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USE OF SUGAR BEET LEAVES FOR BIOGAS PRODUCTION

Summary

The aim of this work was to undertake a study to determine the amount of biogas emitted from fractions prepared from sugar beet leaves. Four types of combinations of batch mass were subjected to analysis. Tests were conducted over a period of 30 days. Measurements were taken twice a day, at the same time, from the moment of placing the batch into fermenters until the end of fermentation. In this study, samples were mixed, thus affecting the intensity of fermentation in the entire volume. The study showed that shredded ensiled leaves ferment best. Biogas obtained in this way can be used as an alternative source of energy, and therefore it is possible to minimize waste generated from agricultural production.
***Key words**: sugar beet, biogas, methane fermentation, renewable resources*

WYKORZYSTANIE LIŚCI BURAKÓW CUKROWYCH DO PRODUKCJI BIOGAZU

Streszczenie

Celem pracy było przeprowadzenie badań dotyczących określenia ilości wydzielania biogazu z frakcji wykonanych na bazie liści buraka cukrowego. Analizie poddano cztery rodzaje kombinacji masy wsadowej. Badania przeprowadzone zostały przez okres 30 dni. Pomiary odczytywano dwa razy na dobę o tej samej porze od momentu umieszczenia wsadu w fermentatorach do momentu zakończenia fermentacji. Podczas przeprowadzonych badań próbki były mieszane, co wpływało na intensywność fermentacji w całej objętości. Z przeprowadzonych badań wynika, że najlepiej fermentują liście zakiszone rozdrobnione. Uzyskany w ten sposób biogaz może być wykorzystany jako alternatywne źródło energii, a dzięki temu można minimalizować powstające odpady z produkcji rolniczej.
***Słowa kluczowe**: burak cukrowy, biogaz, fermentacja metanowa, odnawialne źródła*

1. Introduction

Nowadays, nobody can imagine life without energy. The current problem results from the fact that the resources we use are non-renewable. They are used up faster than they are replenished. Apart from clean air and rational use of land and other resources, energy harvesting is necessary for the survival of life on Earth. Today's civilization is characterized by a high and increasing energy consumption.

The effect of the current situation is that not only the assessment of existing energy resources, but also the search for ways to save energy are more and more often a subject of discussion, assumptions and energy programmes [1].

There are also talks about improving energy efficiency, efficiency of energy sources and energy infrastructure, but mostly about improving the ways of harvesting and searching for energy carriers that do not have a negative effect on the condition of natural environment.

Attention should be paid to the fact that renewable energy resources are important for two main reasons, in regards to the environment and because they play an important role in the economical management of energy. The share of renewable energy resources in the fuel and energy balance of the world amounts to about 18%. This number results from the development of new technologies which utilize renewable energy resources, and also from the fact that there are some people in the world who have no access to conventional energy resources [1, 2].

Renewable fuels include organic products which are generated during photosynthesis with water and carbon dioxide absorbed from the atmosphere, and their combustion does not increase the concentration of carbon dioxide particles in the atmosphere. The use of biofuels not only contributes to reducing carbon dioxide emission, but also reduces the emission of other gases and dusts harmful for humans. Animal droppings, municipal sewage and emission of harmful compounds present in it also have a significant effect on the condition of the natural environment.

For the management of biodegradable waste, the methane fermentation process for biogas (bioenergy) production started to be used [3].

Agricultural by-products are the most commonly used in agricultural biogas plants, and they include, among other things: slurry, manure and poultry droppings (litter), and also plants such as maize, rye, papilionaceous plants. To ensure continuity of biogas production, plants are preserved in the form of silage [4].

Numerous authors [5, 6] state that biogas is a gas which is obtained during anaerobic fermentation of natural fertilizers and organic waste rich in fats, protein and carbohydrates, with the participation of methane bacteria. A positive feature of biogas consists in its formation under natural conditions, mainly on marshes and waterlogged areas (marsh gas), whereas on rubbish dumps dump gas is formed.

Limited reserves of fossil fuels, as well as the risk they pose to the environment when they are combusted, substantiate the need to produce fuels from plant biomass. Overproduction of farm produce which sometimes takes place, as well as the desire to increase its production, should not make a contribution to lowering of its price or cause a problem with selling it. Farm entrepreneurs should aim at increasing plant production for energy purposes. Properly processed agricultural produce should gradually substitute petroleum or coal.

Agricultural biogas plants are a chance for agriculture and multifunctional development of rural areas. Production and energy use of agricultural biogas is one of the aspects of the electric power system which is based on renewable resources.

According to Wiese and Kujawski [5], the use of renewable energy resources is beginning to be an important part of energy security. Increasing prices for energy and first signs of climate changes caused by human activities are the effect of this. If there are conditions for development of this field, actions supporting and promoting renewable energy resources are needed.

The aim of this work was to determine the amount of biogas emitted from a fraction made of sugar beet leaf rosette. To better illustrate the amount of produced gas, the study covered four types of matters which constituted the substrate for methane fermentation: whole leaves ensiled with the addition of an ensiling agent, shredded leaves ensiled with no ensiling agent, whole leaves ensiled with the addition of an ensiling agent, shredded leaves ensiled with the addition of an ensiling agent.

Rosettes of leaves (together with crowns) collected directly after sugar beet harvest underwent proper processing. Silage was prepared from a part of the rosettes, without adding any substances which assist silaging, in two variants from shredded leaves and from non-shredded leaves. In addition, two variants of matter with the addition of a substance which assists preservation of silage from beet leaves were prepared – silage from shredded leaves with the addition of an ensiling agent, and from non-shredded leaves with the addition of an ensiling agent. This choice of composition of batch masses was supposed to illustrate the effect of storage and shredding the mass of sugar beet leaves on the course of methane fermentation process.

To increase the efficiency of biogas yield, a Silaprilis Pro type ensiling agent was added. This ensiling agent has a high concentration of two homofermentative strains of lactic acid bacteria, which make the silaging process very fast and efficient.

The beet leaf rosettes were subjected to homogenization in a hammer shredder manufactured by Stalgast. While carrying out the study, chemical composition of the obtained biogas was determined based on the Nanosens 60 multi-gas meter, and also a comparative analysis of individual samples was done.

2. Material and methods

This work was carried out based on literature sources and results of laboratory experiments. The subject of this study constituted material in the form of beet leaf rosettes [6-8].

The material used for fermentation was collected in Miłocice, in Słomniki commune, after seasonal beet harvest in 2014. After completed production, the farmer sends the beets to a sugar factory, whereas leaves which constitute waste from agricultural production are intended for silage for animals or to be used as a fertilizer (they are plowed). The study commenced on 7 April 2015. The whole process took 49 days. 2 dm^3 fermenters were submerged in a water bath (Fig. 1). Measurements were taken twice a day, at the same time, from the moment of placing the batch into fermenters until the end of fermentation. In this study, samples were mixed, affecting in this way the intensity of fermentation in the entire volume. Temperature in the chamber was constantly monitored and amounted to 40°C, which is optimal temperature for mesophilic bacteria. After 30 days of observing four samples, a comparative analysis was done, showing which sample gave the highest biogas yield. The obtained results allowed to assess which fraction would be the most cost-effective for wide-scale biogas production.

After being transported to the laboratory, the study material was analyzed. Next the moisture content of the sample was determined as it is an important parameter of preparing masses for methane fermentation. Moisture content of the collected mass was determined using a moisture analyzer.

The samples were dried until equilibrium water content was reached, in other words until the analyzer, after 3 consecutive measurements, showed no mass losses.

To calculate the amount of dry matter (DM) subjected to fermentation (m_{sf}), optimal conditions for fermentation are 10% DM of the working volume of the fermenter.

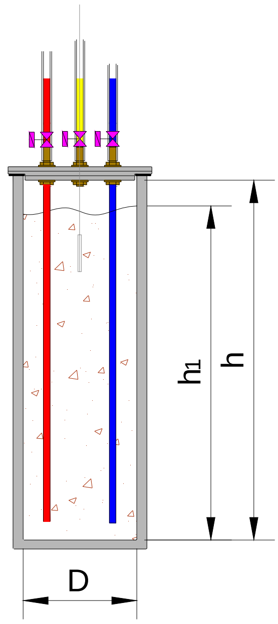

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Fig. 1. Diagram of the fermenter with a volume of 2 dm^3

Rys. 1. Schemat fermentatora o pojemności 2 dm^3

Proper preparation of biomass batch for the fermenter makes it possible to determine the amount of emitted biogas of given organic matter.

Based on the determined moisture content, we can define the mass of batch for fermentation in a 2 dm^3 laboratory fermenter, using relationship (1):

$$m_f = \frac{msf}{100 - wf} * 100 \; [g], \qquad (1)$$

where:

m_f – mass of the fraction [g],

m_{sf} – dry matter of the fraction subjected to fermentation [g],

w_f – moisture content of the fraction [%].

Once the calculations were completed, mass of the batch was established. Measurements of the mass were carried out on an electronic laboratory scales WPE 300 with precision of ± 0.01g. The weighed fraction was placed in a fermenter, then water was added in such a way that dry matter in the chamber constituted 10%.

After shredding, the material was hydrated until moisture content of about 90%, creating optimal conditions for the growth of mesophilic bacteria. The batch was hydrated and placed in the fermentation chamber with a volume of 2 dm^3 with adjustable temperature environment. In a fermenter, pH, redox and temperature of the batch were monitored.

The amount of water was determined based on weight relation (2).

Assuming that under atmospheric pressure conditions water volumetric density amounts to 1 $g \cdot cm^{-3}$, we assume V_{fr} in grams:

$$V_w = V_{fr} - msf - \left(\frac{mf * 100}{wf}\right), \quad (2)$$

where:
V_w – amount of water to be filled in the fermenter [g],
V_{fr} – operating weight of the fermenter [g],
m_f – mass of the fraction [g],
m_{sf} – dry matter of the fraction subjected to fermentation [g],
w_f – moisture content of the fraction [%].

Description of the test stand

Prepared samples were placed in the chamber. Biogas yield was obtained according to DIN 38414 [9]. Fractions were fermented under static conditions, in other words conditions consisting in a single insertion of the batch to fermentation chambers and continuing the process until fermentation is completed. Temperature, water, pressure and the amount of obtained biogas were measured at the test stand whose scheme is shown in Fig. 2.

Devices were attached to the rack (1) located next to the container (2) to keep a stable temperature environment. Everything was controlled with an electronic thermostat ESCO ES-20 (contactor 16A) with precision up to ± 0.2°C resulting from the sensor hysteresis. Turning on 1500 W heaters (3) caused a decrease in temperature by a value exceeding 0.1°C, with simultaneous actuation of the water pump Hanning DPO 25-205 (4). Pump ensures even distribution of temperature in the whole chamber.

Water that reaches a temperature exceeding the set temperature by 0.1°C caused turning off of the heater, with a 30-second delay of the pump.

The switchboard (5) consists of manifolds connected in series, together with cut-off valves (6) and a pressure gauge (7) whose function is to measure pressure.

Application of such a system to control all the fermenters caused that one measuring system was sufficient.

System of volume measurement (8) consisted of two columns filled with water and having drain valves and a tank to refill the level of liquid in the columns (9). The measuring system was connected to the switchboard and to Nanosens 70 meter which determines the composition of biogas (10).

Throughout the tests, measurements of the amount of emitted biogas were taken twice a day, at the same time, from the moment of placing the batch into fermenters until the end of fermentation. Results were saved on computer hard drive using control and archiving software.

The study on the fermentation process conducted in a laboratory allowed to assess the susceptibility of the examined fraction to biochemical processes taking place. This finds confirmation in the obtained results of analysis of gas composition and in the intensity of emitted gas.

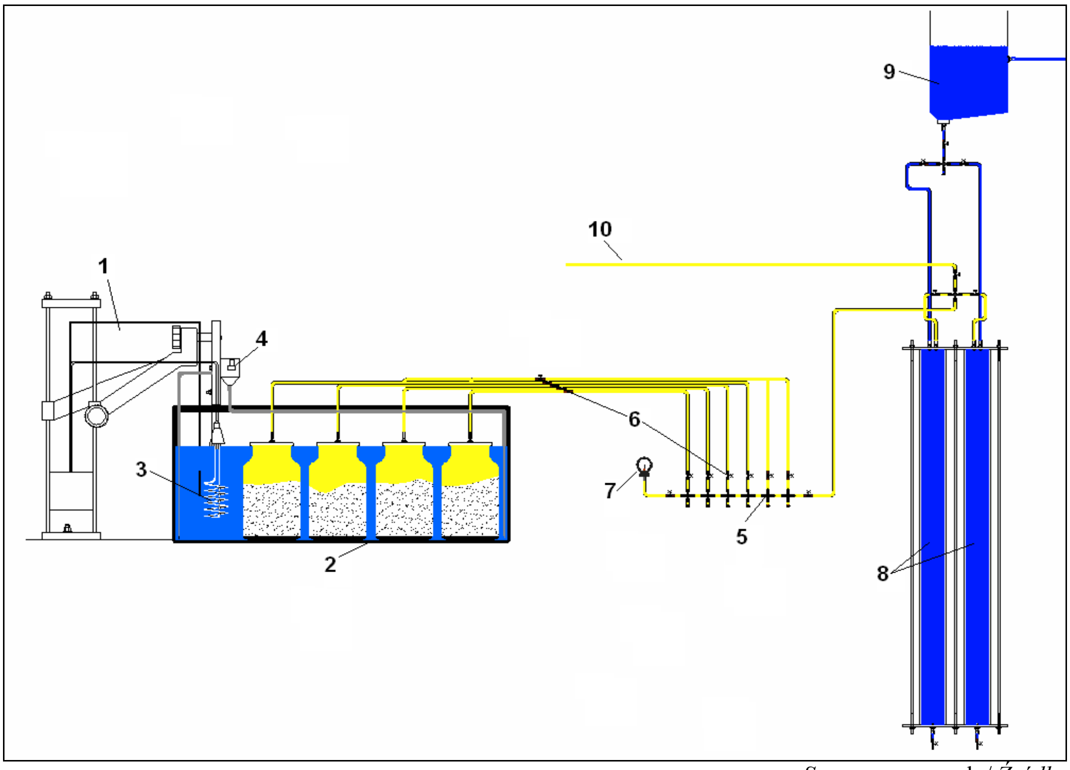

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Fig. 2. Scheme of the test stand with samples: 1 - fixing rack , 2 - glass container, 3 - electrical heater, 4 - water pump, 5 - switchboard, 6 - valves, 7 - pressure gauge, 8 - volumetric columns, 9 - water tank, 10 - measuring device
Rys. 2. Schemat stanowiska badawczego z próbkami

3. Results

Based on the carried out study on the fermentation process of rosettes of sugar beet leaves, it was possible to compare the intensity of biogas emission from substrates accepted for the study. Amount of emitted biogas is presented as a daily yield from individual fermenters.

To prepare substrates, the mass of the batch of fraction for the fermenter was calculated. Parameters of composted batches are presented in Table.

Tab. Parameters of fermenter batches
Tab. Parametry wykonanych wsadów do fermentorów

Dry matter (g)	Mass of beet leaves silage (g)	Moisture content of the sample (%)
beet leaf silage, shredded, with an ensiling agent - batch 1		
200	956	79.07
beet leaf silage, non-shredded, with an ensiling agent - batch 2		
200	871	77.03
beet leaf silage, shredded, without an ensiling agent - batch 3		
200	1,103	81.87
beet leaf silage, non-shredded, without an ensiling agent - batch 4		
200	1,397	85.68

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Figure 3 shows daily yield of biogas from a fermenter in which a batch made of shredded silage with an ensiling agent was fermented.

Maximum intensity of fermentation took place on day 18. The process of batch fermentation ran properly. On the third day, biogas yield increased intensively. This was caused by hydrolysis of biomass in fermentation bed. On day 23 a sudden drop in biogas yield took place, which was connected with completion of the methanogenic phase.

In the fermenter with the fraction of rosettes of non-shredded leaves with an ensiling agent, the obtained biogas contained the highest amount of methane no sooner than on day 12, reaching 50% (Figure 4). That content remained at that level only for several days, after which time it decreased slightly and increased again. Percent level of methane obtained during the study is close to the data provided in source literature.

When analyzing the course of fermentation (Figure 3), it is visible that the fermenter with silage from shredded beet rosettes without the addition an ensiling agent obtained a much higher amount of biogas compared with other samples tested. When analyzing the chart, it becomes apparent that biogas yield was obtained on the second day in this sample, which means that fermentation ran properly. This indicates that this fraction is the most effective since no fibrosis of the batch mass took place. The sample reached the highest amount of biogas on the fifth day of measurements, reaching 3,008 (Nml). The obtained results as well as literature indicate that shredding of the substrate has a great effect on biogas yield as finer particles have a larger surface area on which enzymes work.

Analysis of the amount of biogas emitted from the substrate made of silage from non-shredded rosettes of sugar beet leaves showed that it was comparable to the silage made of shredded sugar beet leaves without an ensiling agent. The highest biogas yield was observed on the eighth day. Results from the study conducted in laboratory conditions indicate that emission of biogas from this fraction also took place on the second day. The highest observed yield was 2,957 (Nml). The amount of emitted biogas is slightly lower than that of biogas obtained from the substrate made of shredded rosettes without an ensiling agent, which means that shredding affects the amount of biogas obtained.

Figure 4 shows percentage content of methane in biogas from individual batches prepared from the sugar beet rosette. In all substrates, methane level increased intensively from day 4 to day 11, whereas on the following days methane remained at a level of 52% until completion of the study. In the fermentation chamber with a batch of shredded leaves without the addition of an ensiling agent, the highest share of methane content (58%) was observed between day 12 and 23. The highest share of methane (51%) in the emitted biogas was recorded for the batch made of ensiled whole leaf rosettes without the addition of ensiling agents.

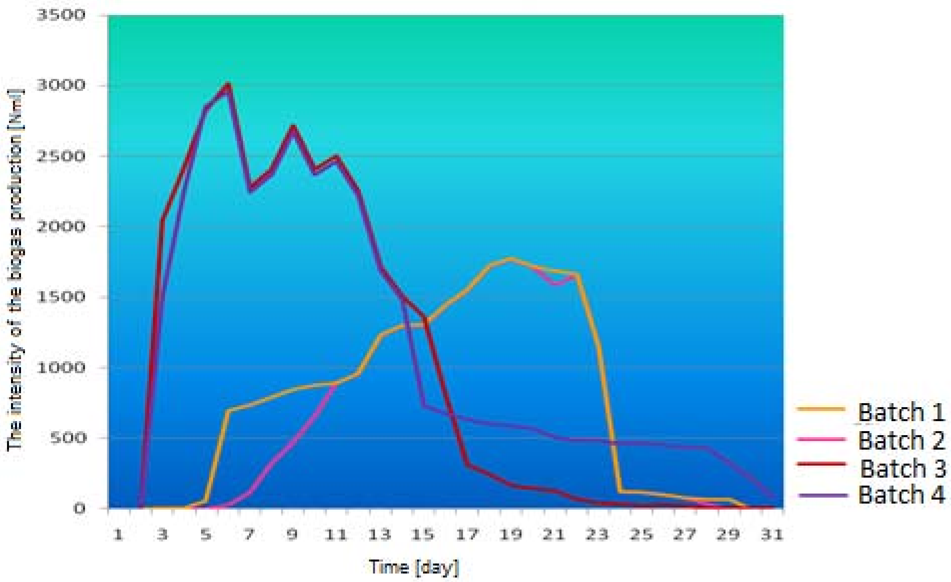

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Fig. 3. The increase in daily emission of biogas
Rys. 4. Przyrost dobowy wydzielanego biogazu

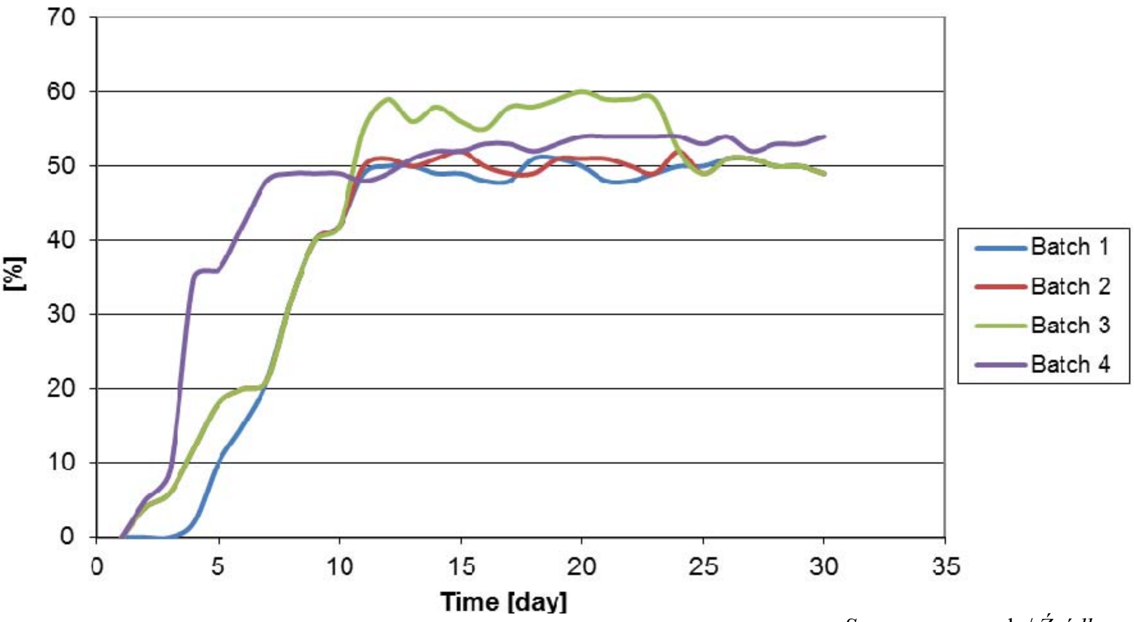

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Fig. 4. Methane content in emitted biogas
Rys. 4. Zawartość metanu w wydzielanym biogazie

4. Conclusions

1. Substrates composed of silages from sugar beet rosettes without ensiling agents fermented better. In addition, a higher methane content was obtained in them than in substrates made of silages with ensiling additives.
2. The drawback of storing biomass of sugar beet leaves with ensiling agents is their fibrous form, which renders them less useful for methane fermentation.
3. The use of the rosette of sugar beet leaves, which is a byproduct of sugar production, can be successfully used for the purposes of methane fermentation. The quantity and quality of emitted biogas suggest that it can be used to propel piston generators.

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