Annals of Warsaw University of Life Sciences – SGGW
Agriculture No 68 (Agricultural and Forest Engineering) 2016: 81–86
(Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 68, 2016)

The potential for biogas production using selected substrates of the agri-food industry

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Abstract: *The potential for biogas production using selected substrates of the agri-food industry.* The aim of the work is to determine the potential for biogas production using selected substrates of the agri-food industry. Due to increase in interest in the renewable sources of energy and the necessity to limit use of conventional energy, alternative energy sources are sought, which would, to a certain extent, secure the domestic energy sector. Biogas production is one of the solutions that can be used, taking into account the raw material opportunities. Use of various fermentation media will allow for increasing energy production and reduction of industrial waste, which can be used as a substrate for the process. Conducting of such research and analyzes will allow for determination of the best variant to achieve the optimum quantity of biogas from co-fermentation.

Key words: production potential, biogas, substrate mix

INTRODUCTION

Production and use of agricultural biogas for energy production is at present one of the most advantageous methods of obtaining renewable energy, which has not been widely used in Poland so far [Pilarska 2013].

Biogas for energy production can be obtained from three types of installations: agricultural biogas plants, sewage sediment fermentation chambers, municipal sewage treatment plants and degassing installations of municipal waste dumps [Furgol and Chrobak 2008]. In the biogas production process, virtually any kind of plant biomass can be used [Fugol and Szlachta 2010]. The potential of available raw materials for production of agricultural biogas has been estimated by the Ministry of Agriculture and Rural Development to amount to 2.0–5.5 billion m^3 in total. It comes mainly from special crops and remnants – 1.9 billion m^3, meadows and pastures – 1.7 billion m^3 and byproducts of agricultural production – 1.5 billion m^3. Biogas is characterized by a substantial base of raw materials, which can be used to obtain it. It consists of bio-waste of animal origin and products and bio-waste of plant origin [MRiRW 2009].

Agricultural biogas plants are used to manage waste of animal origin, including: manure pit and dunghill, waste of plant origin (e.g. silage) and remnants of food processing activity (e.g. fruit and vegetables) [Szlachta and Furgol 2009]. Variability of the medium exerts very positive influence on the fermentation process, as, for instance, food industry waste is a cheap raw material for biogas plants, and thanks to their diversity, they are available for the entire year. During processing of raw materials in the fruit and vegetable industry, post-production waste and sewage is created. The quantity of waste generated during processing of fruit and vegetables is within 10–35% of the mass of raw materials processed [Tarko et al. 2012]. Pomace has the largest share in the waste generated. The large quantities of pomace produced over short periods of time constitute a serious problem for processing companies. Quick processing of pomace generated could solve this problem [Tarko et al. 2009]. The objective of this work is to determine the quantity and quality of biogas, which could be obtained from the process of methane fermentation on the basis of mixes of substrates from silage and apple pomace of diversified composition.

MATERIAL AND METHODS

For research purposes, chopped corn silage and apple pomace was used. The mix of substrates for the process was prepared in two variants. The first variant was corn and pomace silage at the ratio of 25 : 75%, and the second was corn and pomace silage at the ratio of 75 : 25%.

The percentage ratio of substrates was determined, as well as the share of dry mass in the sample using analytical scales of MAC series made by Radwag of accuracy of 0.001%. The next step consisted of grinding and hydration of the raw material.

Research was conducted at the biogas laboratory of the Faculty of Engineering of Production and Power of the University of Agriculture in Krakow, where biogas yield was determined for the selected substrate mixes using the methane fermentation method. Afterwards, tests of biogas quality were conducted to determine the quantities of CH_4, CO_2, O_2 and H_2S in the volume of gas obtained using a Nanosens meter. During research, measurements were read two times in every 24 h, at the same time, from placement of the batch in fermenters until the end of the fermentation process. The results were collected using the Computer Measurement System.

RESULTS AND DISCUSSION

Analysis of the material started by inspection of its properties. The results in terms of properties of the substrates used have been presented in Tables 1 and 2. According to data provided in Tables 1 and 2, apple pomace was characterized by moisture content at the level of about 67%, and corn silage – almost 80%. This was caused by high seed content in the sample and freshness of the material, as well as the harvesting and storing period.

TABLE 1. Properties of the mix – corn silage and apple pomace at the ratio of 25 : 75%

Substrates	Dry mass [g]	Batch mass [g]	Moisture content in sample [%]
Dry mass of fraction subject to fermentation	200	783	hydration to moisture content of about 90
Corn silage	50	235	78.75
Apple pomace	150	450	66.63

TABLE 2. Properties of the mix – corn silage and apple pomace at the ratio of 75 : 25%

Substrates	Dry mass [g]	Batch mass [g]	Moisture content in sample [%]
Dry mass of fraction subject to fermentation	200	783	hydration to moisture content of about 90
Corn silage	150	700	78.75
Apple pomace	50	150	66.63

In accordance with the methodology applied, the biogas yield in 24 h from the selected mixes was determined. The results obtained are illustrated by Figure 1.

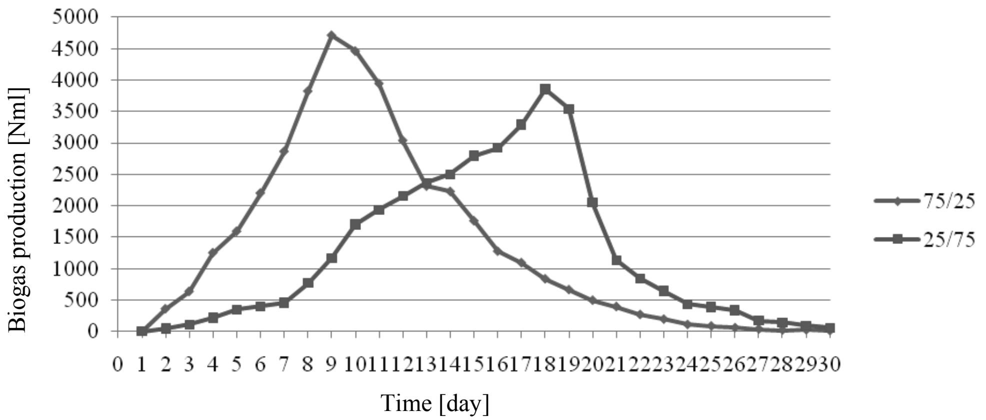

FIGURE 1. Biogas yield in 24 h from corn silage and apple pomace at the ratios of 25 : 75% and 75 : 25%

Increase in biogas yield for fraction 25 : 75% was observed already in the second day of fermentation. The suspected delay in the process was due to slow binding of water particles with the batch material examined. Analyzing the available literature [Fugol and Szlachta 2010, Fugol and Prask 2011, Sikora 2012, Kupryś-Caruk et al. 2014], it should be stated that no such case has been recorded earlier. After the delay period (starting from the seventh day), fast and rapid increase in biogas production was observed until the 18th day, when the biogas value was the highest. After this date, the efficiency values started to drop rapidly.

In the case of the substrate mix in the ratio of 75 : 25%, already on the first day of fermentation, a dynamic increase in biogas yield was observed. It kept growing systematically until the ninth day, when it achieved the highest value. After the ninth day, a decrease in biogas yield was observed until 16th day. In the subsequent period, decrease in biogas yield was slower and systematical.

The fractions analyzed were also subjected to chemical tests to examine the percentage yield of biogas ingredients. The results have been presented in Figures 2 and 3.

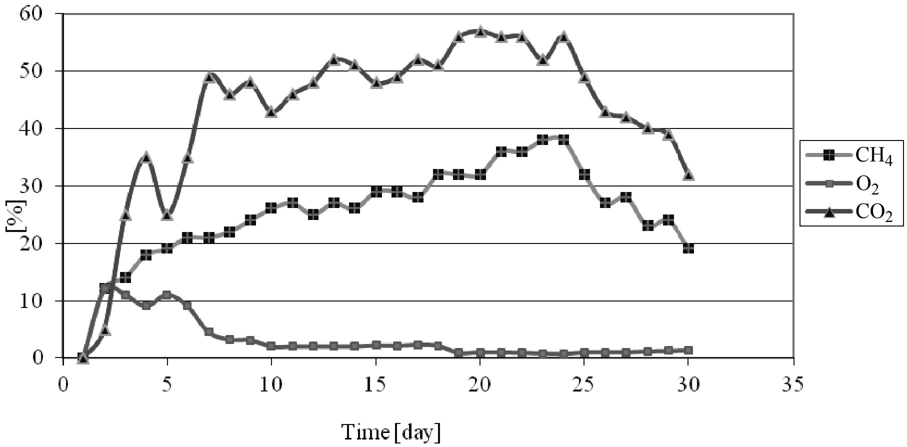

FIGURE 2. Percentage yield of ingredients of biogas from corn silage and apple pomace at the ratio of 25 : 75%

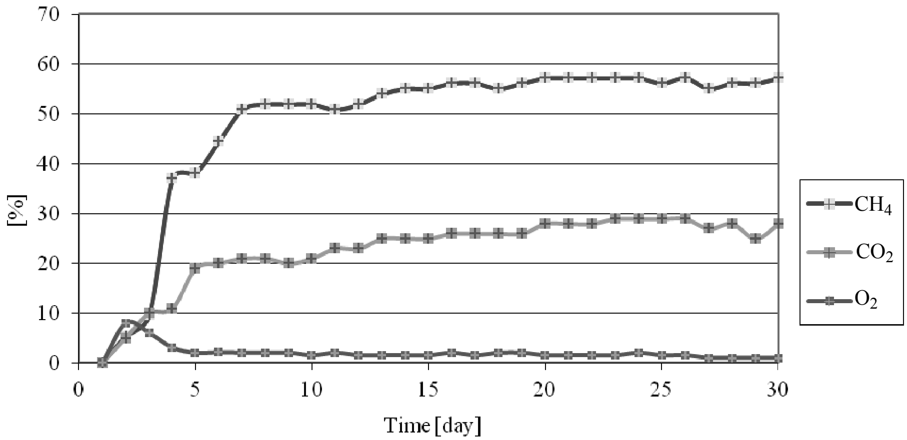

FIGURE 3. Percentage yield of ingredients of biogas from corn silage and apple pomace at the ratio of 75 : 25%

During the fermentation period, the quantity of carbon dioxide was much higher than the share of methane, which may be due to high oxygen content in the fermentation chamber, in which the batch was composed in the ratio of 25 : 75%. Oxygen content was at the level of about 2%. This oxygen is a product of intermolecular bonding. A higher oxygen content at the beginning of the fermentation process was due to oxygen release from the closed spaces in the medium. Static fermentation was assumed for research purposes, and the medium was not interfered with during the process. The maximum value of CH_4 was observed on the 24th day of fermentation, while maximum CO_2 content – on the 22th day of fermentation.

During fermentation of the mix of fraction 75 : 25%, the highest share of methane in biogas was recorded on the fourth day. In the subsequent days, the share increased systematically to reach the highest value among all ingredients. In the first seven days, carbon dioxide achieved a high level of yield of biogas ingredients; in the following days, this yield increased slowly. Despite the initial rapid increase on the second day of fermentation, in the subsequent days the content of oxygen decreased and then maintained a similar level.

CONCLUSIONS AND SUMMARY

Results of analysis of individual fractions consisting of corn silage and apple pomace show that the highest methane yield occurred in the fraction, in which the ratio of substrates amounted to 25 : 75%, since methane yield amounted to 57%. On the other hand, the highest carbon dioxide content was recorded in the fraction, in which the ratio of substrates amounted to 75 : 25%, and the share of carbon dioxide yield was 57%. The sudden increase, and then drop in the content of carbon dioxide and oxygen was caused by opening of the chamber and adding the fermentation inocula.

The highest biogas yield from the chamber in 24 h was recorded in the sample, in which the ratio of the substrate mix was 75 : 25%. The fraction yield reached 4,460 Nml. In the second fraction analyzed, in which the ratio of corn silage and apple pomace was 25 : 75%, was somewhat lower, amounting to 3,960 Nml.

After the research, it should be concluded that by-products of the agri-food industry may be used as substrates for biogas plants. Thanks to continuity of production, they would offer an alternative solution, allowing the fermentation process to be continued without having to worry about the substrate supply. With regard to the results obtained, it can be stated that the substrates chosen, as well as the ratio of their use for biogas production give satisfactory effects and thus can be used in the methane fermentation process. The same results have been indicated in other research projects [Pilarska 2014].

Research has confirmed that batches composed of corn silage and apple pomace should be combined in the ratio of 70% of corn and the remaining part – as the additional co-substrate. At such co-substrate content, we do not limit the quantity of biogas generated, and we additionally make use of waste from agri-food industry.

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Streszczenie: *Potencjał produkcji biogazu z wybranych substratów przemysłu rolno-spożywczego.* Celem pracy jest określenie potencjału produkcji biogazu z wybranych substratów przemysłu rolno-spożywczego. Z uwagi na wzrost zainteresowania odnawialnymi źródłami energii oraz koniecznością ograniczenia wykorzystywania energii konwencjonalnej poszukiwane są alternatywne źródła, które będą w pewnym stopniu zabezpieczać krajową gospodarkę energetyczną. Produkcja biogazu jest jednym z rozwiązań, jakie można wykorzystać z uwagi na możliwości surowcowe. Wykorzystywanie różnorodnego podłoża fermentacyjnego da sposobność zwiększenia produkcji energii oraz zredukowanie odpadów z przemysłu, który może zostać wykorzystany jako substrat do procesu. Prowadzenie takich badań oraz analiz umożliwia określenia najlepszego wariantu do uzyskiwania optymalnej ilości biogazu z kofermentacji.

MS received September 2016

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