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THE BIOGAS PRODUCTION FROM HERBS AND WASTE FROM HERBAL INDUSTRY

Summary

Profitability of many biogas investments depends on the substrate costs and certificates price. Polish reality in this case is especially unstable which makes the biogas business difficult and hard to predict. Price of maize silage (main substrate for biogas production in Poland) is increasing constantly while income from produced bioenergy is decreasing. It forced Polish investors to look for cheaper technologies and especially substrates. This paper is focusing on finding alternative biogas substrates among the wastes from herbal industry.
Key words: *biogas, herbs, waste management*

PRODUKCJA BIOGAZU Z ZIÓŁ I ODPADÓW Z PRZEMYSŁU ZIELARSKIEGO

Streszczenie

Opłacalność wielu inwestycji biogazowych zależy od kosztów substratów oraz cen certyfikatów. Polskie realia w tej sprawie są wyjątkowo niestabilne, co czyni biznes biogazowy skomplikowany i trudny do przewidzenia. Cena kiszonki kukurydzianej (głównego substratu do produkcji biogazu w Polsce) ciągle rośnie, podczas gdy dochód z produkcji bioenergii maleje. Zmusza to inwestorów do poszukiwania tańszych technologii, a w szczególności tańszych substratów. W studium skupiono się na poszukiwaniu alternatywnego substratu biogazowego pośród odpadów z przemysłu zielarskiego.
Słowa kluczowe: *biogaz, zioła, gospodarka odpadami*

1. Introduction

German experiences with maize monoculture indicate the necessity of looking for new kind of energetic plant for biogas market. Plant material with high biomass potential is needed to provide energy based on renewable resources [1]. If looking for the fastest growing plant, probably the biggest expectations are involved with microalgae. Some of them according to papers from all over the world can multiply their weight almost five times within just 24 hours. The maximum theoretical algae biomass productivities (at 8–10% photosynthetic conversion efficiency) are estimated to be in the order of 77–96 g of dry matter (DM) per square meter per day (280–350 ton DM ha yearly) while reasonable target productions are projected as in the order of 27–62 g DM [2, 3]. Other way to feed biogas plant is to use wastes or substrates with biogas potential - sometimes not as high as maize silage, but with good availability and low price. Those alternative substrates still cannot be used i.e. maize straw silage [4]. Following in the footsteps scientists from Institute of Biosystems Engineering (Poznan University of Life Sciences - PULS) decided to test hemp, wastes from herbal production, red clover and grass in order to define their biogas production efficiency.

The aim of the research was to study the potential of large group of biomaterials like herbs, wastes from herbal production, grass and hemp for usage as substrate in agricultural biogas plant.

2. Materials and methods

The study was conducted in Laboratory of Ecotechnologies – the biggest biogas laboratory in Poland, working within the Institute of Biosystems Engineering (PULS). The experimental methods have based on modified German standard DIN 38 414, while chemical and physical analytical methods based on Polish Standard System. The analytical procedures concerning biowaste were also developed within several scientific projects financed within EU 6th Framework Program and Polish Ministry of Science and Higher Education in the years 2006-12 [5].

2.1. Solid waste and inoculum

Substrates were taken from one of the herbal industry factories located in Wielkopolska region. Inoculum (digested pulp) was taken from an agricultural Polish biogas plant working on cow slurry and maize silage.

2.2. Methane production set-up

The experiment of biogas production was conducted through anaerobic digestion in the set of multichamber biofermentor (Fig. 1). This biofermentor is commonly used for testing biogas and biomethane production efficiency for large amount of biomass samples.

Aerobic digestion experiments were carried out in stirred tank reactors constructed of glass in the Laboratory of Ecotechnologies. General rules for biofermentor work were based on the fermentation of organic substrate samples which were put into the chambers with 2 dm^3 capacity. Without oxygen presence and additive of fermentation inoculum the conditions present within the fermentation chamber allowed to create an ideal conditions for methane fermentation of the samples. Glass chambers with samples were placed in water with regulated temperature (around 39°C) – similar to the real conditions of biogas plant. Biogas produced in each separate chamber was transferred to cylindrical store – equalizing reservoirs, filled in with liquid. All samples were tested in 3 replications.

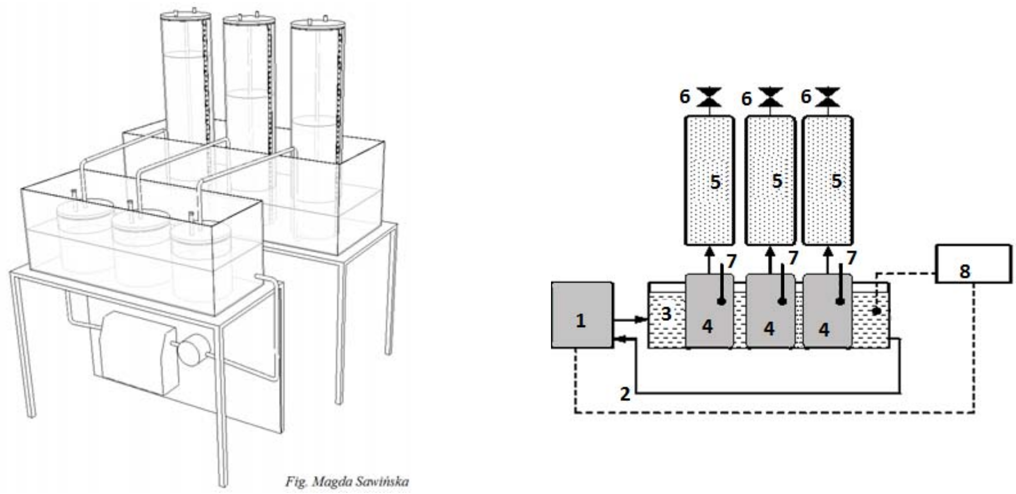

Fig. 1. Scheme of biofermentor for biogas production research (3-chamber section): 1. Water heater with temperature regulator, 2. Insulated conductors of calefaction liquid, 3. Water coat with temp. 35-42°C, 4. Biofermentor with charge capacity 2 dm^3, 5. Biogas reservoir, 6. Cutting off valves, 7. Sampling tubes, 8. Recording central station

2.3. Sampling and analyzes

All samples were prepared with accuracy 0.5 g. Materials before experiment were stored in the fridge in the temperature 4^{o}C. Before starting of experiment, the samples of tested materials were taken in order to analyze dry matter content. This was indispensable to calculate the contents in mixture.

During preparation, part of mixtures was taken for analyses. Prepared samples needed to be analyzed in respect to the correct physical and chemical parameters. The most important one was pH (optimum between 6.8 and 7.5) and ammonium nitrogen concentration (lower than 2.5 g/dm^3 of prepared mixture). The pH was measured using laboratory multi-meter CP-411 (Elmetron). Additionally, dry matter and organic dry matter were determined. It was necessary to calculate biogas production efficiency in typically used units – m^3/Mg of dry matter.

During the experiment the following standard methodology established by Polish Norms (PN) has been used: for dry matter PN-75 C-04616/01, pH - PN-90 C-04540/01, conductivity PN-EN 27888:1999 and organic dry matter PN-Z-15011-3. Ammonia was determined according to Standard Methods [6].

2.4. Gas samples

The volume of the produced biogas has been measured every 24 hours. Gas composition has been checked out from at least each 1 dm^3 of the produced biogas (at the beginning of the experiment it was once a day, and after the culmination point, when the production slowed down, each two-three days). The concentration measurements of methane, carbon dioxide, hydrogen sulphide, ammonia and oxygen in the produced biogas have been carried out with the use of the absorption sensors working in an infrared and electrochemical sensor line. The type Mg-72 and MG-73 heads for gas concentration measurement have been used (ALTER S.A.) [7]. The ranges of detected gaseous compounds were: 0-100% CH_4, 0-100% CO_2, 0-25% O_2, 0-2000 ppm H_2S and 0-2000 ppm NH_3, respectively. Therefore, each sample for biogas production was monitored for the gas compounds daily. The volume of biogas production and the methane content of biogas were calculated in the Excel sheet. According to the graph, it was possible to determine if the sample is working properly during the experiment. Gas-monitoring system has been calibrated each week using calibration gases provided by Messer Company, using the following concentration of gas calibration: 65% of CH_4, 35% of CO_2 (in the same mixture). 500 ppm of H_2S and 100 ppm of NH_3. For O_2 sensor calibration, the typical synthetic air was used.

2.5. Mixture preparations

Preparation of fermentation mixtures established varied proportions between analyzed substrates (Table 1).

Table 1. Fermentation mixtures proportion

Sample	**Substrate** [g]	**Inoculum** [g]
Grass	100	1000
Herbs	100	1100
Red clover	100	1100
Hemp	100	900

Cumulative weight of substrates added to each reactor based on availability of easily-digestible fractions (when the concentration of it is too high may cause acidification process) and started pH of prepared mixtures Tab. 2.

Table 2. Physical and chemical parameters of substrates

	Parameters		
Substrate	**pH**	**TS [%]**	**VS [% TS]**
Grass	6.1	17.65	92.85
Herbs	5.4	32.70	90.13
Red clover	4.2	22.51	91.79
Hemp	9.11	43.74	87.94

3. Results
3.1. Substrate analysis

At the beginning of the research, chemical and physical parameters of substrates have been analyzed. Organic dry matter content was similar for all substrates and it was high, over 85%. The biggest differences appeared in pH. Some substrates characterized acid pH (red clover, herbal wastes, grass) while the hemp was alkaline. The pH and probable presence of easy digestible sugars in substrates have an influence on proportion between substrate and inoculum added to the fermenters.

3.2. Digestion of substrates
3.2.1 Calculation for fresh matter

Fermentation process of all four substrates proceeded without any problems. Results of cumulative methane production in the assays with different substrates are presented in Tab. 3 and Fig. 2.

From the point of view of cumulative biogas production calculated on 1 Mg of fresh matter (FM), herbal wastes appeared as the best substrate (Fig. 2). Biomethane productivity of this substrate is almost twice higher than all the others. Comparing this result with herbs and red clover it is obvious that the reason of that is higher amount of total solids -32.7% instead of 17.62 and 22.51% (Tab. 2).

Tab. 3. Cumulative biogas and methane production

Substrate	Fresh matter	
	Cumulative methane yield [m^3/Mg FM]	**Cumulative biogas yield** [m^3/Mg FM]
Grass	61.18	100.54
Herbs	**112.09**	**172.18**
Red clover	72.12	118.18
Hemp	67.07	134.33

For better visualization results of biogas and methane, the cumulative production has been presented in Tab. 3. Result of over 112 m^3 of methane from one Mg of fresh mater of herbal waste is comparable to maize silage biogas efficiency [8].

The interesting fact is that herbal wastes biogas production reaching over 190 m^3/Mg of fresh matter is close to typical production from fresh maize silage. The production of biogas from grass and red clover is visibly lower but it is related with 1/3 lower dry matter content (17.65 and 22.51% instead 32% for typical maize silage). Thai is why better comparison of biogas efficiency can be obtained by calculating the results from dry matter of described materials.

3.2.2 Calculation for total solids

Looking at the results of biogas efficiency calculated on the base of total solids amount, the aspects contrasting to the results presented in previous chapter can be observed. Grass, herbal wastes and red clover produce similar volume of methane. However hemp reach only about 150 m^3 which is more than twice less than all the other substrates (Tab. 4 and Fig. 3).

Tab. 4. Cumulative biogas and methane production

Substrate	Total solids		
	Cumulative methane yield [m^3/Mg TS]	**Cumulative biogas yield** [m^3/Mg TS]	**Methane concentration** [%]
Grass	**346.62**	**569.74**	56.96
Herbs	**342.78**	**526.23**	**61.04**
Red clover	**320.39**	**525.03**	57.18
Hemp	153.32	307.08	50.78

Other thing worth highlighting is a fact that concentration of methane in herbal wastes was about 4-10% higher contrary to the others (Tab. 4). It makes its biogas energetically more valuable. Reason of that is surely different chemical composition of analyzed substrates. To reach methane concentration over 55% other component than sugar is necessary [9]. Most likely it is protein, but to be sure further chemical analyzes have to be done.

From that point of view (total solids) grass, herbal wastes and red clover seem to produce as much biogas as beet pulp [9]. It proves that those substrates might be successfully use as profitable biogas materials, especially that thy are cheaper. This fact is very important because in typical agricultural plant the cost of substrates (mainly silages) can reach 30-35% of total exploitation costs.

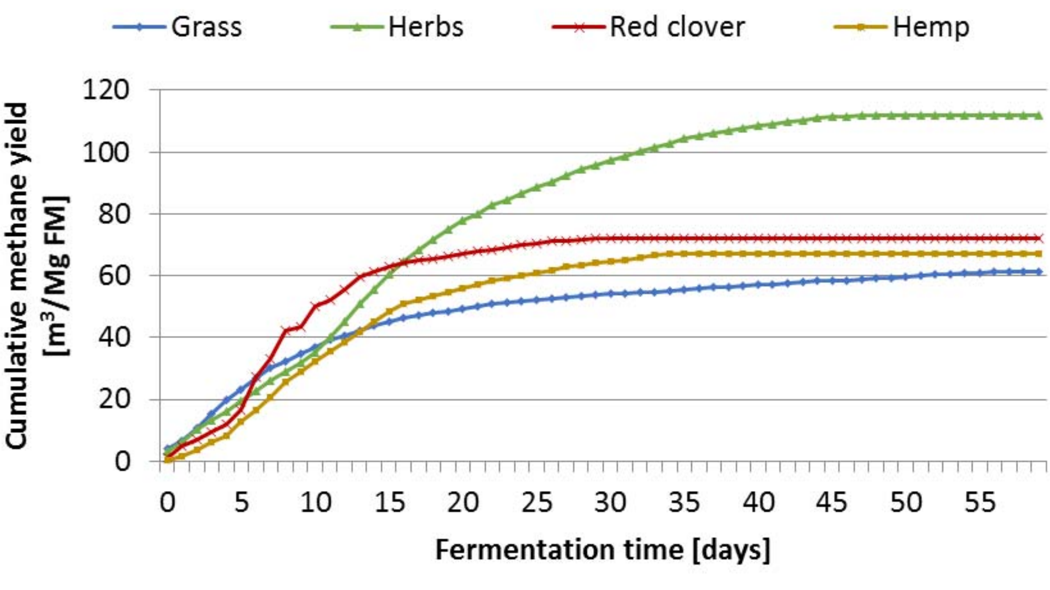

Fig. 2. Cumulative methane production [m^3/Mg FM]

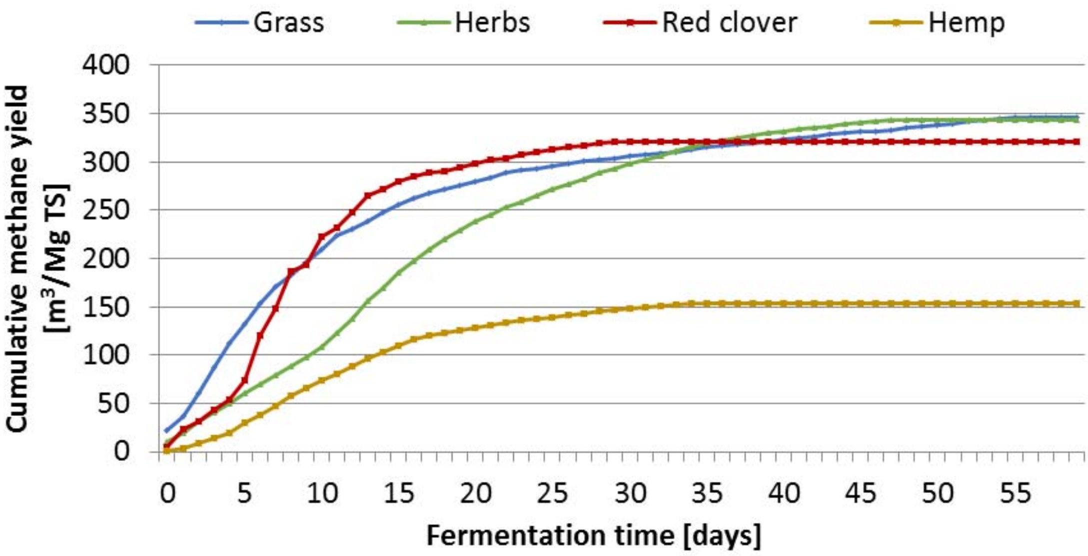

Fig. 3. Cumulative methane production [m^3/Mg TS]

4. Conclusions

On the basis of the conducted research, it can be concluded that there is a great biogas potential in herbal industry. Some of waste produced is characterized by a biomethane production comparable to the most popular biogas substrates, maize silage and beet pulp. Hemp, which was presupposed to be a biogas plant similar to maize, turned out to have a low biogas potential. It is crucial to point out that waste from herbal production is available at little cost or even for free. It proves that cost-effectiveness of biogas investment can be improved by using inexpensive substrates, e.g. herbal waste. The potential of hemp and red clover as biogas substrates depends greatly on their price which is related to cultivation costs and a scale of production.

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