Production of biogas from a mixture of kitchen waste

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Abstract: *The work deals with the testing of biogas production from gastronomic waste by means of anaerobic fermentation. A mixture of waste from a university refectory was used as the test material. The tests were carried out in the Nationwide Reference Laboratory for Biogas Transformation of the Mendel University for a period of 23 days in reactors with a volume of 130 l, at a temperature of 41.9°C. The amount of biogas generated and its composition were measured in the course of the tests.*
Key words: *kitchen waste, anaerobic fermentation, methane, biogas*

INTRODUCTION

As at 01/01/2014, 500 biogas plants with a total capacity of 392.35 MW were registered in the Czech Republic. Agricultural biogas plants, which utilise purpose-grown biomass as the input substrate, account for the predominant part of the installed capacity. In terms of economy of operation, purpose-grown biomass was the most advantageous option as the highest purchase price of electrical energy had been guaranteed for these plants and, at the same time, these were the least problematic operations thanks to the quality of the input materials.

The Energy Regulatory Office, however, stopped operating support of biogas plants commissioned after 01/01/2014. This decision resulted in the immediate termination of designing new facilities. So, at the present time, there is a trend to search for new profitable substrates for biogas production. Gastronomic waste forms a significant group of such raw materials. This term includes wastes from kitchens, canteens or food discarded from the sales network. These types of waste have not been utilised too much at biogas plants in the Czech Republic so far; nevertheless their utilisation is a logical process in obtaining energy from renewable resources.

The economic profitability of a biogas plant is affected by the quantity of biogas produced and its quality, in particular the content of methane in biogas. The qualitative and quantitative parameters are dependent upon many factors, primarily upon the composition of the substrate, the anaerobic fermentation technology employed, and upon the content of catalytic or inhibitory substances. Gastronomic waste is of a very variable composition, which may lead to significant complications in the processing thereof. The objective of this work was to verify the properties of the mixture of these wastes when it is utilised in the form of anaerobic fermentation.

MATERIAL AND METHODS

The tests were carried out in the Nationwide Reference Laboratory for Biogas Transformation at the Mendel University in Brno (Czech Republic). The tests took place in fermentation reactors with a volume of 0.130 m3. Laboratory fermenters are equipped with a control unit that records and regulates the temperature of the material and ensures that it is regularly stirred. A temperature of 41.9°C was chosen for the tests, which corresponds to the most common temperature regime used in operating biogas plants (Schulz, 2004).

Inoculation material for the testing was used from an agricultural biogas plant that processes the most commonly used mixture of maize silage and liquid pig manure. The inoculation substrate was taken from a reactor of the second stage of anaerobic fermentation. This material is suitable for laboratory testing since it contains a very small amount of degradable substances, thus reducing the risk of the tests being influenced by non-homogeneity of the material. 100 kg of the inoculation material was dosed into all of the reactors. Immediately after the dosing, the reactors were closed and after 24 hours the production and composition of the biogas of individual reactors was checked in order to eliminate the risk of a reactor leaking or a problem with the biological component.

During the test two reactors were earmarked as control ones, which only contained the inoculation substrate. A mixture of gastronomic waste amounting to 2.69 kg and 5.38 kg was inserted into the other ones. The material under test was sampled once a day for a period of one working week from a container for biodegradable waste from the university refectory of the Mendel University in Brno. The quantity of a sample taken was always 10 kg. The sample was homogenised and frozen. The resultant tested material was created by mixing five samples.

Table 1. Characteristics of the mixture in individual reactors

Reactor	Organic loading rate	Inoculum			Gastronomic waste		
		Quantity [kg]	Dry matter [%]	Combustible substances, [%]	Quantity [kg]	Dry matter [%]	Combustible substances, [%]
1, 2	-	100	4.2	63.1	-	-	-
3, 4	0.147	100	4.2	63.1	2.69	23.5	97.4
5, 6	0.294	100	4.2	63.1	5.38	23.5	97.4

The dry matter and the quantity of combustible substances of the inoculation material and the tested waste were determined before the commencement of the test. The quantity of the biogas produced was measured during the test on a daily basis by means of a flow meter as well as the composition of the biogas generated – the content of methane, carbon dioxide and hydrogen sulphide was measured by means of a Combimass GA-m gas analyser.

RESULTS AND DISCUSSION

The average value of production of the control reactors was deducted from the productions of biogas and methane of the testing reactors to ascertain the actual amount of biogas and methane generated from the added material.

Reactors R3 and R4 had an average specific biogas production of 0.796 $m^3.kg^{-1}$, and reactors R5 and R6 had an average specific biogas production of 0.660 $m^3.kg^{-1}$. This difference is likely to be due to a different mass loading rate, where in the first case there was a mixing ratio of 0.147 kg of the dry matter of added material per one kilogram of the dry matter of the inoculum, whereas in the second case it amounted to 0.294 $kg.kg^{-1}$. The designed dosing was based on previous tests, during which the maximum biogas production was achieved at a loading rate of the fermenter of 0.1515 $kg.kg^{-1}$ (Koutný, 2012). The biogas production ascertained in both cases is very high and comparable to the most frequently used material, maize silage. Dohányos (2010) states that energy maize varieties reach a specific biogas production of 0.50-0.55 $m3.kg^{-1}$. So, from this point of view, it is a high-quality raw material. However, the calorific value of biogas is given by the methane content and, therefore, it is important to make a conversion into specific methane production. This value indicates a real energy potential obtained from the fermentation of the given material.

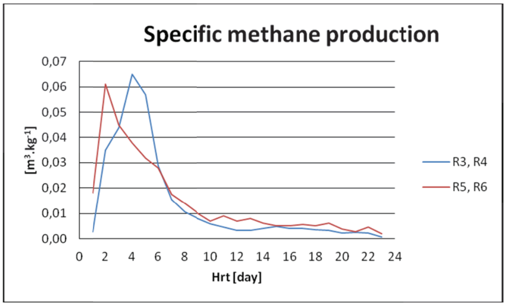

Figure 1. Specific methane production

An advantage of discontinuous fermentation reactors lies in the possibility to test the dynamics of methane formation. The information is of importance especially in designing a residence time in the fermenter. After the material is dosed into the fermenter, a sharp increase in methane production is noticeable, where the maximum value was reached in the course of day 2 to 5. Afterwards, the production was decreasing and, approximately from day 10, it was very low. Such a rapid process is characteristic of materials containing predominantly easily decomposable substances and a small amount of substances such as lignin and hemicellulose.

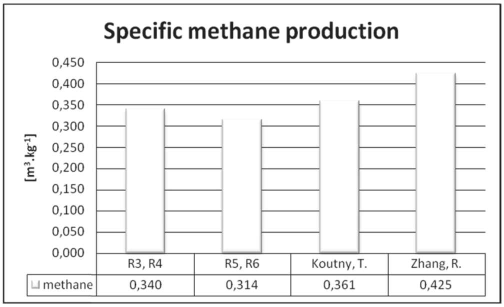

Figure 2. Comparison of specific methane production

The specific methane production measured in reactors R3 and R4 was 0.340 m3.kg-1 and in reactors R5 and R6 it was 0.314 m3.kg-1. These values are also very similar in comparison with energy maize varieties. R. Gao of China has ascertained a specific methane production of 0.322 m3.kg-1 (Gao, 2012) in maize variety GY622. Ruihong Zhang states that a mixture of gastronomic waste originating from San Francisco tested by him generated 0.425 m3.kg-1 of methane in 26 days (Zhang, 2007). So, from this point of view, gastronomic waste is a high-quality raw material for biogas production.

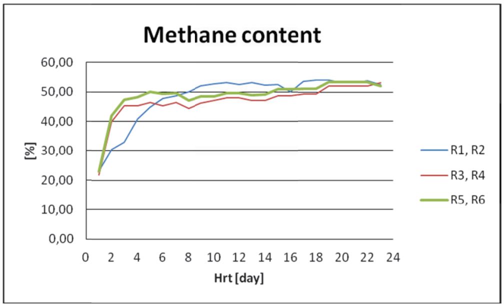

Figure 3. Methane content in biogas

It is obvious from Figure 3 that the methane content in the biogas oscillated at very low values, especially in the initial days of the test, when the biogas production is highest at the same time. A methane content of more than 45 % is suitable for combusting biogas in a cogeneration unit; otherwise there is a decrease in the efficiency of the unit and an increase in servicing costs. The average methane concentration in the biogas measured in reactors R3 and R4 was 42.7 % and 47.5 % in reactors R5 and R6.

CONCLUSIONS AND FUTURE WORK

The objective of the work was to carry out a test of the anaerobic fermentation of gastronomic waste to verify its properties for utilisation at a biogas plant. A mixed sample of waste taken from a container for biodegradable waste in a staff canteen on the premises of the Mendel University in Brno was used as the test material.

The test took place for a period of 23 days at a temperature of 41.9°C. Productions of biogas and its composition, in particular methane representation, were recorded on a daily basis during the test. It follows from the results of the test that the gastronomic waste is characterised by a very high biogas production. The value of 0.796 m3.kg-1 was measured in the case of a loading rate of 0.147 kg.kg-1. In the case of a mass loading rate of 0.294 kg.kg-1, a biogas production of 0.763 m3.kg-1 was measured. However, specific methane production, the measured value of which was 0.340 m3.kg-1 at a mass loading rate of 0.147 kg.kg-1 and 0.329 m3.kg-1 at a mass loading rate of 0.294 kg.kg-1, serves as a more appropriate indicator. These values are also very high; they correspond to methane production, for instance, from maize silage.

In terms of the methane content, however, the biogas from the gastronomic waste is of very low quality, the average methane concentration oscillated below 50% in both cases. It is not suitable to use a biogas with such a low methane content by direct combustion in a cogeneration unit. Its co-fermentation with another material that produces biogas with a high methane content such as maize silage or possibly waste from starch production appears to be a suitable method of utilising waste from kitchens and canteens.

ACKNOWLEDGEMENT

The research was conducted with the support of the project “Postdoktorské pozice v technických a ekonomických oborech na MENDELU” CZ.1.07/2.3.00/30.0031.

This study was financed by the Internal Grant Agency of the Faculty of Agronomy MENDELU in Brno, project No. TP 8/2014 “Bioenergetické transformace a jejich řízení“.

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The report is reviewed.