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PRELIMINARY COMPARISON OF BIOGAS PRODUCTIVITY FROM MAIZE SILAGE AND MAIZE STRAW SILAGE

Summary

The paper presents the comparison of biogas and biomethane production efficiency from maize silage (as typical biogas plant substrate) and maize straw silage in order to estimate the possibilities of maize straw application for biogas production. The experiment of biogas production was conducted in the 21-chamber biofermentor at the Institute of Agricultural Engineering. The results show that methane fermentation of typical maize silage can generate over 40% of biogas volume comparing with silage obtained from maize straw (calculated in dry matter of the substrates). However, because of the high market price of maize silage, usage of maize straw silage as a substrate for agricultural biogas plants can be more even interesting from economic point of view than typically used maize silage produced from whole maize plants.

WSTĘPNE PORÓWNANIE PRODUKTYWNOŚCI BIOGAZU Z KISZONKI KUKURYDZY I KISZONKI ZE SŁOMY KUKURYDZIANEJ

Streszczenie

W pracy zaprezentowano wstępne wyniki badań nad efektywnością zastosowania jako substratu do biogazowni kiszonki z kukurydzy oraz kiszonki ze słomy kukurydzianej. Do badań użyto mieszanki kiszonek z gnojowicą świńską i dodatkiem zaszczepki fermentacyjnej. Badania przeprowadzono z wykorzystaniem 21-komorowego biofermentora znajdującego się w laboratorium Ekotechnologii Instytutu Inżynierii Rolniczej UP w Poznaniu. Stwierdzono, że wydajność biogazowa typowej kiszonki z kukurydzy jest o ponad 40% wyższa niż kiszonki ze słomy kukurydzianej. Biorąc jednak pod uwagę fakt, że cena rynkowa kiszonki z kukurydzy osiąga poziom 100 zł/tonę i jest ponad 2 razy większa od kosztu wyprodukowania kiszonki ze słomy kukurydzianej, zastosowanie tego drugiego materiału jako substratu do biogazowni wydaje się ekonomicznie uzasadnione.

1. Introduction

For the past decades, rapid depletion of fossil fuel resources and gradual climate changes resulting from excessive greenhouse gases emissions have increasingly attracted people's attention, worldwide. In order to achieve sustainable development, comprehensive utilizations of renewable resources, efficient energy production and the reduction of energy consumption have become our major tasks [1]. Anaerobic digestion is a very mature technology which has been widely applied for the treatment of organic waste, such as livestock manure, organic fraction of municipal solid waste and sewage sludge [2]. When converted into biogas by anaerobic digestion, corn stalk will reduce the adverse impact on the environment as well as consumption of fossil fuel [3]. What is also important, the anaerobic digestion of the biowaste offers the advantage of both a net energy gain by producing methane as well as the production of a fertilizer from the residuals [4].

In several countries i.e. in Denmark or China waste management is one of the main ways to biogas production [5]. However, in Europe mostly the main substrates for biogas plants are plant materials. Maize is the most dominating crop for biogas production and is considered to have the highest yield potential of field crops grown in Central Europe [6]. Maize stover is the stalks, leaves, husks, tassels, and cobs of the corn plant remaining after removal of the corn kernels. This material is heterogeneous; the composition of each anatomical fraction is slightly different, and each fraction is known to respond differently to enzymatic cellulose hydrolysis [7].

There is a difference between maize usage for energetic (biofuels) purpose between Europe and USA. In the last 15 years, maize has been used as raw material mainly for bioethanol production.

The biogas plant development in Central Europe has created the growth of maize silage price and sometimes – deficit of this substrate on the local markets (case of East Germany where the maize silage is imported from Poland for sometimes 200-400 km). That is why the alternative materials used as co-substrates for biogas plant have to be used in the nearest future. In Poland, because of large area of maize grain production, the maize straw seems to be on of the best alternative substrate of biogas production [9].

2. Aim of the research

The aim of the work is to compare the efficiency of biogas and biomethane production between maize silage (as typical biogas plant substrate) and maize straw silage in order to estimate the possibilities of maize straw application for biogas production.

3. Materials and methods

The experiment was carried out from November 2009 to July 2010. Maize straw was collected in November 2009 from field after harvesting the grains. ThEn maize was cut and used for silage process in 10-liters containers. Typical bacteria additives were used in order to accelerate the silage process. However, for the described experiment, maize silage was taken from real windrow filled in with maize silage in the cow farm placed near Poznań.

The experiment of biogas production was conducted in a 21-chamber biofermentor (Fig. 1) at Eko-technology Laboratory within the Institute of Agricultural Engineering. This biofermentor is commonly used for testing biogas efficiency for large amount of biomass samples [10].

General rules for biofermentor work were based on the fermentation of organic substrate samples which were put in the chambers with 2 dm^3 capacity. Without oxygen presence and additive of fermentational inoculum (10% of total volume) the conditions present within the fermentation chamber let to create an ideal condition for methane fermentation of the samples. Glass chambers with samples were placed in water with regulated temperature (usually 38^oC) which accelerated fermentation process and helped to imitate the real conditions of biogas plant. Biogas produced in each separate chamber was transferred to cylindrical store – equalizing reservoirs, filled in with liquid. The samples were tested in 3 replications.

Both silage samples from whole maize plants (MS) and maize straw (MSS) were solved with poor pig slurry (3,54% of d.m.) in order to achieve the dry matter content on the level of 9%. The net results of maize samples production were calculated by reduction from the totally produced biogas volume the volume produced only from slurry and inoculum which was tested additionally in the same time during the experiment.

Biogas composition was measured using gas analyzer with chemi-electric sensors. The typical analysis of physical (dry matter, organic matter) and chemical (total and ammonia nitrogen, pH, conductivity, organic carbon, C:N ratio) parameters were made at start and at the end of the experiment.

4. Results

The experiment showed that in both kinds of materials, the biogas emission was intensive within first 50-60 days. However, from the first days of experiment, a clear difference between maize silage (MS) and maize straw silage (MSS) fermentation was observed (fig. 2).

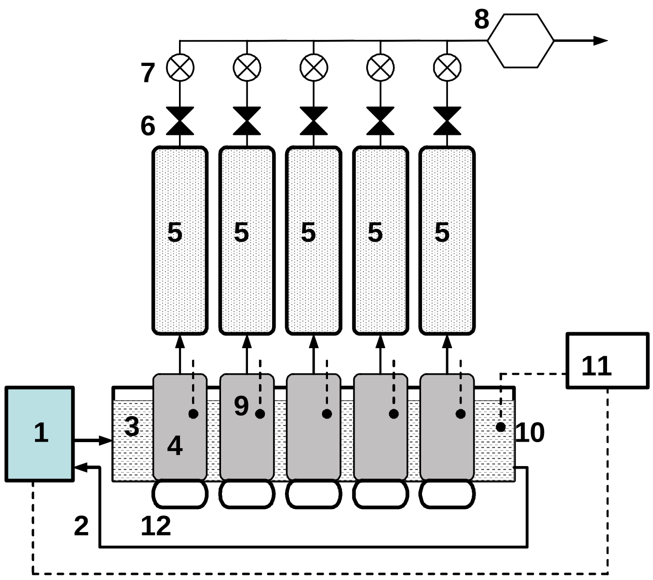

Fig. 1. Scheme of biofermentor for testing biogas production (5-chamber section): 1. Water heater with temperature regulator, 2. Insulated conductors of calefaction liquid, 3. Water coat with temp. 36-38°C, 4. Biofermentor with charge of capacity 2 dm^3, 5. Biogas reservoir, 6. Cutting off valves, 7. Gas flow-meters, 8. Gaseous analyzers (CH_4, CO_2, NH_3, H_2S), 9. pH sensors, 10. Temperature sensor, 11. Steering – recording central station, 12. Magnetic mixers of charge

Rys. 1. Schemat biofermentora (sekcja 5-komorowa): 1. Ogrzewacz wody z regulatorem temperatury, 2. Izolowane przewody cieczy ogrzewającej, 3. Płaszcz wodny o temp. 36-38^oC, 4. Biofermentor z wsadem o pojemności 2 dm^3, 5. Zbiornik na biogaz, 6. Zawory odcinające, 7. Przepływomierze gazowe, 8. Analizatory gazowe (CH_4, CO_2, NH_3, SH_2), 9. Sensory pH, 10. Sensor temperatury, 11. Centrala sterująco-rejestrująca, 12. Mieszadła magnetyczne wsadu

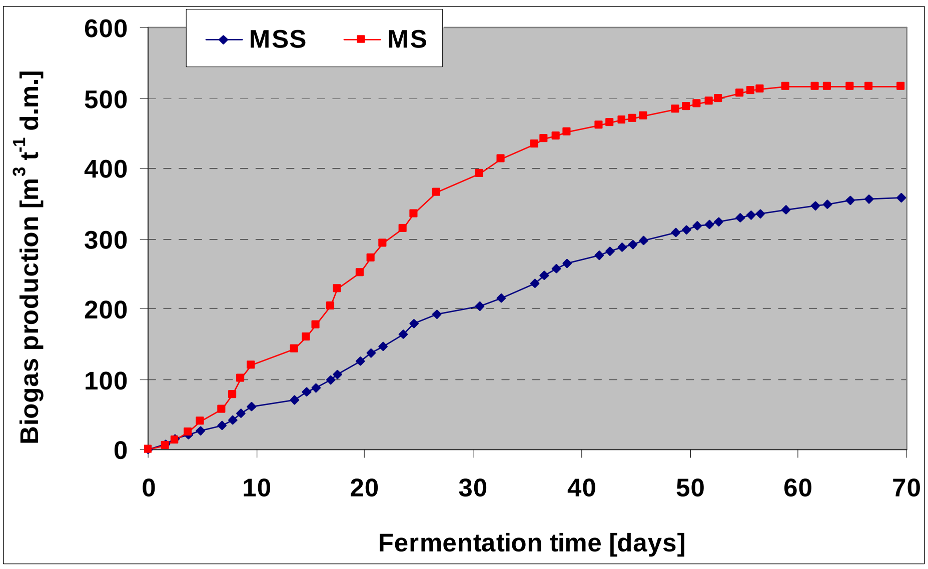

Fig. 2. Cumulative production of biogas from maize straw silage (MSS) and maize silage (MS) calculated for 1 ton of dry matter

Rys. 2. Skumulowana produkcja biogazu z kiszonki ze słomy kukurydzianej (MSS) i z kiszonki z całych roślin (MS) obliczona dla 1 tony suchej masy

The total production of biogas from maize straw samples reached 516 m^3 from 1 ton of dry matter. However, for maize straw silage the total production of biogas was 44% lower and reached 358 m^3. The content of methane was relatively similar because in average was 56 and 54%. This result was unexpected because we thought to receive rather a little bit higher content of methane from maize silage samples. The total methane production from 1 ton of dry matter was respectively 199,5 (MSS) and 277,5 m^3 (MS) (fig. 3).

For a better analyse of biogas and methane production, the total gas production was calculated in reference to the organic matter of the samples (volatile organic compounds – VOC). Results are presented in Fig. 4.

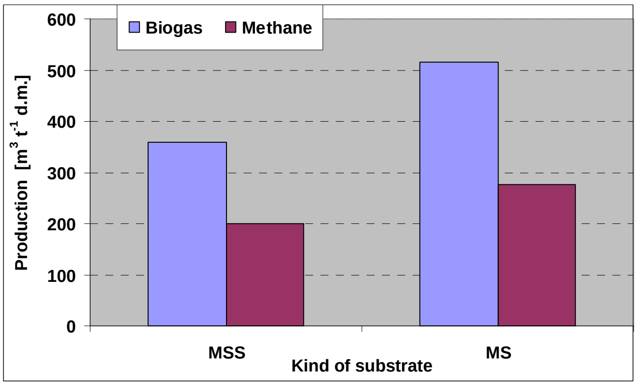

Fig. 3. Comparison of biogas and methane production from analyzed samples
Rys. 3. Porównanie produkcji biogazu i metanu z badanych próbek

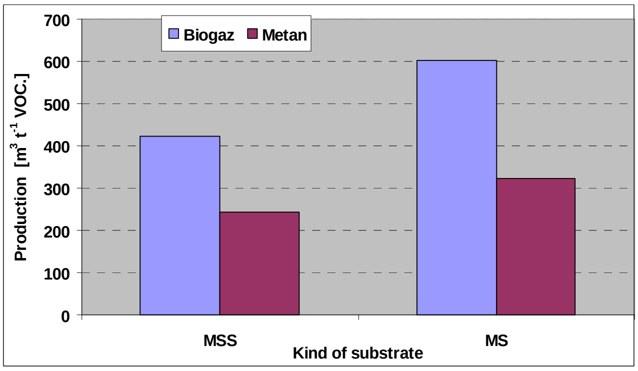

Fig. 4. Comparison of biogas and methane production from analyzed samples calculated from 1 ton of VOC
Rys. 4. Porównanie produkcji biogazu i metanu z badanych próbek w przeliczeniu na 1 tonę materii organicznej

Results show that efficiency of biogas production is over 40% higher from typically produced maize silage comparing with the silage obtained from maize straw. From this point of view use of maize straw seems to be not very attractive. However, if we compare the production costs of both substrates, the situation changes completely. In Western Poland the price of maize silage has been growing continuously within last years and reached actually 90-100 PLN (23-25 euro) because of high export to German biogas plants. However, cost of maize straw harvest and storage can be at least 50% lower. Comparing with 40% lower biogas efficiency obtained in this research we can conclusion that the use of maize straw silage can be even more interesting from economic point of view than typically used maize silage produced from the whole plants.

5. Conclusions

1. Methane fermentation of typical maize silage can generate over 40% of biogas volume comparing with silage obtained from maize straw (calculated in dry matter of the substrates).
2. The effective time of retention for untreated both maize and straw maize silage is 60 days.
3. Because of the high market price of maize silage, the use of maize straw silage as a substrate for agricultural biogas plants can be more interesting from economic point of view than typically used maize silage produced from whole plants.

6. Literature

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