substances and methane. Emission of these substances occurs during collecting and storing waste from animal husbandry for a required period before using them to fertilize and during this process (Marczak H. 2009). Reduction of odors is greater than 80%. Also fertilizing conditions of cultivated fields are improved, compared with unfermented liquid manure. Disinfection process eliminates pathogens. Functioning of agricultural biogas plant reduces the risk of groundwater and surface water contamination. An important advantage is the reduction in fossil fuels consumption and compounds emission produced during their combustion.

The use of meadows and pastures for purposes other than feeding, including the energy purposes, can also bring many benefits, such as (Wasilewski Z., Barszczewski J. 2011):

- quantitative and qualitative enrichment of plant material intended for the use in biogas plants, in particular in combination with the liquid manure;
- using meadows and pastures abandoned due to disposing of ruminants – such grounds erode and lose their valuable functions, particularly non-productive ones;

- maintaining or even improving precious value of the rural landscape;
- maintaining or even increasing a biodiversity.

Produced biogas can be sold as a fuel or used in facilities which are adjacent to the biogas plant for the production of (Marczak H. 2009):

- heat;
- electricity and heat:
  - in the cogeneration system using gas engines,
  - in the system using a steam (steam turbines);
- electricity (spark engines).

MATERIALS AND METHODS

Data used came from the Agricultural Market Agency and concerned the amount of agricultural biogas produced as well as the amount of electricity and heat produced from agricultural biogas. Data from professional literature allowed to indicate substrates that generate the biggest quantities of biogas and substrates that generate the most methane-rich biogas.

Table 2. List of raw materials used to produce agricultural biogas in 2011-2012 and in the first half of 2013 (as on 30th September 2013)

Type of raw material used to produce agricultural biogas	**The amount of raw materials consumed in the production of agricultural biogas (in tonnes)**		
	2011	2012	First half of 2013
liquid manure	265 960.79	349 173.12	212 465.43
corn silage	108 876.14	241 590.19	145 485.53
decoction of the distillery	30 465.11	146 607.49	162 427.51
manure	11 640.53	23 502.98	17 020.66
residues from fruit and vegetables	10 984.35	86 109.22	15 939.54
a mixture of lecithin and soaps	8 906.87	2 086.42	0
potato pulp	7 258.49	6 627.27	1 463.14
grass silage	7 217.10	1 683.17	622.44
pulp	6 922.45	37 081.80	45 447.62
cereal silage	5 973.80	348.48	485.52
whey	1 933.00	12 854.34	6 883.00
cereal	1 611.77	690.78	240.45
stomach contents	1 278.30	1 056.62	0
fatty waste	285.65	305.17	0

Type of raw material used to produce agricultural biogas	The amount of raw materials consumed in the production of agricultural biogas (in tonnes)		
	2011	2012	First half of 2013
flour, bread and breadcrumbs	101.71	450.4	0
protein deposits	0	1 020.08	0
fodder	0	1 951.94	0
liquid leftover wheat	0	864.79	706.49
slaughterhouse waste	0	663.19	3 411.20
sludges from refined rapeseed oil	0	620.54	0
sludges protein-fatty	0	408.65	0
washings chocolate	0	342.52	0
glycerine	0	302.71	2 578.76
Waste plant-	0	292.98	0
sediment of yeast	0	230.08	1 060.40
straw	0	153.45	603.65
residues from the processing of plant products	0	50.06	0
overdue food	0	36.54	0
fats	0	15.5	0
plant oils	0	1.08	0
liquid waste from potato processing	0	0	123 920.60
waste protein-fatty	0	0	3 388.98
hens manure	0	0	2 128.86
waste chocolate	0	0	1 253.56
waste from food processing	0	0	505.39
wastes from the production of plant oil	0	0	190.77
fusel oils	0	0	87.38
protein hydrolyzate	0	0	39.62
fodder	0	0	2.3

Source: Agricultural Market Agency

DISCUSSION OF RESULTS

Table 2 shows the raw materials used in the production of agricultural biogas during the analyzed period. Table 3 shows the possibilities of biogas and methane yield from each substrate, Figures 1 and 2 respectively illustrate it graphically. In Table 4 production of agricultural biogas, electricity and heat

from agricultural biogas in 2011-2012 and in the first half of 2013 is shown. Figure 3 shows production of agricultural biogas, whereas Figure 4 – electricity and heat from agricultural biogas in years 2011-2012 and in the first half of 2013.

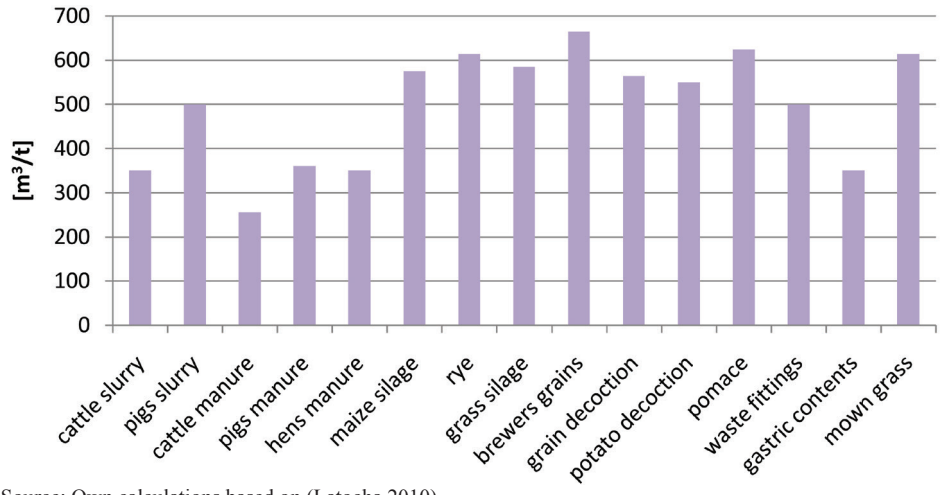
In the analyzed period the dominant substrates were: slurry, corn silage, decoction of the distillery. The share of the residue of fruit and vegetables increased significantly in 2012, while in the first half of 2013 there was a high share of liquid waste from potato processing.

It may be indicated that suitable substrates for biogas plant, in order to achieve its optimal work, are still being searched. New materials are being used and there is a shift from the ones which have not worked in agricultural biogas plants.

Table 3. Characteristics of selected plants and selected products for biogas yield

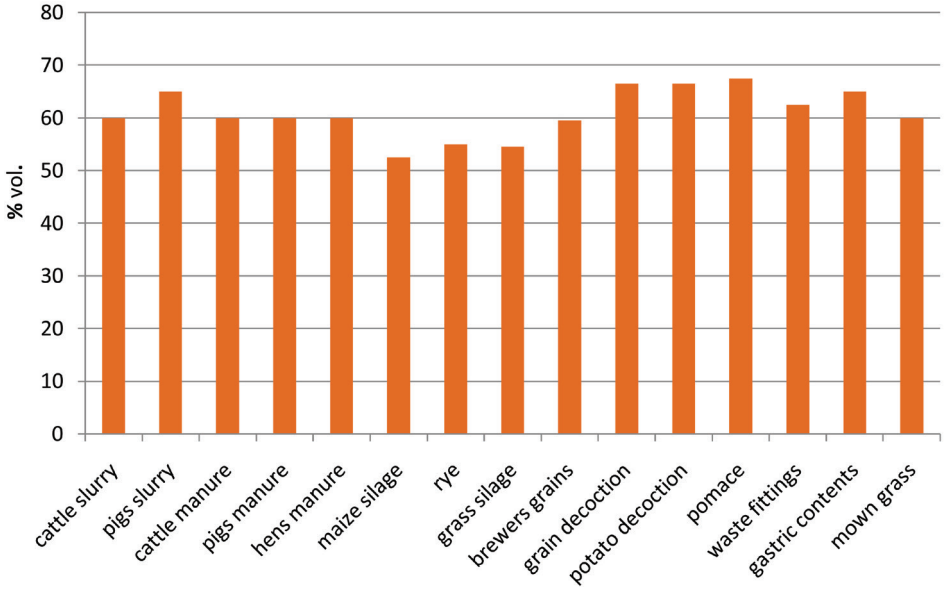
Base	The dry matter content (%)	The dry matter content of organic (%)	The yield of biogas (m^3/t)	The content of methane CH_4 (% vol.)
Natural fertilizers				
cattle slurry	8-11	75-82	200-500	60
pigs slurry	about 7	75-86	300-700	60-70
cattle manure	about 25	68-76	210-300	60
pigs manure	20-25	75-80	270-450	60
hens manure	about 32	63-80	250-450	60
Plants				
maize silage	20-35	85-95	450-700	50-55
rye	30-35	92-98	550-680	about 55
grass silage	25-50	70-95	550-620	54-55
Products of the agricultural industry				
brewers grains	20-25	70-80	580-750	59-60
grain decoction	6-8	83-88	430-700	58-65
potato decoction	6-7	85-95	400-700	58-65
pomace	25-45	90-95	590-660	65-70
Other substrates for biogas plants				
waste fittings	5-20	80-90	400-600	60-65
gastric contents	12-15	75-86	250-450	60-70
Grasses				
mown grass	about 12	83-92	550-680	55-65

Source: Land Technik Weiher Stephen H.Mitterleitner (Latocha 2010)



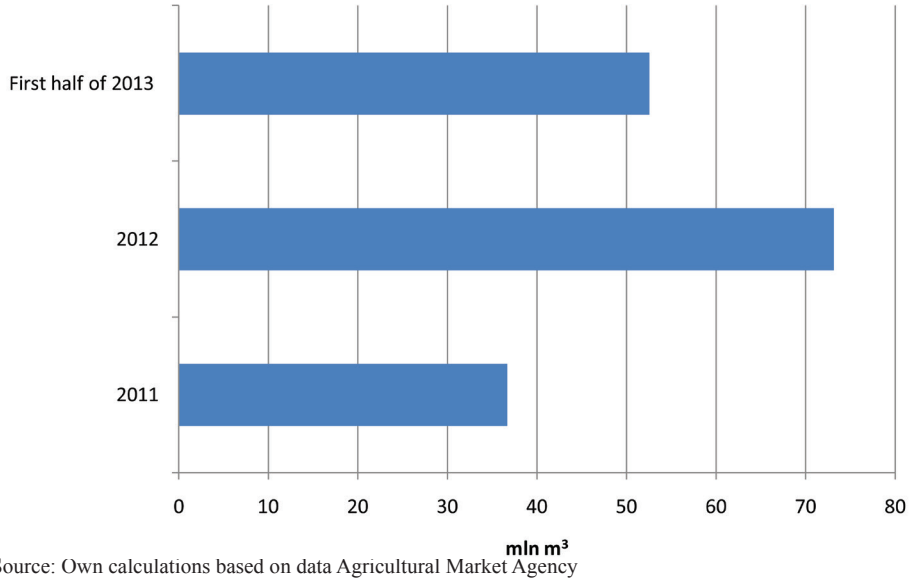
Source: Own calculations based on (Latocha 2010)

Figure 1. Biogas production from selected plants and by-products



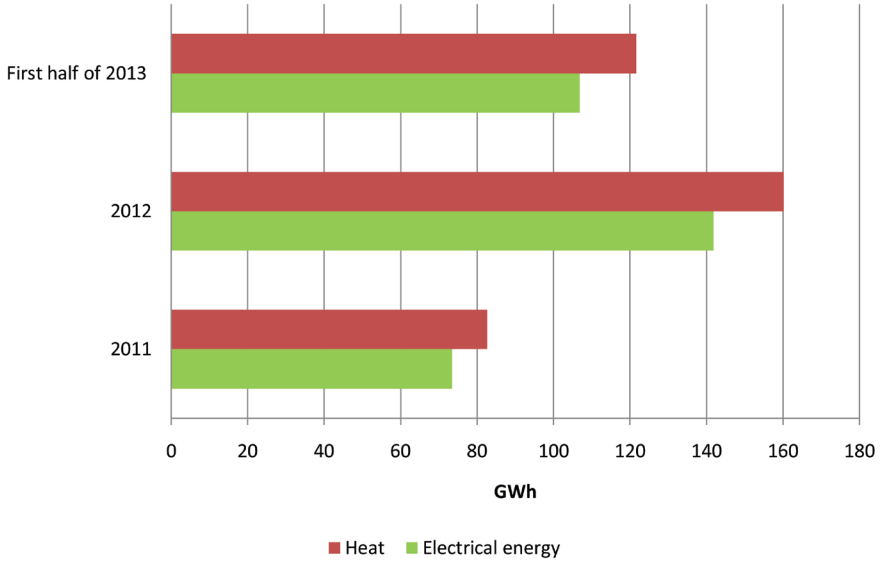
Source: Own calculations based on (Latocha 2010)

Figure 2. The volume of methane in the biogas obtained from selected plants and by-products



Source: Own calculations based on data Agricultural Market Agency

Figure 3. Agricultural biogas in 2011-2012 and first half of 2013



Source: Own calculations based on data Agricultural Market Agency

Figure 4. Electrical energy and heat production from agricultural biogas in 2011-2012 and first half of 2013

Maize silage, rye, grass silage, brewers grains, pomace, mown grass can provide a large amount of biogas.

Grain decoction, potato decoction, pomace, gastric contents can provide biogas with the highest methane amount.

Table 4. Production of agricultural biogas, electricity and heat from agricultural biogas in 2011-2012 and in the first half of 2013 (as on 30th September 2013)

	Unit	2011	2012	first half of 2013
The amount agricultural biogas produced	mln m^3	36,65	73,15	52,53
The amount of electricity generated from agricultural biogas	GWh	73,43	141,80	106,80
The amount of heat produced from agricultural biogas	GWh	82,63	160,13	121,54

Source: Agricultural Market Agency

In 2012, compared to 2011, increased the amount of biogas produced as well as electricity and heat generated from it. Prospects for growth in 2013 are enormous, as indicated by semi-annual survey.

CONCLUSIONS

1. The amount and composition of produced biogas is highly dependent on the composition of the raw mix undergoing the process of fermentation.
2. Due to the possibility inhibitory effect of substrates on the fermentation process, new substrates should be thoroughly tested for performance and usability.
3. Every year the amount of biogas plants in Poland increases, and consequently - also the amount of electricity and heat from agricultural biogas.
4. Searching for new starting materials and resignation from inefficient ones enables optimal solutions of methane fermentation.

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