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BIOGAS PRODUCTION FROM CORN SILAGE AND APPLE POMACE

Summary

The objective of the paper was to determine the amount and quality of the obtained biogas on the fermentation medium from the selected substrates of agri-food industry. The need to reduce the use of traditional energy and the growth of interest in RES is related to searching for alternative energy sources. To some extent they are to secure the national energy economy. Biogas installations are the only solution which may be used mainly due to possibilities related to resources. The use of various fermentation media will provide an opportunity to increase energy production and at the same time will give a chance to reduce waste from industry, which may be used as a medium for the process. Results of analysis for the set up fermentation medium (corn silage and apple pomace) prove that the highest generation of methane was 61% and the highest daily biogas yield from the chamber took place on the ninth day of the process.
***Key words**: fermentation medium, biogas, potential, corn silage, apple pomace, productivity, biogas production*

RODZAJ I STRUKTURA PODŁOŻA FERMENTACYJNEGO A WIELKOŚĆ WYDZIELANEGO BIOGAZU

Streszczenie

Celem pracy było określenie ilości oraz jakości biogazu uzyskanego na podłożu fermentacyjnym z wybranych substratów przemysłu rolno-spożywczego. Z konieczności ograniczenia wykorzystywania energii konwencjonalnej a zarazem wzrostem zainteresowanie OZE prowadzone są poszukiwania alternatywnych źródeł. Mają one w pewnym stopniu zabezpieczyć krajową gospodarkę energetyczną. Instalacje biogazowe są jednym z rozwiązań, jakie można wykorzystać przede wszystkim z uwagi na możliwości surowcowe. Wykorzystywanie różnorodnego podłoża fermentacyjnego da możliwość zwiększenia produkcji energii a zarazem da możliwość zredukowania odpadów z przemysłu, który może zostać wykorzystany jako substrat do procesu.
***Słowa kluczowe**: podłoże fermentacyjne, biogaz, potencjał, kiszonka z kukurydzy, wytłoki jabłkowe, wydajność, produkcja biogazu*

1. Introduction

Industrial revolution and development of civilization have led to troublesome climatic changes [1]. It causes the increase of energy consumption. This phenomenon is particularly noticeable in developing countries. Traditional methods of energy production are based on fossil fuels which resulted in excessive emission of greenhouse gases [9].

Production and energy use of agricultural biogas is presently one of the most favourable methods of obtaining renewable energy. However, it has not been widely used in Poland so far [5].

Biogas for energy purposes may be obtained in three types of installations: in agricultural biogas plants, fermentation chambers of sludge, municipal sewage treatment plants and installations that degas municipal landfills [2]. Generally each type of plant biomass may be used in the process of biogas production [3].

Agricultural production of biomass for energy purposes constitutes a competition for food production due to limitation of the crop area designated for food and fodder for farm animals. The problem of such competition does not occur in case of biogas if it is produced from by-products of agriculture which cannot be consumed or used for other purposes, and not from energy plants [4]. Variability of the medium very positively influences the fermentation process since, inter alia, wastes of the food industry are a cheap raw material for biogas plants and their diversity causes that they are available through the entire year. Agricultural biogas plants are designated for management of animal waste including: liquid manure and manure, animal waste (e.g. silage) and remaining after the processes of food production (e.g. fruit and vegetable) [6]. During processing of raw materials in fruit and vegetable industry, post-production waste and sewage is being formed. The amount of waste produced from fruit and vegetables processing is within 10-35% of the mass of the processed raw material [7]. The biggest participation in the formed waste is in case of pomace. A great mass of pomace which is produced in a short time constitutes a problem for processing plants. Fast processing of the produced pomace could be a solution for this problem [8]. The objective of the paper was to determine the composition and amount of biogas produced during methane fermentation of the medium composed on substrates from agri-food industry. Corn silage from target plantation and apple pomace in the form of waste from apple juice production, were selected for co-fermentation.

2. Material and methods

The main objective of the paper was to determine a fermentation medium based on substrates from agri-food industry and the amounts and quality of biogas which may be obtained in the methane fermentation process made on the medium consisting of two substrates. Laboratory research was carried out in the biogas laboratory in the Department of

Production Engineering and Power Energy of the University of Agriculture in Krakow. Ensiled chaff of whole plants and apple pomace were used in the research. The selected substrate for the process was made in the 50/50% variant.

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A biogas yield was defined during research and then tests on the biogas quality were carried out, where the amounts of CH_4, CO_2, O_2 and H_2S were calculated. The beginning of research consisted in obtaining material. Then, a percentage relation of substrates, the amount of dry mass in a sample was determined with the use of moisture analyser Mac by Radwag with precision of 0.01%. When dry mass was determined in a sample, the amount of the fraction mass was calculated which should be collected so that dry mass of the medium constitutes 10% in a digester. The collected fractions for research are weighted on a laboratory scale WPE 300 with precision of ±0.01 g. The next step includes the process of defragmentation and material hydration to the moisture of approx. 90% creating thus optimal conditions for development of mesophile bacteria. Medium composed on corn silage and apple pomace in the organic mass proportion of 50 to 50% was divided into 5 batches and placed in six chambers where one chamber fermented only with inoculum. The prepared batch was introduced to the fermentation chamber where the fermentation processes were carried out. During the tests, measurements of the volume of the produced biogas were read out two times a day at the same moment of a day from the moment of placing a batch in a digester to the moment when the fermentation process was finished. The analysis of biogas composition and fermentation parameters was recorded automatically by the Computer Measuring System.

When the process was finalized the necessary readouts were taken from devices. It gave an opportunity to present biogas yield from the selected fraction and to determine a percentage yield of components which were noticeable during the process.

3. Research results and discussion

The need to search for new energy sources generates the need to find such a process that its execution would bring an expected effect and the cost of realization would be profitable and mainly would allow generation of profit. In the research which was carried out an attempt of using waste from agri-food industry was made. In biogas installations, the use of various substrates positively influences the process which takes place. The use of waste as a substrate would give a basis to maintain a sustainable process throughout the entire year.

In the presented sample (Table 1) apple pomace had moisture at the level of 67%. While corn silage was at the level of 80%. Nonetheless, it should be mentioned that in the moisture tests this was at the level of ca. 80%. It resulted from high amount of seeds in a sample and freshness of material and the period of yield and storage.

Table 1. Properties of corn silage and apple pomace in relation 50 to 50%

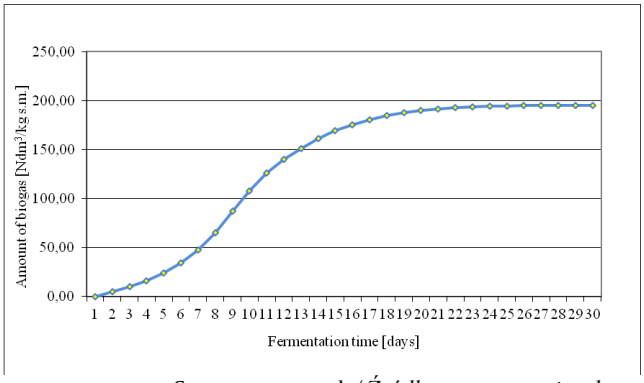
Tab. 1. Właściwości kiszonki z kukurydzy oraz wytłoków jabłkowych w stosunku 50:50%

Substrates	Dry mass [g]	Batch mass [g]	Moisture samples [%]
Fermented dry mass	200	783	hydration to the moisture of approximately 90
Maize silage	100	467	78.57
Apple pomace	100	300	66.63

Source: own work / Źródło: opracowanie własne

In the initial stage one may notice a sudden biogas increase. Only from the twentieth day this increase was slow and slight. The entire process was gradual and without disturbances to the end of fermentation. The highest total biogas yield in this sample was 195 $Ndm^3 \cdot kg\ s.m.^{-1}$ (Fig. 1).

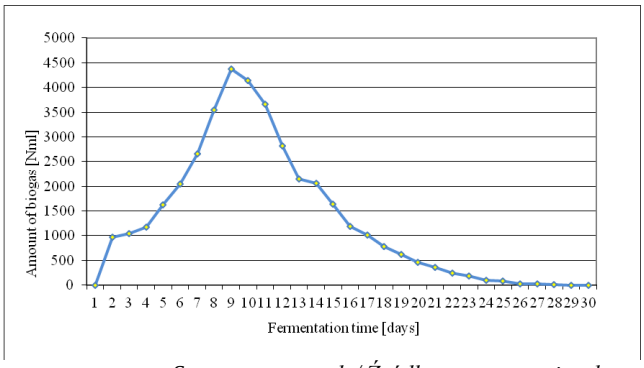
Fig. 2 presents the highest daily biogas yield which was reported in the 9th day of fermentation.



Source: own work / Źródło: opracowanie własne

Fig. 1. Total yield of biogas from corn silage and apple pomace in proportion 50/50%. Unit (Ndm^3) stands for measurement of biogas measurement from methane fermentation at the atmospheric pressure

Rys. 1. Sumaryczny uzysk biogazu z kiszonki z kukurydzy oraz wytłoków jabłkowych w stosunku 50:50%. Jednostka (Ndm^3) oznacza pomiar objętości biogazu wydzielanego podczas fermentacji metanowej przy ciśnieniu atmosferycznym



Source: own work / Źródło: opracowanie własne

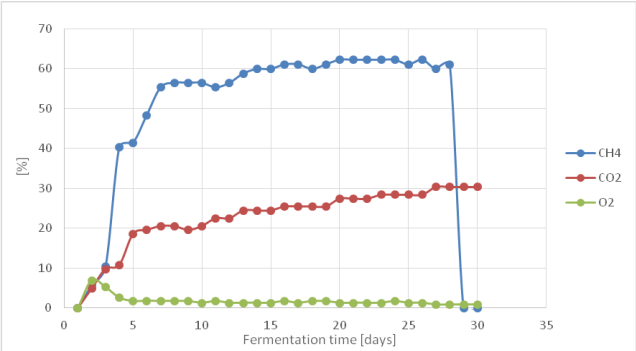
Fig. 2. Daily biogas yield from corn silage and apple pomace in proportion 50/50%

Rys. 2. Dobowy uzysk biogazu z kiszonki z kukurydzy oraz wytłoków jabłkowych w stosunku 50:50%.

The beginning of the process was very sudden with high biogas increase. When the highest value was achieved, values started to decrease to absolute end of fermentation.

In such case, a dehydration phase is very fast since particles from co-substrate, in this case apple pomace, dissolve in liquid faster and are available for fermentation bacteria, in the first days of fermentation when there is no feed from the apple pomace fraction, available mass from corn silage occurs.

Fig. 3 shows that the yield of particular biogas components started to grow from the second day of fermentation. As early as on the third day, methane achieved a satisfactory level and then was increasing systematically to the 28th day after which it suddenly dropped to zero. Oxygen suddenly grew in the first day of fermentation. Then, after the third day of fermentation it started to decrease its amount and was more or less at the same level to the moment when fermentation ended. The obtained results of the analysed gases in the biogas mixture separated from methane fermentation of the medium made on the basis of corn silage and apple pomace in the 50/50 proportion do not constitute a total one hundred percent composition since they refer to the percentage participation of the volume of particular components. In order to present the total volumetric composition of the biogas mixture one should describe moisture of gas and other trace gases which occur in the mixture. A measuring device of the biogas composition (Nanosens 70) based on which the composition of the produced biogas was determined, indicates the value of hydrogen sulphide in (ppm); the read out of these values was not presented in Fig. 3 since the value of the read-out indications would not be visible in the percentage scale. During measurements, the measuring device showed on average 270 ppm of hydrogen sulphide in the research period.



Source: own work / Źródło: opracowanie własne

Fig. 3. Percentage yield of biogas elements from corn silage and apple pomace in 50/50% proportion
Rys. 3. Procentowy uzysk biogazu z kiszonki z kukurydzy oraz wytłoków jabłkowych w stosunku 50:50%.

4. Conclusions

Presently, installations which use co-fermentation, namely a mixture of several substrates, are the most often used. Diversification of substrates favours obtaining better biogas parameters and increases safety of raw material supplies. Batch for biogas production should be selected also on account of maximization of biogas yield, stability of the fermentation process and possibility of using the post-fermentation mass.

Results of analysis of the fermentation medium made of corn silage and apple pomace show that the highest methane generation was 61%. The highest level of carbon dioxide was approximately 30%.

The highest daily biogas yield from the chamber took place on the 9th day of the process. The sample efficiency achieved the value of 4460 Nml.

After the initial tests, one may state that by-products of agri-food industry, namely pomace, may serve as a substrate for biogas plants and may be an alternative in comparison to other substrates.

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