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Answering the Case for Optimum Mesophilic Reaction Temperature

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Corresponding Author:	Emmanuel Ogbonna, Awaiting PhD University of Hertfordshire Hartfield, Hertfordshire, UNITED KINGDOM
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	University of Hertfordshire
Corresponding Author's Secondary Institution:	
First Author:	Emmanuel Ogbonna, Awaiting PhD
First Author Secondary Information:	
Order of Authors:	Emmanuel Ogbonna, Awaiting PhD
	Rashid Ali, PhD
Order of Authors Secondary Information:	
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Answering the Case for Optimum Mesophilic Reaction Temperature

E. C. Ogbonna* and R. Ali**

*Science and Technology Research Institute, University of Hertfordshire, Hartfield, Hertfordshire, AL10 9AB, UK
(E-mail: E.ogbonna2@herts.ac.uk; emmanuel.ogbonna1@gmail.com)
**Science and Technology Research Institute, University of Hertfordshire, Hartfield, Hertfordshire, AL10 9AB, UK
(E-mail: r.4.ali@herts.ac.uk)

Abstract
Four laboratory experiments under mesophilic condition with varied temperatures were conducted to determine the correlation between biogas production and temperature, as well as establish the optimum temperature value for mesophilic anaerobic digestion. The empirical study shows that biogas production increases from 3.54 dm^3 to 7.92 dm^3 as the temperature increases from 36 ^oC to 39 ^oC respectively, as represented in figure1.1 below. Then production remained constant between 39.2 ^oC and 40.0 ^oC, afterwards; it decreases as temperature marginally increases beyond 40.0 ^oC. The optimum temperature of mesophilic anaerobic digestion was elevated from 37.0 ^oC to 39.0 ^oC for 15 days and 29.84% increase in biogas was achieved. The experiments also established that the optimum temperature value for mesophilic anaerobic digestion is 39.0 ^oC.

Keywords
Optimisation; anaerobic digestion; optimum temperature; mesophilic condition; sodium hydroxide; hydraulic retention time

INTRODUCTION

The optimisation of biogas production in anaerobic digestion depends on the rate of substrate degradation and bacteria growth, which are influenced by the operational temperature of the digester (Gerber and Span, 2008). Temperature is one of the most important parameters that affect anaerobic digestion. Raising and maintaining digestion temperature at its optimum value can significantly increase biogas production, and also help to make the performance of the digestion system more efficient (Choorit and Wisarnwan, 2007). Sudden temperature change can slow or halt the process, and this may take some time to restart, resulting in less or no biogas production (Ahn and Forster, 2002; Gao et al., 2011). The affirmation that the rate of reaction increases with temperature in a chemical process (Clark J., 2002) was observed to guide the anaerobic reaction process up to the optimum temperature value. However, the reaction remained constant for a further increase in temperature of about one degree Celsius, afterwards; it decreases with more increase in temperature.

This paper presents the findings of the experiments performed to determine the relationship between temperature and biogas production; confirming the optimum temperature for mesophilic anaerobic digestion; and the effectiveness of elevating the temperature of anaerobic digestion at mesophilic condition from 37.0 ^{o}C to 39.0 ^{o}C.

LABOURATORY EXPERIMENT

A range of laboratory experiments were carried out to determine the correlation between rate of biogas production and the temperature inside the digester.

Materials and Methods

The experiment was carried out with a 2.0 litres lab-scale digester (BioFlo 111 – Batch/Continuous digester, New Brunswick Scientific, Edison N. J. USA) operated in batch system at mesophlilic condition. The slurry fed to the digester was formed by mixing 100g of medium maize flour with 950 cm^3 of water and 50 cm^3 of active digester sludge, the inoculum, which was obtained from Thames Water Rye Meads Sewage Treatment Works, Stanstead Abbortts, UK. The slurry in the digester was continuously stirred at 200 rpm, and has a Hydraulic Retention Time (HRT) of 15 days. The pH was maintained at 7.4, which was made possible by the supply of 2.5 moles concentration of Sodium Hydroxide (NaOH). The temperature was initially set at 36.0 ^{o}C and gas collection tube was inserted into the headspace to let venting of biogas into a Non-Diffusing Gas Collection Bag attached to it. Three more experiments were repeated under the same condition with the same digester and slurry content, however, with different operating temperatures (37.0 ^{o}C, 39.0 ^{o}C and 42.0 ^{o}C).

Results

The table below shows the result of biogas yield at different operating temperatures, while all other parameters remained constant.

Table 1. Biogas yield at different operating temperatures

Experiment	Slurry (kg)	Temperature (^oC)	Biogas (dm^3)	HRT (days)
1	0.10	36.0	3.54	15
2	0.10	37.0	6.10	15
3	0.10	39.0	7.92	15
4	0.10	42.0	7.60	15

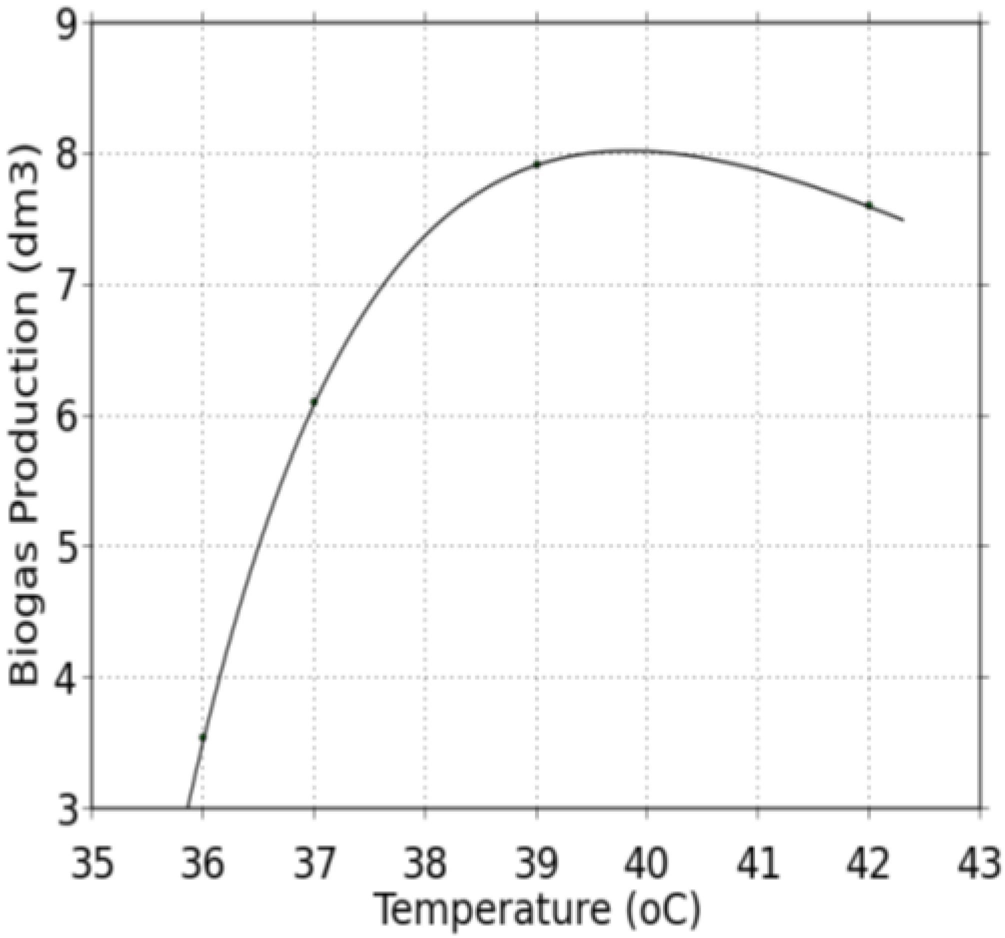

Figure 1. Biogas productions with varying operating temperature

It was observed from the graph in figure 1 that biogas yield increases from 3.54 dm^3 to 7.92 dm^3 as the temperature increases from 36.0 ^oC to 39.0 ^oC respectively; although the relationship is not linear. However, the same graph indicated that biogas production remained constant between 39.2 ^oC and 40.0 ^oC, afterwards; it decreases as temperature marginally increases beyond 40.0 ^oC. Therefore, in this study the optimum temperature value for mesophilic anaerobic digestion was found to be 39.0 ^oC.

Effectiveness of Maintaining Mesophilic AD Temperature at 39.0 ^{o}C

In order to verify the efficacy of raising and maintaining the operating temperature of mesophilic anaerobic digestion at 39.0 ^{o}C as indicated in the graph above, theoretical analysis of the excess biogas production is compared with the extra energy input required.
Hence,

The quantity of heat energy (Q) input required to raise the temperature of the slurry:

$$Q = m\, C_p\, (T_2 - T_1)$$

Where,

m = mass of slurry = 0.01kg

C_p = specific heat of water (4.2 kJ/kg ^{o}C)

T_1 = ambient temperature = temperature of slurry = 10.0 ^{o}C

T_2 = Raised Temperature (^{o}C)

Thus,

The quantity of heat input required to elevate the slurry temperature to 37.0 ^{o}C gives,

$$Q_{37} = 0.01 \text{ kg x } 4.2 \text{ kJ/kg } ^{o}\text{C x } (37.0 - 10.0)\ ^{o}\text{C}$$

$$= 1.134 \text{ kJ}$$

Also,

The quantity of heat input required to elevate the slurry temperature to 39.0 ^{o}C gives,

$$Q_{39} = 0.01 \text{ kg x } 4.2 \text{ kJ/kg } ^{o}\text{C x } (39.0 - 10.0)\ ^{o}\text{C}$$

$$= 1.218 \text{ kJ}$$

Therefore,

The difference in heat input required to elevate the slurry temperature from 37.0 ^{o}C to 39.0 ^{o}C = ΔQ

Hence,

$$\Delta Q = (1.218 - 1.134) \text{ kJ} = 0.084 \text{ kJ}$$

Then,

The percentage of the difference in heat input required to elevate slurry temperature from 37.0 ^{o}C to 39.0 ^{o}C, gives:

$$\frac{0.084}{1.134} = 0.074 = 7.8\%$$

Furthermore,

The difference in the quantity of biogas production when the operating temperature was elevated from 37.0 °C to 39.0 °C, taken from table 2.2.1 above, is = (7.92 – 6.10) dm^3 = 1.82 dm^3

However, in percentage gives,

$$\frac{1.82}{6.10} = 0.2984 = 29.84\%$$

The analysis shows that 7.8% of extra heat input was used to raise slurry temperature from 37.0 °C to 39.2 °C and 29.84% increase in biogas production was achieved.

Therefore, from this study it was found that the digestion system under mesophilic condition was most effective when operating at temperature 39.0 °C.

CONCLUSIONS

This paper has presented the following findings from the empirical study:

- The optimisation of biogas production in mesophlic anaerobic digestion largely depends on the optimum temperature value.
- By elevating the optimum temperature of mesophilic anaerobic digestion from 37.0 °C to 39.0 °C for 15 days an additional 29.84% of biogas was obtained.
- The optimum temperature value for mesophilic anaerobic digestion was found to be 39.0 °C.

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