

# OPERATING DIAGNOSTICS OF BIOGAS PLANTS

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*Abstract:* This research deals with characteristics of processed organic material and its changes during anaerobic fermentation. Laboratory testing of anaerobic fermentation was performed in the Nationwide reference laboratory of biogas transformation at the Mendel University in Brno. The test took 26 days. During this period the composition and quantity of the biogas, conductivity, redox potential, pH, dry matter and total organic carbon in the processed material has been monitored. Determination of dry matter and total organic carbon proved to be unsuitable operating parameters for the diagnosis of biogas plants due to complicated sampling. The quantity of generated biogas, content methane in the biogas, conductivity, redox potential and pH of processed material are parameters which could provide descriptive information about process of anaerobic digestion and which can be useful for operational diagnostics of biogas plants. These parameters are closely related. For example development of redox potential correlates directly with the methane content in the biogas. And change of pH is in inverse proportion to development of redox potential. The conductivity during anaerobic fermentation gradually rose while the pH decreased. On the other hand determination of dry matter and total organic carbon proved to be unsuitable operating parameters for the diagnosis of biogas plants due to complicated sampling.

*Key Words:* anaerobic fermentation, biogas, redox potential, pH, dry matter, total organic carbon

## INTRODUCTION

In recent years production of biogas and its use as a source of electric power and also heat energy is clearly rising. Biogas is generated from an anaerobic fermentation, which is a complex of microbial processes. Therefore, it is really important to monitor and control process of anaerobic fermentation regularly to ensure optimal conditions for microbial community and thus achieve the highest possible production and quality of biogas. That is why this research deals with characteristics of processed organic material and their changes during the anaerobic fermentation. The laboratory testing of anaerobic fermentation was performed in the Nationwide reference laboratory of biogas transformation at the Mendel University in Brno. There was monitored composition and quantity of the biogas, conductivity, redox potential, pH, dry matters and total organic carbon in the processed material within the test. Obtained results and options of monitored parameters used in screening diagnostic of biogas plants condition were evaluated.

## MATERIAL AND METHODS

In this research, laboratory test of anaerobic fermentation was performed In the Nationwide reference laboratory of biogas transformation at the Mendel University in Brno. The 6 anaerobic bioreactors were used, the volume of each was 0.12 m<sup>3</sup>. There were applied 100 kg of fresh inoculums (38 kg of dry matter) into each bioreactor which was transported from the operations of the biogas plant in Čejč, Czech Republic. One bioreactor contained only the inoculum without the addition of any tested material to represent a control sample of the process of anaerobic fermentation. There were added tested materials into other bioreactors in an amount as is shown in Table 1.

The test was set in following process conditions: temperature of 41.9±0.5°C with mixing for 60 seconds at an interval of 15 minutes. The test was carried out for 26 days. During this period quantity and quality of the produced biogas has been monitored.

Table 1 Tested materials

| Tested material                        | Amount of dry matter [kg] |
|--|---------------------------|
| Thai foodwaste 1                       | 1.560                     |
| Czech foodwaste                        | 1.572                     |
| Thai foodwaste 2                       | 1.555                     |
| Foodwaste + fats, oils and grease(FOG) | 1.325                     |
| FOG                                    | 1.152                     |

The quantity was measured with the BK G4 gas meter. The biogas quality (content of methane, carbon dioxide and hydrogen) was analysed by means of the device Combimas GA-m.

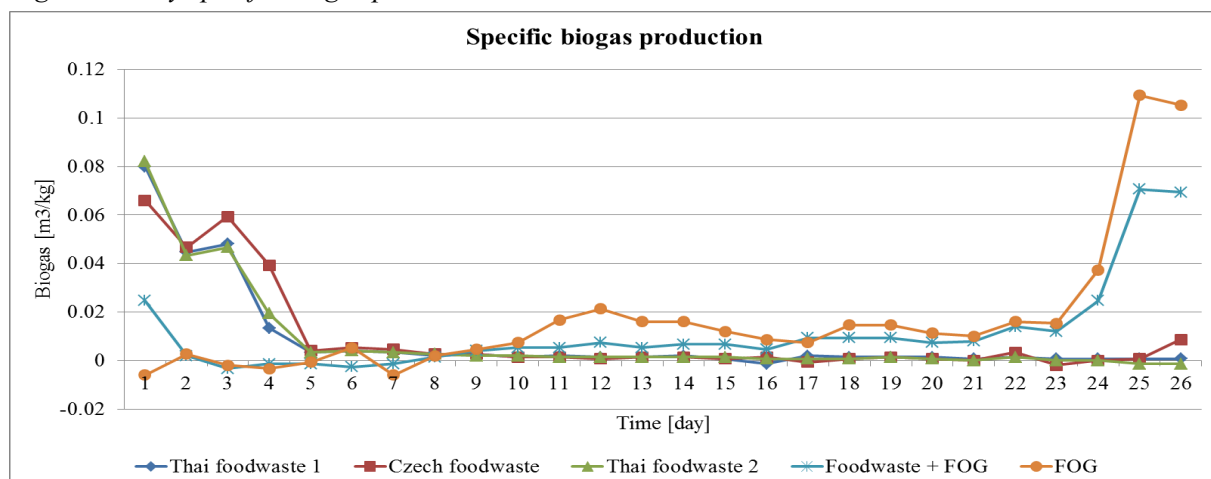
Samples of processed material (volume about 150 ml each) were taken first and second day and then every third day during the test. In these samples were determined following parameters: conductivity, redox potential, pH, dry matter, total organic carbon. The conductivity was measured in whole fresh samples at temperature  $30.0 \pm .0^{\circ}\text{C}$  by laboratory multimeter WTW inoLab Multi 720 using conductivity graphite cell TetraCon 325 with 4 electrodes and built- in temperature sensor. Redox potential and pH were measured in whole fresh samples at temperature  $30.0 \pm 1.0^{\circ}\text{C}$  by laboratory multimeter WTW inoLab Multi 720 using pH-combined electrode SenTix 41 with a diaphragm made of ceramic frits, gel electrolyte and built- in temperature sensor. Determination of dry matter was carried out according to standard ČSN EN 15934 drying fresh samples at  $105^{\circ}\text{C}$ . Total organic carbon was carried out according to standard ČSN EN 15936 by multi N/C 2100S analyzer. Then, each dry sample in amount of 0.06 g was burned in combustion tube at temperature  $1250^{\circ}\text{C}$  in the oxygen flow. The total carbon contained in the sample was converted to the carbon dioxide and it was detected by infrared spectrometry via the NDIR detector (NonDispersiveInfraRed absorption detector).

## RESULTS AND DISCUSSION

### Quantity of biogas

The biogas production from tested material was obtained by deducting the biogas production in control bioreactor. The biogas production was also recalculated on the specific production from dry matter of tested material. The highest total biogas production ( $0.434 \text{ m}^3 \cdot \text{kg}^{-1}$ ) was achieved in the bioreactor containing FOG only, which corresponds with states according to Hobson et al. (1981). The daily specific biogas production in bioreactors containing foodwaste had increasing character within first 5 days. However, there was a different trend of the daily specific production in the anaerobic treatment of FOG. The biogas production started to increase significantly after 25 days. Measurement error is eliminated by the same development in both bioreactors containing FOG, while the daily production increase of FOG with foodwaste was lower. Furthermore, Martin-Gonzalez et al. (2010) also observed this fact during anaerobic fermentation of fats. According to this, it occurred due to the easily decomposable substances contained in the inoculation material. The biogas production is not too high during their decomposition. And energy-rich fats are decomposed after the exhaustion of easily degradable substances. The daily specific biogas production is shown in Figure 1.

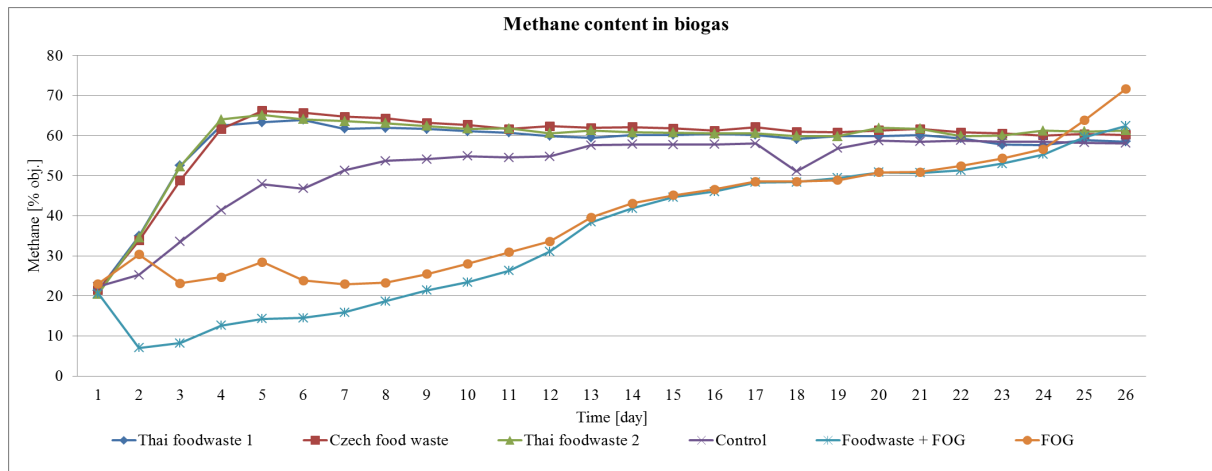
Figure 1 Daily specific biogas production



### Quality of biogas

Onset of methanogenic phase is slower during anaerobic processing of fats and waveform characteristic does not match the production of methane in a batch process dosing of bioreactors, as reported Schnurer, Jarvis (2010). Thus, the method of filling a batch bioreactor causes that methane production initially increases rapidly and reaches a maximum and then decreases by time. This model corresponds to the methane production by anaerobic fermentation of foodwaste as is illustrated in Figure 2.

Figure 2 Methane content in biogas

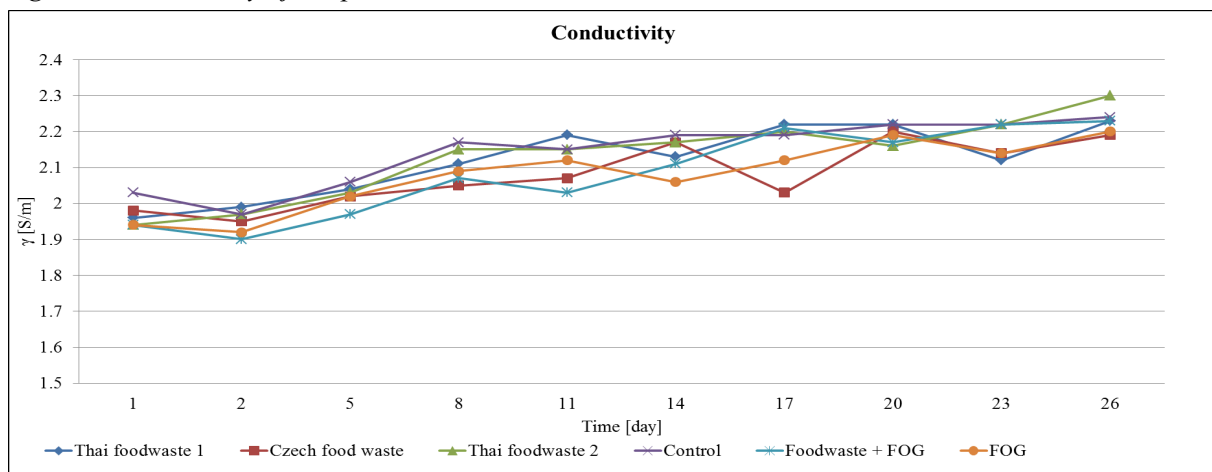


In the literature (e.g. Straka et al. 2010) an increased content of hydrogen in the biogas is associated with failure of anaerobic fermentation. During the laboratory testing the content of hydrogen in the biogas was below 140 ppm, which proves correctly running process of anaerobic fermentation.

### Conductivity

Kana et al. (2013) reported that the conductivity during anaerobic fermentation gradually rose while the pH decreased, which corresponds with results achieved during laboratory test. During the test the conductivity achieved predicted values, which exhibited growing trend being same for all bioreactors as is shown in Figure 3

Figure 3 Conductivity of the processed material

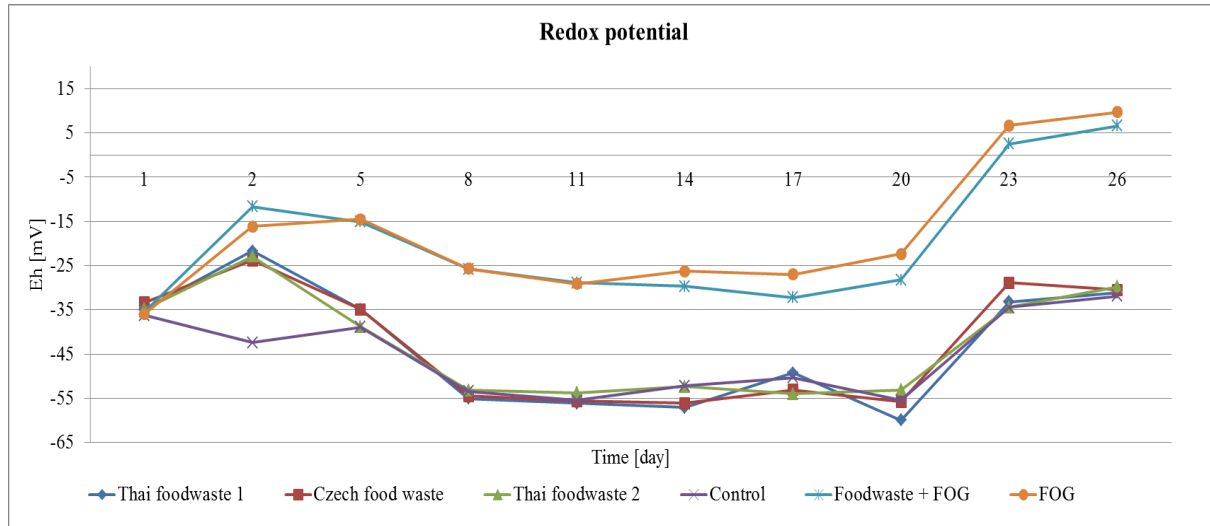


### Redox potential

The correlation between redox potential and methane content in biogas was observed during the test. Foodwaste and control bioreactor have a very similar development of methane and its content in biogas was nearly identical as the development of redox potential (see Figure 4). On the fifth day, the methane content in biogas achieved a maximum and at the same time redox potential of processed material began to decrease. At the end of the test, if production of biogas was negligible, value of redox

potential started growing again. In bioreactors containing FOG redox potential achieved values higher by about 20 mV during the entire test and its development correlates directly with the methane content in the biogas. Redox potential in these bioreactors reached an end test positive which is probably associated with a sharp increase in daily production of biogas and methane content in biogas.

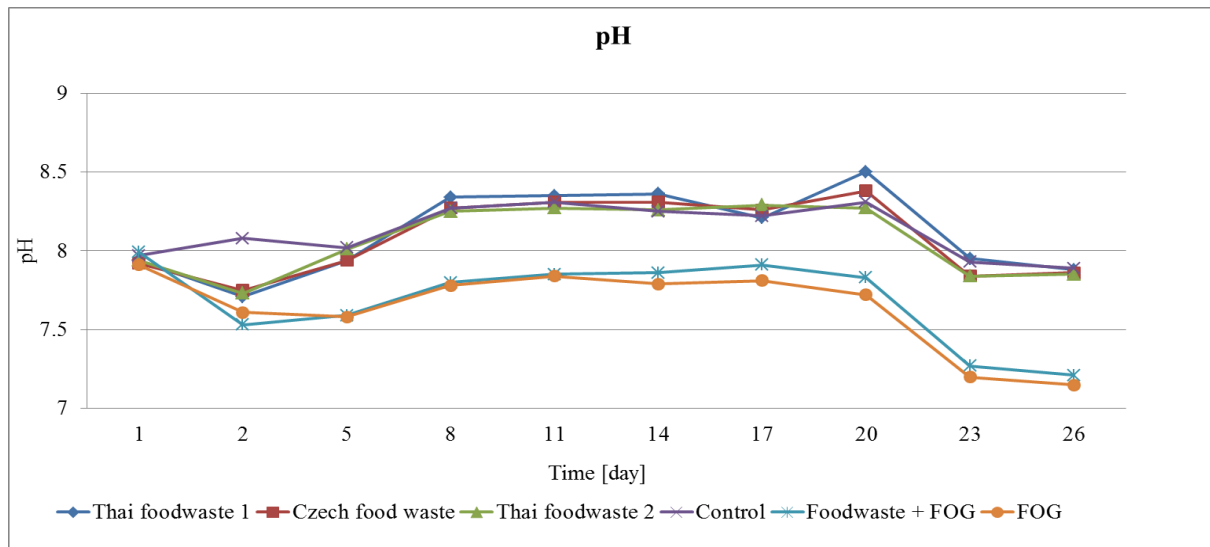
Figure 4 Redox potential of processed material



**pH**

Liebertau et al. (2012) reports that the pH in single stage anaerobic fermentation is stabilized at the optimal value itself, because of microbial communities formed autoregulatory system. This fact can be seen in Figure 5. Change of pH had almost concave course which is in inverse proportion to the convex development of redox potential.

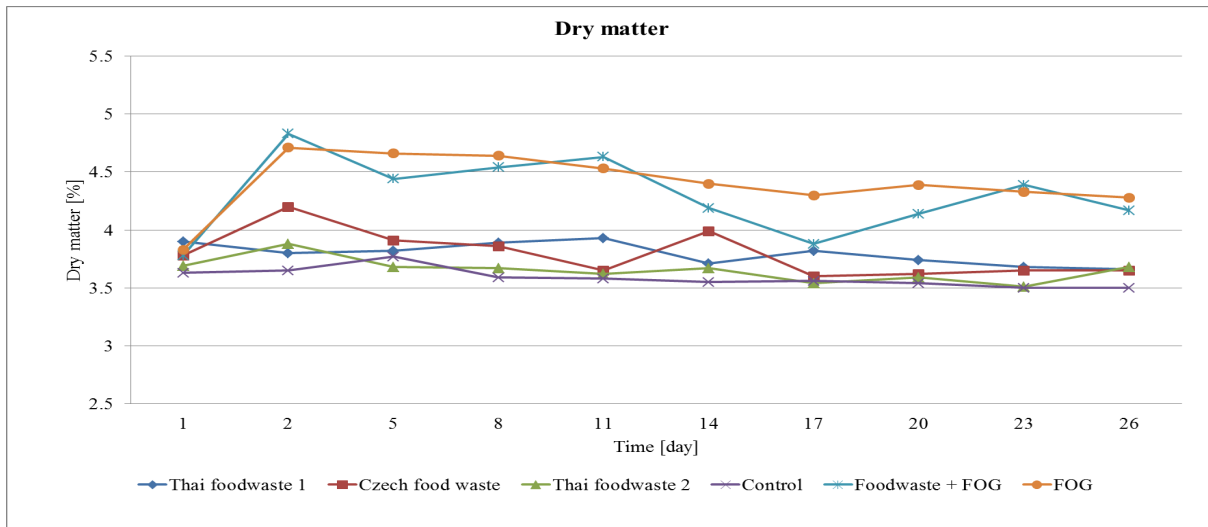
Figure 5 pH of processed material



**Dry matter**

Determination of dry matter proved to be unsuitable operating parameter for the diagnosis of biogas plants. Content of dry matter in the samples has changed greatly during the test as it is shown in Figure 6. This may be caused by simultaneous decomposition of organic substances, through which dry matter should decrease, and removal of water steam by biogas, which increase value of dry matter. Moreover sampling is complicated. The bioreactor cannot be opened to prevent the entry of air and distortion of anaerobic conditions. Valve intended for the sampling of the processed material at the bioreactor has long sleeve, where processed material tends to fouling.

Figure 6 Dry matter of processed material

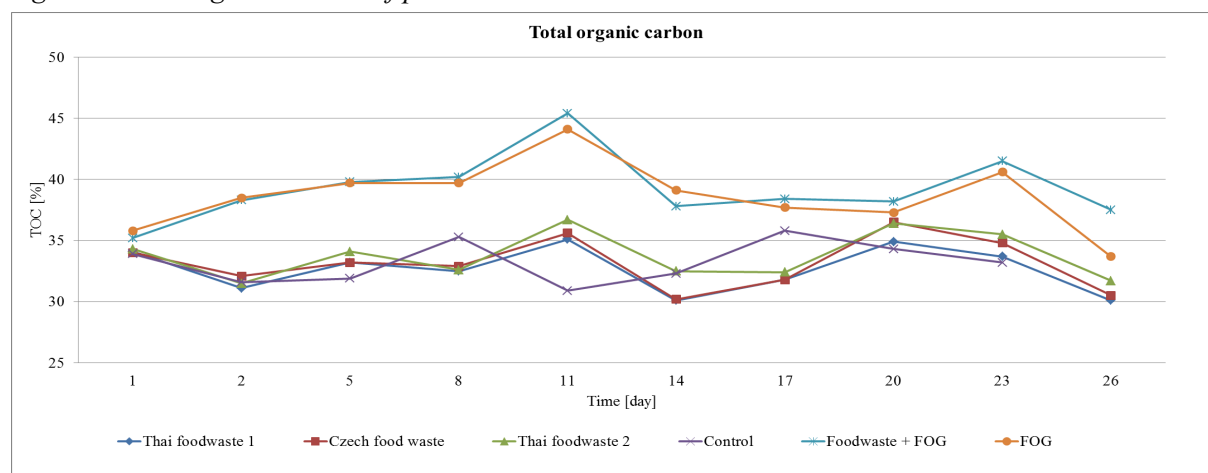


**Total organic carbon**

The small decrease can be observed (by 0.2 to 4.8%, as it is illustrated in Figure 7) during the test. However, according Tombone et al. (2013) total organic carbon in processed material decrease significantly (by 12.5%) during the anaerobic fermentation, because microorganisms utilize sugars, proteins, amino acids and fatty acids as a carbon source.

Determination of total organic carbon proved to be unsuitable operating parameter for the diagnosis of biogas plants. Total organic carbon reached implausible values (rising, falling, rising) during test. This fact is as well as for determination of dry matter caused due to complicated sampling. Additionally, error of determining total organic carbon may occur due to a small amount of incinerated sample (0.06 g) which will never contain the same ratio of manure and silage, eventually grains and stems of corn, contained in the inoculation material, despite every effort to sample homogeneity.

Figure 7 Total organic carbon of processed material



**CONCLUSION**

The quantity of generated biogas, content methane in the biogas, conductivity, redox potential and pH of processed material are parameters which could provide descriptive information about process of anaerobic digestion and which can be useful for operational diagnostics of biogas plants. These parameters are closely related. For example development of redox potential correlates directly with the methane content in the biogas. And change of pH is in inverse proportion to development of redox potential. The conductivity during anaerobic fermentation gradually rose while the pH decreased. On the other hand determination of dry matter and total organic carbon proved to be unsuitable operating parameters for the diagnosis of biogas plants due to complicated sampling.

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