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BUILDING OF A MINI DIGESTER FOR MESOPHILIC ANAEROBIC DIGESTION

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Professional paper

Anaerobic digestion is the biological degradation of organic material in the absence of air and may imply environmental benefits with regard to waste treatment, pollution reduction, energy production, and improvements in agricultural practices. An anaerobic digester is a system that harnesses this natural process to treat waste, produce biogas that can be converted to heat and electricity and anaerobic digestate, a soil improving material. The paper presents the building of a mini digester for mesophilic anaerobic digestion. With the mini digester the amount of biogas production (methane) from different organic wastes is observed. The basic structure is made of stainless steel, on which other components are fixed. The most important components are the eudiometers, pump and heater with thermostat, fermenters, thermometer and barometer. The experiment is made according to DIN 38 414, part 8. After building of a mini digester some experiments with different organic materials are made.

Keywords: *Mini digester, mesophilic anaerobic digestion, organic wastes*

Izgradnja mini digestera za mezofilnu anaerobnu probavu

Strukovni članak

Anaerobna probava (digestija) je biološka razgradnja organskih materijala u nedostatku zraka i može imati ekološke prednosti u odnosu na obradu otpada, smanjenje onečišćenja, proizvodnju energije te poboljšanja u poljoprivrednoj praksi. Anaerobni digester je sustav koji obuhvaća ovaj prirodni proces za tretiranje otpada, proizvodnju bioplina koji se može pretvoriti u električnu i toplinsku energiju te anaerobni proizvod probave, materijal za poboljšanje tla. U radu je prikazana izgradnju mini digestera za mezofilnu anaerobnu probavu. Promatran je opseg proizvodnje bioplina (metana) iz različitih organskih otpada s mini digesterom. Osnovna konstrukcija je izrađena od čelika otpornog na koroziju. Na ovu konstrukciju su postavljene druge komponente. Najvažnije komponente su eudiometeri, pumpa i grijač s termostatom, fermentar, termometar i barometar. Eksperiment je napravljen u skladu s DIN 38 414, 8. dio. Nakon izgradnje mini digestera napravljeno je nekoliko eksperimenata s različitim organskim materijalima.

Ključne riječi: *Mini digester, mezofilna anaerobna probava (digestija), organski otpad*

1 Uvod
Introduction

The 21st century faces the problem of growing energy consumption and diminishing supplies of fossile fuels, which has led to researches of the use of renewable energy sources and, consequently, the development of new technological processes of energy production. One of the most efficient energy sources is the biogas produced from green energy crops and organic waste matters. The biogas has a very positive impact on the environment, since less CO_2 is formed during its combustion than used for photosynthesis by the plants from which it is produced [1, 2, 3].

The biogas is formed during anaerobic fermentation of organic matters such as: farmyard manure, liquid manure, energy crops, organic waste materials, slaughter-house waste etc. In case the degradation process takes place in accurately specified conditions, the biogas is released. In the biogas device it is possible to use any organic-biological matters whose composition changes due to the effect of microorganisms and does not contain more than 15 % of dry matter. With less than 5 % of dry matter the degradation process still takes place, but is economically not justified. The top limit of the dry matter is the limitation, where the substrate can still be pumped and mixed. It often happens that the substrate must be thinned with water as a preparatory measure, which increases the cost of operation. After completion of fermentation a separator of the liquid and solid phase of the fermented mass is used as a resource. By the return of the liquid phase a great quantity of water is saved, the transport cost is reduced and the freshly supplied substrate is enriched with the bacterial flora. The methane bacteria can not process the fats, proteins, carbohydrates in pure form. For processing they need nitro-compounds and microbic compounds which abound in the manure and animal slurry. Materials such as straw, long grass and other biological waste must be crushed, otherwise the fermentation process takes too much time (the retention time in the fermentor is prolonged very much) and the sediments on the fermentor bottom and the fragments on the surface of the fermenting mass accumulate [4, 5, 6].

The substrate consists of a mixture of animal droppings and several ensiled energy crops on which the gas profitability relies. The conditions for optimum production are limited by the anaerobic process at 35 °C (mesophilic range) and steady mixing of substrate in the digester. A covered gas-tight roof, i.e., the so-called gasometer is provided at the digester top, where the biogas produced is stored. Electric energy is produced through constant supply of the biogas into the gas engine driving the electric generator. The generator must be connected to public electric mains for the purchase of the electric energy. During internal combustion of the water-cooled engine the heat is created which can be used for heating of the digester and other devices CHEE (co-generation of heat and electric energy). The biogas production from animal droppings and green mass of energy crops is shown in Figure 1.

2 Construction of mini digester for biogas production
Konstrukcija mini digestera za proizvodnju bioplina

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 material. It comprises of twelve gas cells. The basic structure of the mini digester

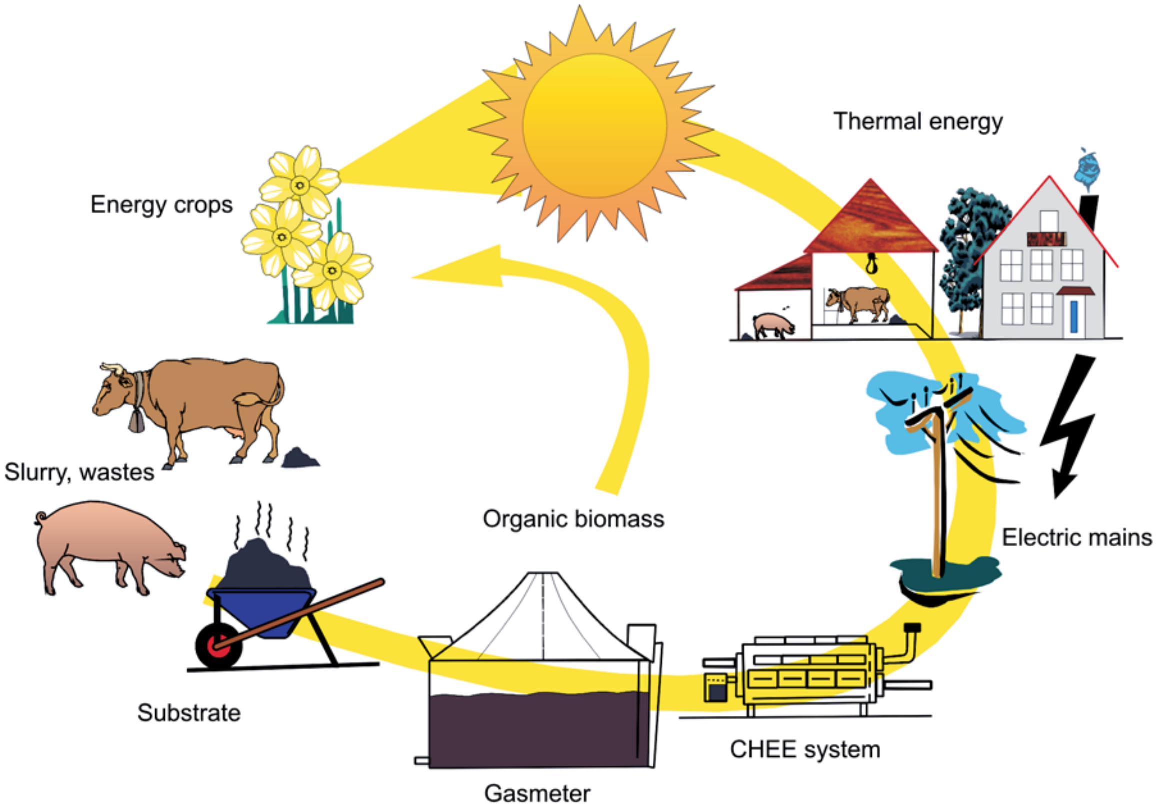

Figure 1 *Diagram of device for production and utilization of biogas from cattle-breeding, representing a natural energy circle*
Slika 1. *Dijagram uređaja za proizvodnju i korištenje bioplina iz stočarstva, predstavlja prirodni energetski krug*

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 × 200 × 200 mm lined with insulating material is provided to prevent excessive heat losses and to enable the fermenters to be in the dark. Heating pump is placed beside the eudiometers and ensures constant temperature and water circulation. 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. The barometer serves for measuring air pressure.

Three tests with three repetitions simultaneously are possible, whereas three units serve for the control (inoculum). 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 (CH_4, CO_2 and O_2) is measured by gas detector Geotechnical Instruments GA 45.

Each gas cell consists of a reaction vessel (500 ml fermenter) and a well closed gas pipe (Figure 2). The gas pipe - eudiometer contains the confining liquid and is of 350 ml size. It is connected to the levelling vessel with solution. The biogas 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 °C (mesophilic anaerobic digestion) 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, ...).

Figure 2 shows the draft of gas cell in waterbath.

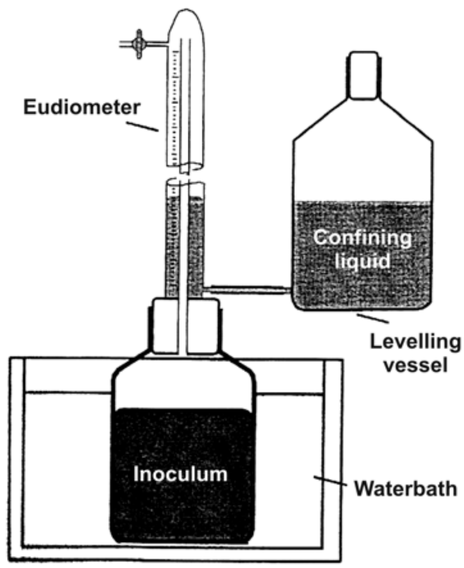

Figure 2 *The draft of gas cell in waterbath*
Slika 2. *Crtež plinske stanice u vodenoj kupki*

3 Measuring biogas production
Mjerenje proizvodnje bioplina

Measurements were conducted according to DIN 38 414, part 8 [7]. Mini digester consists of twelve digesters (Figure 3). The biogas produced is collected in an

Figure 3 *Series of tests of biogas production*
Slika 3. *Serija pokusa proizvodnje bioplina*

equilibrium vessel and the biogas production is monitored every day. A water bath tempers the digesters. The substrates are mixed every day for 10 min. Biogas production is given in norm litre per kg of volatile solids (L/kg), i.e. the volume of biogas production is based on norm conditions: 273 K, and 1013 mbar [7]. Each variant was replicated three times and then the average biogas production was given. 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.

Substance and energy turnover during anaerobic digestion were measured in 0,5 L eudiometer batch digesters at constant temperature 35 +/- 1 °C. Biogas yields and biogas composition from each treatment were measured in three replicates.

Actively digested pig manure slurry was collected from biogas plant that digests energy crops (maize, millet), filtered and used as inoculum to prepare substrate/inoculum ratios. 15 grams of substrate is digested together with 385 grams of inoculum. Biogas production from inoculum is measured as well. The analysis of biogas energy crops can be conducted in combination with mini digester and multi criteria decison analysis [8]. The multi criteria decision analysis is a generally accepted solution for problems in sustainable agriculture [9, 10, 11].

Biogas quality (CH_4, CO_2, O_2) is analysed 10 times in the course of the 5- week digestion. Figure 4 shows gas detector GA 45 [12].

3.1 Measuring biogas production from maize
Mjerenje proizvodnja bioplina iz kukuruza

The following maize varieties were included in the experiments:
NK PAKO (FAO 440),
PR 34N43 (FAO 580),
RAXXIA (FAO 420).

Maize was chopped after harvest and then mixed in certain ratios, prior to the ensiling process. Particle size was 2,0–4,0 mm.

Figure 4 *Gas detector GA 45*
Slika 4. *Detektor plina GA 45*

In the course of the vegetation period, specific biogas yield and biogas quality during anaerobic digestion in eudiometer batch experiments were determined for all varieties [13, 14, 15, 16]. Whole maize crops were anaerobically digested and biogas yields were compared [17].

Biogas production was measured during 5-week digestion. The highest biogas yield at mesophilic temperature range was achieved for maize variety NK PAKO, 409 L/kg. The lowest biogas yield was in the case of maize variety PR 34N43, 315 L/kg. Biogas production in mesophilic temperature range from three maize varieties is shown in Table 1.

Table 1 *Biogas production in mesophilic temperature range*
Tablica 1. *Proizvodnja bioplina u mezofilnom temperaturnom području*

Maize variety	Biogas production, L/kg
NK PAKO	409
PR 34N43	315
RAXXIA	357

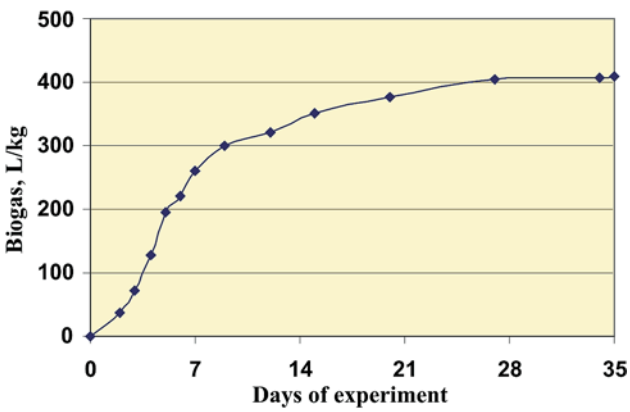

Figure 5 *Biogas production of maize variety NK PAKO during 5-week digestion*
Slika 5. *Proizvodnja bioplina kukuruznih vrsta NK PAKO tijekom 5-tjednih probava*

Biogas production of maize variety NK PAKO in norm litre per kg of volatile solids (L/kg) during 5- week digestion in mesophilic temperature range is shown in Figure 5.

In the mesophilic temperature range most of the biogas is produced in the first ten days of the experiment, after two weeks the anaerobic digestion is mostly finished. After 35 days the amount of biogas is very low.

***Table 2** Biogas composition of three maize varieties*
***Tablica 2.** Sastav bioplina od tri vrste kukuruza*

Maize variety	Mesophilic temperature range	
NK PAKO	CH_4	57,7 %
	CO_2	32,5 %
	O_2	0,4 %
PR 34N43	CH_4	56,9 %
	CO_2	34,6 %
	O_2	0,2 %
RAXXIA	CH_4	57,7 %
	CO_2	34,8 %
	O_2	0,3 %

Table 2 shows the biogas composition of three maize varieties in mesophilic temperature range. The average methane content ranged from 56,9 % to 57,7 % and 32,5 % to 34,8 % for CO_2 in mesophilic temperature range. Oxygen content in the biogas was under 1 %. That means that the digestion was anaerobic. The biggest differences in biogas composition occur in the first ten days of the digestion and then the gas content is more or less stable.

4 Conclusions
Zaključci

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. Economic efficiency of anaerobic digestion depends on the investment costs, on the costs for operating the biogas plant and on the optimum methane production. The biogas is a renewable source of energy and reduces CO_2 emissions.

The aim of the paper is the building of the mini digester for biogas production from energy-rich plants. The mini digester serves for the tests of biogas production from energy rich plants (maize, sorghum, amaranth) in laboratory. The basic structure is of welded construction from stainless steel (inox). The mini digester consists of twelve units so that four tests simultaneously with three repetitions can be performed. So, the resulting data are accurate and diverse. Each unit consists of an eudiometer, a fermenter containing the substrate and a levelling bottle for surplus closing liquid. Other components ensuring correct functioning of the mini digester are the pump and heater with thermostat, the thermometer, barometer, eudiometer clamps and rubber hoses connecting individual components. The final analysis of the produced biogas is effected by the gas detector GA 45.

Plant biomass is treated anaerobically for 35 days, in order to generate biogas. Measurements are conducted according to DIN 38 414 part 8 and then calculated according to the norm conditions, so that the data can be compared with results from literature.

The anaerobic digestion of three different maize varieties (NK PAKO (FAO 440), PR 34N43 (FAO 580) and RAXXIA (FAO 420)) in the mesophilic temperature range was studied. Biogas yields ranged between 315 - 409 L/kg.

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