Effect of Temperature and pH on The Anaerobic Digestion of Grass Silage

Noxolo T Sibiya, Edison Muzenda and Habtom B. Tesfagiorgis

***Abstract*—the operating temperature and pH level in the digester during anaerobic digestion and the retention period are among the major factors that affect the rate of biogas production. Therefore, this paper evaluates the effects of temperature and pH in anaerobic digestion of grass silage. Grass silage was digested in 1000ml at different temperatures (35 °C, 40 °C, 45 °C and 50 °C) and pH (6.5, 6.8 &7.2). The digesters were shaken everyday to prevent the formation of surface crust which may prevent contact between microorganisms and the substrate. The characteristics of grass and cow dung and the optimal retention time are also reported. The results show that as the temperature was increased the biogas production and methane was also increased, however the high amount of biogas production rate and methane content was observed in the digester operated at 45 °C and pH of 6.5. The process was carried out for 11days; however the optimal hydraulic retention time for digester that had high biogas was 8 days.**

***Keywords*—**Biogas, pH, Retention time, Temperature,

I. Introduction

GRASS represents an important source of biomass that can serve as a substrate for biogas production. It is the second largest biomes in South Africa, covering almost 30% of the country's land surface and it grows faster than any other energy crops [1]. Although grass is primarily used for feeding animals, the study done by Du Plessis [2] shows that garden waste, mainly grass, occupies 28% of landfill in SA. South Africa has taken an initiative to use grass, particularly Giant grass (elephant grass), for biogas production [3]. The generation of biogas from grass could be used to reduce the consumption of traditional fuels, especially for vehicle fuel; hence, the methane from grass has been shown to be sustainable, with energy balance of about 7.5-15.5MWh [4].

Biogas is produced from a biological process that involves microorganism in the absence of oxygen [5]. Four stages are usually used to portray the anaerobic digestion (AD) process: hydrolysis, acetogenesis, acidogenises and methogenises [5]. Anaerobic digestion process is affected by many factors including temperature and pH of the digester [5]. Although, there are three possible ranges of temperature in which the process can be carried out (psychrophilic10–20ºC, mesophilic 20–40 °C and thermophilic 45–60 ºC) [8], mesophilic (37-40ºC) and thermophilic (55 °C) conditions have been observed to be the most favorable condition for the anaerobic digestion of grass silage [6], [7]. Retention time in anaerobic digestion is a function of the temperature; which means that the time the substrate spends in the digester is dependent on the operational temperature.

Microorganisms are classified according to their optimal pH range. Methanogenic bacteria work effectively at the pH range of 6.5 and 8. However, for hydrolysis and acidogenisis, ranges between 5.5 and 6.5 have been reported to be optimal. Anaerobic digestion may also be carried out at a neutral pH. The decrease in pH is due to the accumulation of carbon dioxide and volatile fatty acid as a result of digester overloading [8].

In this study, the effects of temperature and pH on the biogas production rate, biogas yield and methane content in digestion of grass silage as well as the retention time were investigated. The amount of gas produced was compared in different experimental conditions, to identify the optimal process parameters for the process.

II. Material And Procedure

A. Material

Fresh grass was obtained from Johannesburg Zoo Lake which serves as substrate for this study. The grass was kept at 4ºC refrigerator until the day of usage. Cow dung was used as a source of inoculums for the anaerobic process. The characteristics of these substrates are shown in TABLE **I**.

B. Digester and operating conditions

A schematic diagram of experiment set up that was used in this study is shown in Fig. 1. Twelve batch digesters (plastic bottle), each having a total volume of 1000ml were used. The effective working volume was maintained at 800ml and 200ml was left for the gas. The digesters were provided with appropriate arrangement for gas collection. The digesters were agitated every day to ensure intimate contact between microorganisms and substrate. When the substrate was added

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the digester was squeezed to eliminate air from the digester. Biogas produced from the reactor was monitored daily by water displacement method and methane was analyzed in the gas chromatography (GC). The digesters were incubated in water bath operated at the temperature variation of 35ºC, 40 ºC, 45 °C and 50 °C. At the start of the process, the pH of the digesters was set at three different levels (6.5, 6.8 and 7.2).

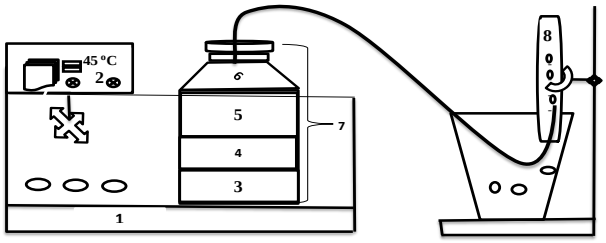

Fig. 1 Schematic view of the experimental set up during anaerobic digestion of grass silage.1: water bath, 2: temperature control, 3: inoculums, 4: grass silage, 5: buffer solution: 6: space for gas, 7: digester (1000ml), 8: measuring cylinder.

C. Characteristics of Substrates

The rate of biogas production and the composition of the gas yielded depends greatly on the substrate characteristics such as organic content, (COD), ammonia concentration etc [9]. Hence, all the relevant substrate characteristics such as pH, total solids (TS), volatile solids (VS), and moisture content (MC) were measured and analyzed according to the Standard Methods [10]. TABLE **I** shows the characteristic of cow dung and grass. These characteristics indicate that grass is suitable for anaerobic digestion.

TABLE I
CHARACTERISTIC OF FEED STOCK

Parameters	Cow dung	Grass
MC[%]	25	83.12
TS[%]	19.97	83
VS[%]	72.3	93.7
C	38	52
pH	7.3	6.8

MC = moisture content, TS = total solids, VS = volatile solids; C = carbon

D. Data analysis

The experiment was conducted three times, making three replicates per treatment. Data collected during the experimental period was pooled together and analyzed using GenStat 12 [13]. Means off all the parameters were comparisons between means of each parameter which was made using Fisher's protected least significant difference.

III. Results And Discussion

A. Biogas and methane Gas production

pH and temperature had significant effects on the rate and total biogas production (P<0.001). **Error! Reference source not found.** shows the analysis of variance on effect of pH, temperature and retention time on the rate of biogas production from grass silage with data given as the average of duplicates. The results show the interaction between the three parameters.

The influence of the digestion pH on biogas production is shown in Fig. 2, regardless of the temperature and retention time. Biogas production of about 195.4ml which was the highest biogas yield was observed in the pH of 6.5, while 137.2 and 176.9ml was observed for the pH of 6.8 and 7.2, respectively. This may be attributed to the increase in growth of acidophilic (methanogenesis) bacteria, which are responsible for methane production, and their activity.

Temperature also had a significant effect on the rate of biogas production; regardless of the pH (Fig. 3). According to the results, the biogas production rate was high at the temperature of 45ºC, followed by the temperature of 35 ºC. It has been observed that biogas production decreased drastically at the temperature of 50ºC. This may be due to the annihilation of microorganism metabolism due to high temperature. Biogas production was 178 mL, 157 mL, 208.6 mL, 134 mL at the temperature of 35 ºC, 40 ºC, 45 ºC and 50 ºC, respectively.

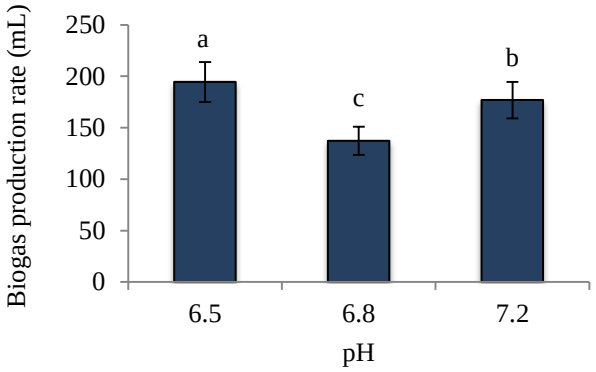

Fig. 2 Effect of pH in biogas production from grass silage

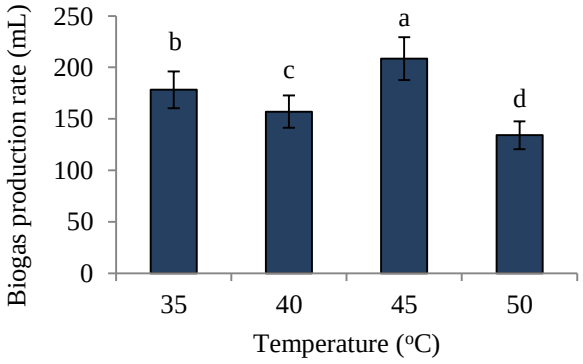

Fig. 3 Effect of temperature in biogas production from grass silage

TABLE II

TABLE OF ANALYSIS OF VARIANCE (ANOVA) ON THE EFFECTS OF PH, TEMPERATURE AND RETENTION PERIOD ON THE RATE OF BIOGAS PRODUCTION FROM SILAGE GRASS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	5839.	2920.	1.87	
pH	2	227562.	113781.	72.92	<.001
Temperature	3	298427.	99476.	63.75	<.001
Retention Period	10	1213042.	121304.	77.74	<.001
pH *Temperature	6	1393093.	232182.	148.80	<.001
pH * Days	20	1364721.	68236.	43.73	<.001
Temperature * Retention Period	30	842202.	28073.	17.99	<.001
pH* Temperature * Retention	60	1667488.	27791.	17.81	<.001
Residual	262	408817.	1560.		
Total	395	7421191			

Retention time has a remarkable effect on methane production rate Fig. 4. When the hydraulic retention time of grass silage increased inside the digester, biogas production increased. This may be linked to the activity of biogas producing bacteria increase regularly as time passes. The biogas production rates in the digesters reached its peak value of 232mL/day on day eight. After day 8 biogas production rate decreased, this decrement may be attributed to the low methanogenic activity and or the number of methanogens, in the digesters, that could result in the accumulation of the biogas production inhibitors during the acidogenic step.

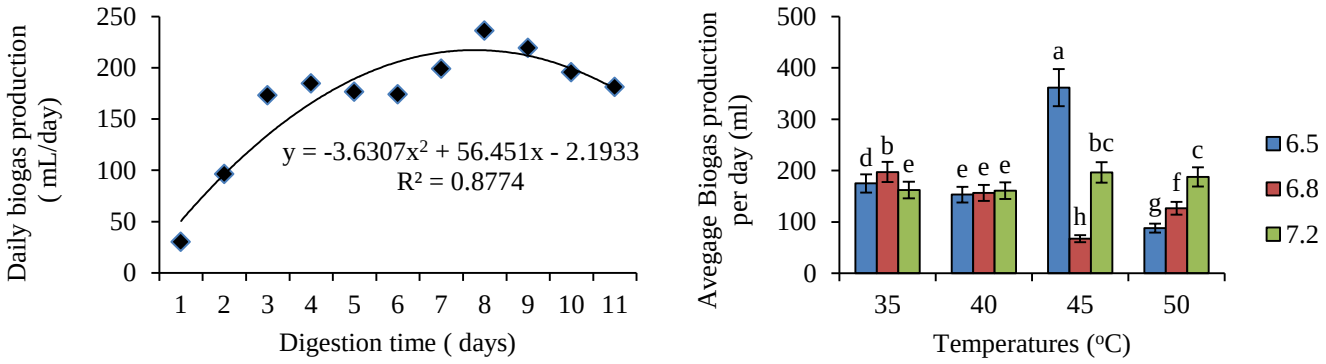

Fig. 4 daily biogas production and average biogas production from grass silage

Fig. 4 also indicates the significant of pH and temperature during anaerobic digestion. The highest biogas production rate of 361.7ml was observed in the digestion operated in 45ºC and the pH of 6.5. The lowest biogas production rate was observed in the digester operated at 45ºC and pH of 6.8. This may be due to the availability of acidophilic microbes, which work effectively at the acidic solution and high temperature. These results indicate that the microorganism involve in anaerobic digestion have an optimal temperature for a specific pH level.

Methane content in biogas is presented in Fig. 5. The methane content is low in the first stage, and then increases gradually. After 8 day of anaerobic digestion, the proportion of methane slightly decline then remained constant for the rest of experiment. Between day 8 and 11, methane content range between 63% and 65%.The methane content obtained in this study is comparable to those obtained by Asama [12]who reported 60-70% of methane content in biogas, when they

were investigating the techniques to improve bio-methane production per unit feed stock including grass in biogas plant .

Average methane contents were relative to the biogas production. Digester that was operated at 45ºC and pH of 6.5 had maximum methane content than other digesters. This can be attributed to the volume of a biogas production, which was also the highest at this condition. All digesters with the pH of 6.5 exhibited a successful startup with comparable average methane content of 57%, 52%, 67% and 50% for temperature of 35 °C, 40 °C, 45 °C and 50 °C at the pH of 6.5, respectively. Methane content at the pH of 6.8 was 64%, 54%, 18%, and 45% at the temperature of 35 °C, 40 °C, 45 °C and 50 °C, respectively. For the pH of 7.2, the methane content was 45%, 50%, 52%, and 50% at the temperature of 35 °C, 40 °C, 45 °C and 50 °C, respectively. All these results show that the digester operated at 45 ºC had high methane content for all pH values.

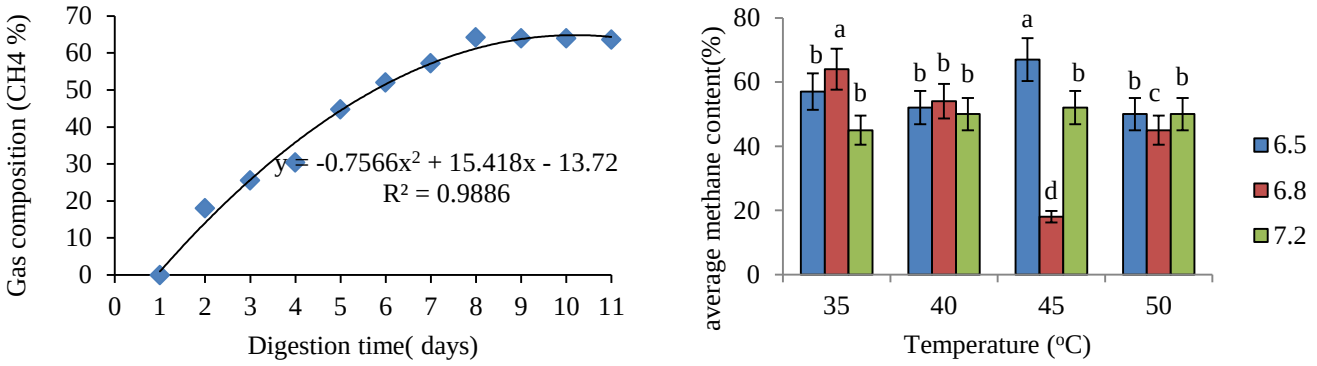

Fig. 5 Daily methane composition and average methane content in biogas production from grass silage

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IV. CONCLUSION

Based on the results reported in this work, it can be concluded that temperature and pH play a huge role in anaerobic digestion of grass silage. The biogas production rate and methane content was found to be increasing with the temperature. However, beyond the optimal temperature the biogas production decreases. The highest yield was obtained at 45 °C and pH of 6.5. This was attributed to the rapid growth of bacteria required to breakdown organic matter into biogas and also the digester stability. The optimal retention time of anaerobic digestion of grass silage was found to be 8 days, regardless of the effect of temperature and pH. Methane content in biogas was above 50% for all digesters at the pH of 6.5. It can also be mentioned that grass had high VS and TS which showed that it was suitable for anaerobic digestion.

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