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Biogas production with the use of mini digester

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ABSTRACT

Purpose: of this paper is to present the construction of a mini digester for biogas production from different energy plants and organic wastes. With the mini digester the amount of biogas production (methane) is observed.
Design/methodology/approach: Firstly, the mini digester consisting of twelve units was built and secondly some measurements with energy plants were performed. The measurements were performed with mini digester according to DIN 38414 part 8. Four tests simultaneously with three repetitions can be performed.
Findings: The mini digester was built and then parameters such as biogas production and biogas composition from maize and sugar beet silage were measured and calculated. The highest biogas and methane yield was 493 NI kg VS^{-1} or 289 NI CH_4 kg VS^{-1}.
Research limitations/implications: The interest in the use of the biogas as a renewable source of energy is increasing and also the scope of substrates for the anaerobic digestion process is on the increase. With the mini digester it is possible to observe the amount of biogas (methane) production and thus the most suitable plant, giving the maximum methane yield, can be determined.
Practical implications: The biogas is a renewable source of energy. On big farms the liquid manure and different energy plants can be used for biogas production. That can improve the economical efficiency of the farm and reduce the CO_2 emissions.
Originality/value: For biogas production a special device, the mini digester, was built. The composition of produced biogas is determined with the gas analyser GA 45.
Keywords: Technological devices and equipment; Mini digester; Biogas, Energy plants

1. Introduction

The Biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits [1] and is an additional source of income for farmers. Renewable energy is produced. Nearly two-thirds of renewable energy sources in the European Union stem from the biomass, including wastes. The principle of a closed circuit is strengthened, because particularly the nitrogen is being hold stronger in the system [2]. Methane emissions during manure storage are reduced and the fertiliser quality of the digestate is high. Suitable substrates for the digestion in agricultural biogas plants are different energy crops, organic wastes, and animal manures. Maize (Zea mays L.), herbage (Poacae), clover grass (Trifolium), Sudan grass (Sorghum sudanense), fodder beet (Beta vulgaris) and others may serve as energy crops. The predominant crop for biogas production is maize. Maize is considered to have the highest yield potential of field crops grown in Central Europe [3]. Biogas is a product of the metabolism of methane bacteria and is created when the bacteria decompose a mass of organic material.

The methane bacteria can only work and reproduce if the substrate is sufficiently bloated with water (at least 50%). In contrast to aerobic bacteria, yeasts and fungi they cannot exist in a solid phase.

Economic efficiency of anaerobic digestion depends on the investment costs, on the costs for operating the biogas plant and on the optimum methane production [1, 4].

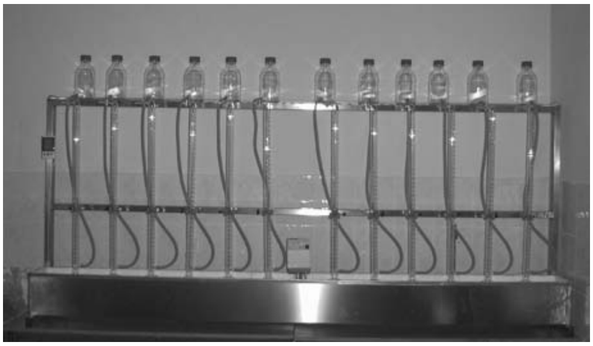

Fig. 1. Mini digester for biogas production

The European Union has made a commitment to reduce its emissions by 8% in 2010 compared to 1990. Coal, natural gas and oil fired energy production plants are major contributors to CO_2 emissions in the atmosphere. Mitigating the current trend of increasing CO_2 emissions relies on taking measures to reduce final energy consumption, to encourage a more rational use of primary energy sources and to exploit renewable energy sources more intensively. Specific measures have been taken at the European level to encourage the production of electricity from renewable sources (‘‘green electricity’’). Several countries have implemented a ‘‘green certificates’’ market in order to support this production. In such a market, green certificates are issued by a regulating authority to the green electricity producers. The producers can then sell them to electricity distributors. As the latter need to acquire green certificates up to a certain percentage of the electricity sold to final customers, and as there are penalties for electricity distributors with insufficient green certificates, supply and demand in the green certificates market determine their price [5-7].

2. Description of the approach, work methodology, materials for research, assumptions, experiments etc.

2.1. Construction of mini digester for biogas production

The mini digester, used for laboratory tests, comprises twelve gas cells. Each cell consists of a reaction vessel (500 ml fermenter) and a well closed gas pipe. The gas pipe - eudiometer contains the confining liquid and is of 350 ml size. It is connected to the levelling vessel with solution. The bio gas produced in fermenters supplants the confining liquid in the gas pipe into the outside levelling vessel of 750 ml volume. The gas produced is read on the gas pipe. The fermenters are submerged into water with constant temperature 35+/-1 degrees C and are connected with the glass gas pipe. The biogas produced contains 50 - 75% of methane, 10 - 40% of carbon dioxide and other matters (H_2, H_2S, N_2, NH_4,...). The exact composition is determined by the gas detector. Figure 1 shows the entire structure (mini digester) for biogas production for laboratory purposes.

The basic structure of the mini digester is made of stainless steel (inox), it is 2500 mm long, 1000 mm high and 350 mm wide. At the top a shelf is provided on which there are the levelling vessels for surplus confining liquid. At the bottom, a trough 2500 x 200 x 200 mm lined with insulating material is provided to prevent excessive heat losses and to enable the fermenters to be in the dark. In the trough a heating pump, ensuring constant temperature and water circulation, is placed beside the eudiometers. Thus, as uniform water temperature as possible is reached over the entire trough. The eudiometers are fixed to a metal beam above the structure, so that they can not overturn and that they can be removed and fixed as easily as possible for test purposes. A thermometer and a barometer measuring, through a sensor, the water temperature in the trough and separately the adjacent air temperature are fixed on the left side of the steel structure [8-10].

The mini digester serves to produce the biogas from various energy plants and other organic waste material. It consists of twelve units so that three tests with three repetitions simultaneously are possible, whereas three units serve for the control. During the test the biogas production must be read daily. The volume produced is let out in case of each reading, each day at the beginning of test, later on every two or three days, when the gas formation diminishes. The gas composition is measured by gas detector Geotechnical Instruments GA 45 [11-13].

2.2. Maize and sugar beet for anaerobic digestion

Whole maize and sugar beet crops in certain ratio were anaerobically digested and biogas yields and biogas composition were measured and compared. Maize and sugar beet were chopped after harvest and then mixed in certain ratios, prior to the ensiling process. Particle size was 2.0–4.0 mm. Three experiments with maize and sugar beet mixed in different ratios and their dry matter are shown in Table 1. Substrates were analysed prior to digestion for pH, dry matter, crude protein, crude fibre, starch, crude fat, ash and C/N ratio with standard analysing procedures.

Table 1.
Maize and sugar beet mixed in different ratios

Sample	Sample in certain ratio	Dry matter (%)
1	50% sugar beet + 50% maize	25.1
2	75% sugar beet + 25% maize	21.3
3	25% sugar beet + 75% maize	26.2

2.3. Measuring biogas production

Substance and energy turnover during anaerobic digestion were measured in 0.5 l eudiometer batch digesters at constant temperature 35 +/- 1 degree C. Biogas yields and biogas composition from each treatment were measured in three replicates.

Measurements were conducted according to DIN 38 414 [14,15]. Mini digester consists of twelve digesters. A water bath tempers the digesters. The substrates are mixed every day for 10 min. The biogas is collected in an equilibrium vessel and the biogas production is monitored every day. Biogas production is given in norm litre per kg of volatile solids (NI (kg VS) $^{-1}$), i.e. the volume of biogas production is based on norm conditions: 273 K, and 1013 mbar. Biogas quality (CH_4, CO_2, O_2) was analysed 10 times in course of the 5 - week digestion. Each variant was measured in three replicates. Biogas production from inoculum alone was measured as well and subtracted from the biogas production that was measured in the digesters that contained inoculum and biomass.

Inoculum was received from biogas plants that digest energy crops (maize, millet) 15 grams of substrate was digested together with 385 grams of inoculum.

3. Description of achieved results of own researches

3.1. Biogas production

Figure 2 shows the biogas and methane yield in norm litre per kg of volatile solids (NI (kg VS) $^{-1}$) with standard deviation from three replicates per treatment during 5 – week digestion.

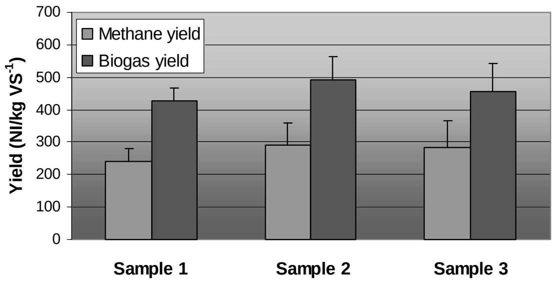

Fig. 2. Average production of methane and biogas in NI/kg VS^{-1} during 5 – week digestion

The highest biogas and methane yield was achieved in case of sample 2 (75% sugar beet + 25% maize). The highest biogas yield was 493 NI kg VS^{-1} or 289 NI CH_4 kg VS^{-1} (standard deviation of three replicates +70.2 NI biogas VS^{-1}). The lowest biogas yield was in case of sample 1 (50 % sugar beet + 50% maize), 428 NI kg VS^{-1} or 242 NI CH_4 kg VS^{-1} (standard deviation of three replicates +38.8 NI biogas VS^{-1}). Sample 3 (25% sugar beet + 75% maize) has a biogas production of 455 NI kg VS^{-1} or 282 NI CH_4 kg VS^{-1} (standard deviation of three replicates +85.7 NI biogas VS^{-1}).

Figure 3 shows biogas production of sample 1 (50% sugar beet + 50% maize) in norm litre per kg of volatile solids (NI (kg VS)$^{-1}$) during 5- week digestion.

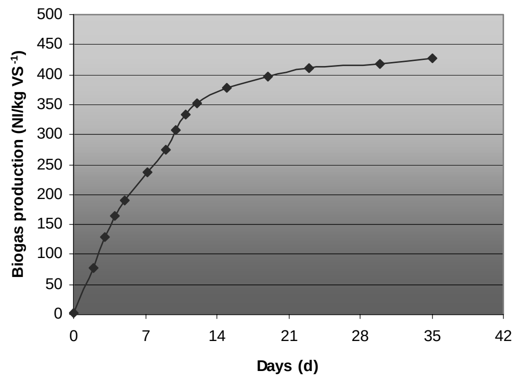

Fig. 3. Biogas production of sample 1 during 5 – week digestion

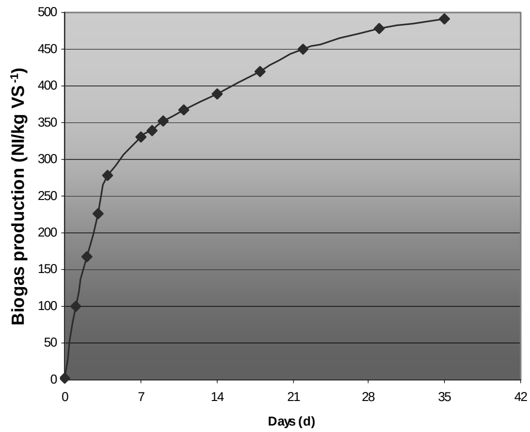

Fig. 4. Biogas production of sample 2 during 5 – week digestion

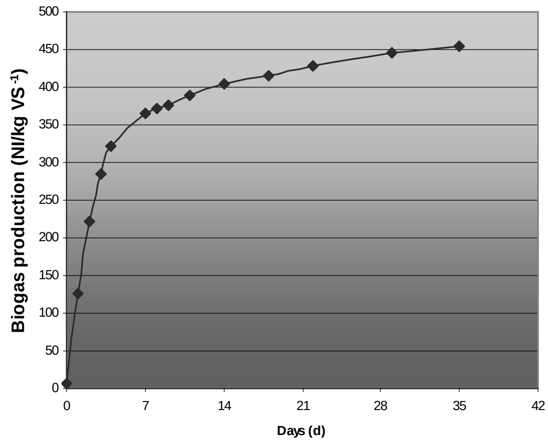

Fig. 5. Biogas production of sample 3 during 5 – week digestion

Most of the biogas is produced in the first week of the experiment, after twenty days the anaerobic digestion is mostly finished. After 35 days the amount of biogas is very low.

Figure 4 shows biogas production of sample 2 (75% sugar beet + 25% maize) in norm litre per kg of volatile solids (NI (kg VS)$^{-1}$) during 5 - week digestion.

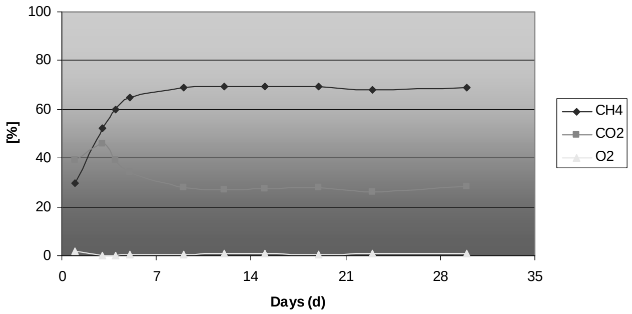

Fig. 6. Biogas quality

Figure 5 shows biogas production of sample 3 (25% sugar beet + 75% maize) in norm litre per kg of volatile solids (NI (kg VS)$^{-1}$) during 5- week digestion.

3.2. Biogas quality

Biogas quality (CH_4, CO_2 and O_2) was analysed 10 times in course of the 5 - week digestion. Figure 6 shows the biogas quality of sample 3 where the methane content ranged from 30 to 69.1% (mean: 62.1%, n = 30). The average content of CO_2 was 32.3% during 5 – week digestion. Oxygen content in the biogas was under 1%. That means that the digestion was anaerobic. The biggest differences in biogas quality occur in the first week of the digestion and then the gas content is more or less stable.

4. Conclusions

The biogas is a renewable source of energy. The biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits and is an additional source of income for farmers.

The mini digester, used for laboratory tests, was built. The mini digester serves to produce the biogas from various energy plants and other organic waste materials. Four tests simultaneously with three repetitions can be performed. Measurements were conducted according to DIN 38 414. Whole maize and sugar beet crops in certain ratio were anaerobically digested and biogas yields and biogas composition were measured and compared. Biogas quality (CH_4, CO_2, O_2) was measured by gas detector Geotechnical Instruments GA 45.

The highest biogas and methane yield was 493 NI kg VS^{-1} or 289 NI CH_4 kg VS^{-1} (standard deviation of three replicates +70.2 NI biogas VS^{-1}) in case of sample 2. The lowest biogas yield was in case of sample 1, 428 NI kg VS^{-1} or 242 NI CH_4 kg VS^{-1} (standard deviation of three replicates +38.8 NI biogas VS^{-1}). Sample 3 has a biogas production of 455 NI kg VS-^{1} or 282 NI CH_4 kg VS^{-1} (standard deviation of three replicates +85.7 NI biogas VS^{-1}).

Biogas quality (CH_4, CO_2, O_2) was on average 62.1% of CH_4, 32.3% of CO_2, O_2 content in the biogas was under 1%.

Acknowledgements

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