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# MODELLING OF DAILY METHANE YIELD FROM THE LABORATORY SCALE PLUG FLOW ANAEROBIC BIOREACTOR

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## ABSTRACT
*This paper deals with the assessment of daily methane yield from anaerobic digestion (AD) of slaughterhouse waste using mathematical modelling based on data obtained from 15 days long experimental period. The experiment is carried out using laboratory scale Plug Flow Reactor (PF) operated under different temperature and inclination conditions. The waste mixture was composed of manure from cattle depots and vehicles for cattle transport (labelled as O1) and inedible offal, stomach contents, sludge from washing and cleaning, and the meat leftovers (labelled as O2). The ratio used was O1:O2=80:20. The result of the experiment shows that the higher the bioreactor inclination is, the higher is the methane yield regardless of the temperature. For both experimental levels carried out at lower temperatures, daily methane yield is variable indicting problems with mesophilic bacteria adaptation to lower temperature zones.*
**Key words:** methane yield, anaerobic digestion, slaughterhouse waste, PF, mathematical modelling.

## 1. INTRODUCTION
Mathematical modelling is based mainly on physical principles, while AD, a complex process by nature, is significantly influenced not only by physical but also by chemical and biological principles. Therefore, in the case of AD, more acceptable mathematical modelling would be the one done based on experimental results. Such mathematical modelling can be defined as the system of identification that predominantly involve physical parameters that will be checked for the nature of the impact they exert on the process, at the same time not diminishing the importance of other principles [1,2,3]. One of the methods for quantitative analysis of a certain phenomena is a statistical regression method that enables the collection of information necessary to make conclusions and determine the mathematical relations. The regression analysis is used to provide appropriate solution in form of an analytical expression of a theoretical curve for a set of depended and independent variables. Here is to be noted that the duration of the process is also an independent variable [4,5]. The aim of regression is to determine the nature of relationship or dependence among the variables, which is achieved by using a model that is monitored on a daily basis [6,7]. In order to analyse the level and intensity of two variable parameters (temperature and slope) and their influence of methane yield, a standard biomethane potential (BMP) test is performed for the mixture of slaughterhouse waste [8] treated in

laboratory scale PF bioreactor [9]. A waste mixture from slaughterhouse was composed of two types of input substrates: manure from cattle depots and transport vehicles for the transport of livestock (labelled as O1) and inedible offal, the contents of the stomach, sludge from washing and cleaning, and meat leftovers (labelled as O2). The ratio used was O1:O2 = 80:20 [8]. The assessment of methane yield was done using regression model that best fits the biogas production pattern.

## 2. MATERIAL AND METHODS

The experiment started with characterization of slaughterhouse waste based on the physical and chemical parameters of each waste type and their mixture. The stability of the process was monitored performing standard set of analysis on the bioreactor effluent samples including pH, alkalinity, total solids, volatile organic acids, ammonia content, chemical oxygen demand, total phosphor, sulphide, N-Kjeldahl as well as biogas quantity and quality [1]. All laboratory tests were performed using the corresponding reference measurement method and standard laboratory equipment [10,11]. The concentration of methane and carbon dioxide in biogas was measured automatically using device GUARDIAN Plus by Edinburgh Instruments.

In the industrial use, the PF bioreactor is a systems of cylindrical geometry. However, for the purpose of simplicity, in this research, the PF model bioreactor was constructed as a system of cuboid geometry with working volume of 9l [1,11] (Figure 1). The PF model bioreactor was operated under two different temperature conditions and two different inclination angles that impacted mixing pattern in the bioreactor (Table 1). With this design, the main benefits of bioreactor with «horizontal movement» of substrate are preserved (simple design, simple handling, low investment and operational costs) while at the same time the open surface susceptible to forming of crust and foam is decreased to the minimum. For the purpose of this experiment, a simple mixer was installed to mix and homogenize the reactor's content after feeding [1]. Duration of the experiment for each experimental point was 15 days.

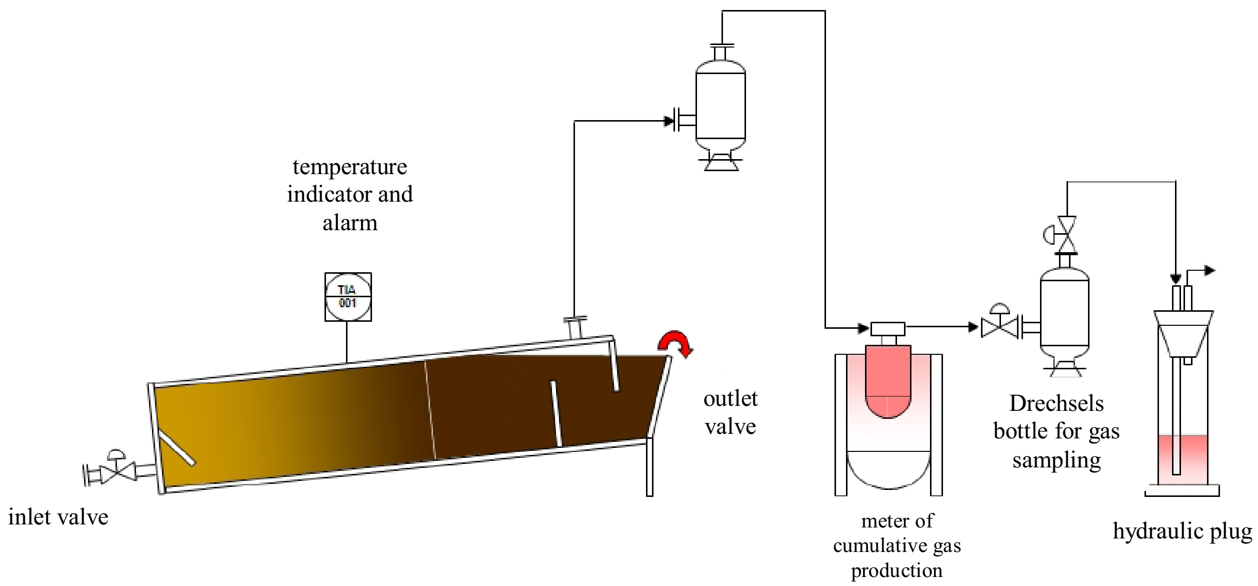


*Figure 1. Scheme of Plug Flow Reactor with the accompanying equipment [1,11].*

*Table 1. Experimental variables*

| Variables | | Level of factors | |
|---|---|---|---|
| | | Lower (-1) | Upper (+1) |
| Temperature | A = T (°C) | 25 | 35 |
| Slope | B = δ ( °) | 40 | 20 |

## 3. DAILY METHANE YIELD PER EXPERIMENTAL POINT

Figure 2 shows daily methane yield for four experimental levels.
The results for experimental **"level (1)"** (t= 25 °C, δ= 20°) show that methane yield has variable methane yield. For the whole experimental period the methane production slightly decreases. The linear approximation curve with determination coefficient ($R^2$ =0,55) does not fit well to describe this experimental level, however indicates the decreasing trend. This is confirmed by extrapolation of data for three more days using data from the 15-day experimental period and the obtained fitting curve. The result indicates that increase in number of experimental days would not result in increase of methane production [1].

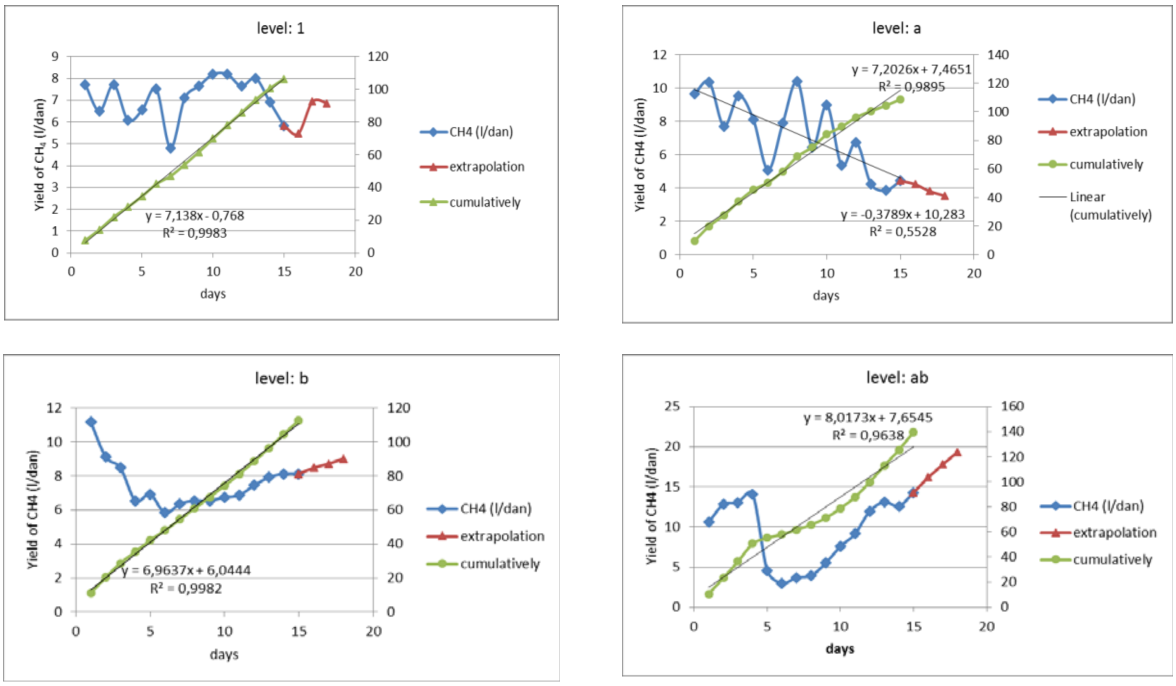


*Figure 2. Daily yield of methane for the experimental points of PF bioreactor [1].*

**"Level a"** (T=35 °C, δ= 20°) has variable methane yield. The obtained results and fitting curve indicate the same conclusions as for the level 1 confirming that the increase in number of experimental days would not result in increase of methane production in this case as well.
**"Level b"** (T=25 °C; δ= 40°), shows that at the beginning of experimental period methane yield has decreasing characted after which it gets stabilised and continues to rise. The increasing trend is confirmed using extrapolation of data for three more days using data from the 7-day experimental period. The simple fitting curve that would strongly fit this experimental pattern was not found [1].
**"Level ab"** (T=35 °C; δ= 40°) is a level that has variable methane yield for the whole duration of experiment with significant magnitude of an amplitude from 3 to 15 l/d. The yield was growing at the beginning of the experiment, followed by desrease and then again an increase that remained untl end of the experiment. . The increasing trend is confirmed using extrapolation of data for three more days

using data from the 7-day experimental period. The simple fitting curve that would strongly fit this experimental pattern was not found. The experiment was performed at the maximum level of both variables where the energy consumption is the highest. The expected methane yield can be explained by impact of higher temperatures on activity of mesophilic bacteria [1].

## 4. CONCLUSION

It can be concluded that experimental levels with higher inclination angle result in higher methane yield. In addition, for both experiments carried out at lower temperatures, daily methane yield is variable indicting problems with mesophilic bacteria adaptation to lower temperature zones. Negative side of this process is the need to keep operation temperature at 35 °C, which increases energy consumption in cooler periods of the year thus creating additional pressure on energy resources.

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