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MODELLING OF DAILY METHANE YIELD FROM THE LABORATORY SCALE CSTR ANAEROBIC BIOREACTOR TREATING SLAUGHTERHOUSE WASTE

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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 in laboratory scale continuous stirred tank reactor (CSTR) operated under different temperature and mixing conditions. The waste mixture was composed of two input substrates: 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 results show that operating temperature of 35°C and mixing speed of 20 °/min is the most promising modus of work that produces stable yield but with lower methane quantities.
Keywords: methane yield, anaerobic digestion, slaughterhouse waste, CSTR, 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]. 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 [5,6]. In order to analyse the level and intensity of two variable parameters (temperature and mixing speed) and their influence of methane yield, a standard biomethane potential (BMP) test is performed for the mixture of slaughterhouse waste [7] treated in laboratory scale CSTR bioreactor [8]. 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 [7]. 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 [9,10]. The concentration of methane and carbon dioxide in biogas was measured automatically using device GUARDIAN Plus by Edinburgh Instruments.

The CSTR model bioreactor is characterized by a simple and reliable design and represents a typical single phase bioreactor in which all the anaerobic reaction are conducted in one, almost perfectly mixed, tank. The working volume of CSTR bioreactor is 5 l [1,10]. The waste was fed daily though the inlet valve constructed at the same height as the propeller of the mixer that ensured instant mixing of substrate with bioreactor contents. The treated waste was discharged though the outlet siphon, which prevented the penetration of air into the bioreactor. The amount of waste fed and waste discharged was equal in order to preserve a constant volume of waste in the bioreactor. Bioreactor was operated in a batch mode of operation, meaning that output and input valve were opened only at the time of feeding and emptying the system. The content of the reactor was continually mixed with two different motor speeds. The methane yield potential was analysed in response to the change of mixing speed and temperature [1]. Duration of experiment for each experimental point was 15 days. Schematic diagram of the bioreactor CSTR was given in Figure 1.

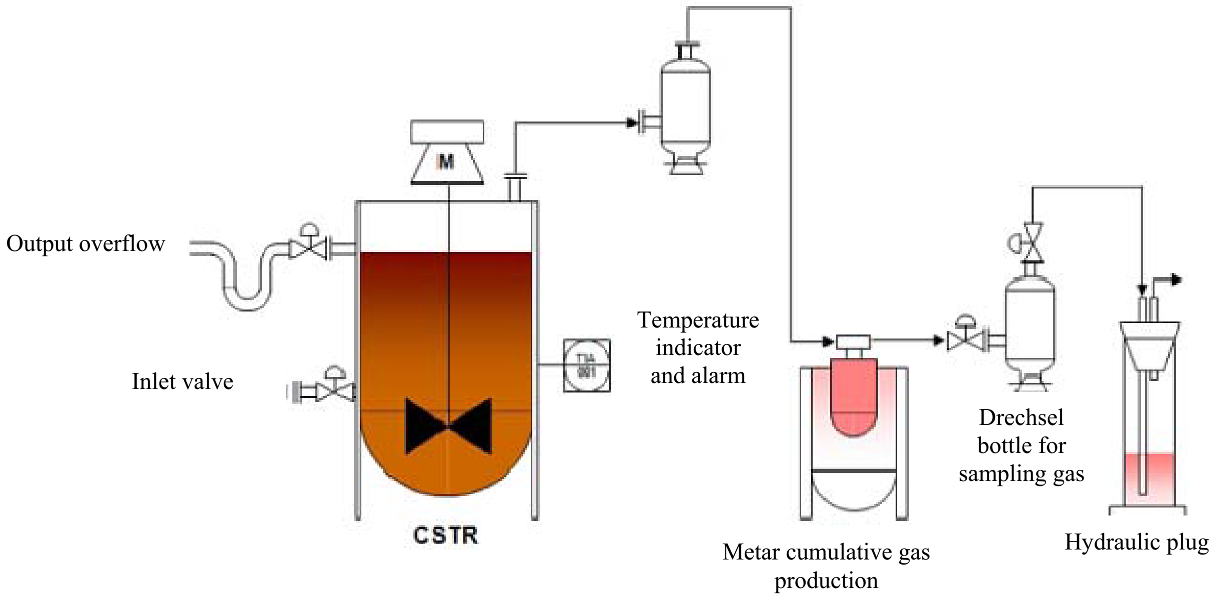

Figure 1. Scheme of Continuous Stirred Tank Reactor with the accompanying equipment [1,10].

Table 1 gives values of variable parameters (temperature of the process and mixing speed) for the given experiment.

Table 1. Experimental variables

Variables		Level of factors	
		Lower (-1)	Upper (+1)
Temperature	A = T (^oC)	25	35
Mixing speed	B = n ($^o/min$)	10	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 ^oC, n=10 $^o/min$) show that methane yield increases in the first couple of days and then starts to decrease between day 4 and day 11, followed by slow increase and final decrease till the end of experimental period. The given step function with coefficient of determination R^2=0,71 and extrapolation done for the 3 following days based on the last 8 days of experiment best describe methane yield pattern. It is clear that level (1) is not giving as well as not promising high methane yields, which is contributed to mesophilic bacteria working in lower temperature range and substrate being poorly homogenised with low mixing speed [1].

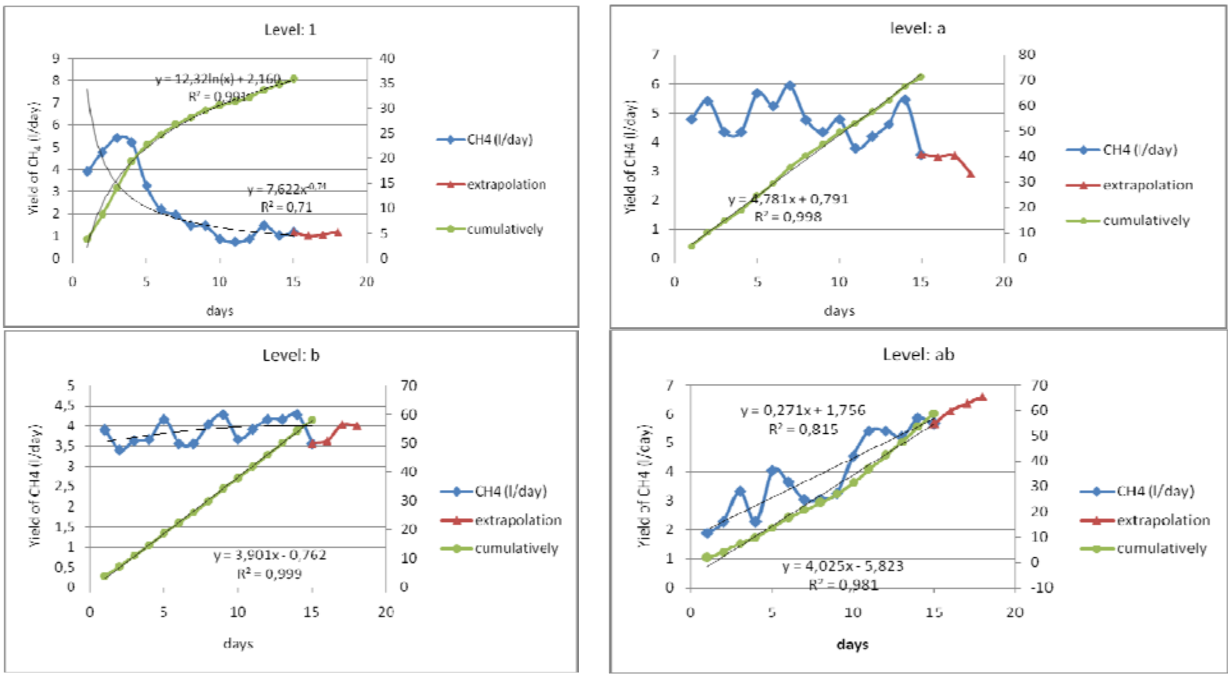

Figure 2. Daily yield of methane for the experimental points of CSTR bioreactor [1].

"Level a" (T=35 ^oC; n=10 $^o/min$) has variable methane yield in range of 3.57 to 5.95 l/day. It is also visible that during experimental period of 15 days methane yield show mild decrease supported by descending trend of extrapolation curve prepared for the following three days based on the last three days of the experiment. A simple regression curve fit that would be sufficient to describe this level and its methane yield is not obtained.

"Level b" (T=25 ^oC; n=20 $^o/min$), almost identical to "level a", has variable methane yield with lower oscillation amplitude and mild increase in methane yield as given by the extrapolation curve for the first 15 days of experiment. Extrapolation curve for the three days is prepared based on the last 4 days of the experiment. A simple regression curve fit that would be sufficient to describe this level and its methane yield is not obtained [1].

The only experimental level that has significant increase in methane yield is the **"level ab"** (T=35 °C; n=20 °/min). The experiment is carried out at the upper range of both parameters where electricity consumption is certainly the highest with not so high cumulative methane production. The approximate function that describes this experimental level is linear with strong coefficient of determination (R^2=0,81). Additional argument to this conclusion is the pattern of extrapolation curve obtained based on the methane yield for 15 days. The expected increase in methane yield can be explained with suitable process temperature and higher mixing speed that homogenized substrate content [1].

4. CONCLUSION

For all experimental levels it can be observed that daily methane yields have lower oscillation amplitude in lower temperature range. Monitoring of anaerobic process in CSTR reactor shows that in average 70% of organic matter is removed and converted to methane. However, the daily methane yield obtained lead to the conclusion that anaerobic treatment is not sustainable, except for "level ab" operated at higher temperature and higher mixing speed. 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.

5. REFERENCES

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