

## Studies on Biogas Generation from Agricultural Waste; Analysis of the Effects of Alkaline on Gas Generation

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**Abstract:** The focus of the research paper is to investigate the importance of biogas as an alternative energy sources. A survey was done to ascertain the amount of biogas that can be generated from various feed stock. A practical laboratory scale experimental design using agricultural waste was also done to find out the effects of Alkaline [NaOH] on the volume of biogas generated using a mixture of pineapple, plantain and cassava peelings as the feed stock. Results obtained reveals a high volume of gas generated when the operating conditions inside the digester is maintained at moderately alkaline condition. Further findings also reveal that the digester temperature remained within the range of 27 to 35.5°C throughout the period of experimentation.

**Key word:** Anaerobic degradation • Biomass • Biogas • Agricultural waste • Alkalinity

### INTRODUCTION

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of biofuels [1]. One type of biogas is produced by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure or sewage, municipal waste, green waste and energy crops [2]. This type of biogas comprises primarily methane and carbon dioxide. The other principal type of biogas is wood gas which is created by gasification of wood or other biomass [3]. This type of biogas is comprised primarily of nitrogen, hydrogen and carbon monoxide, with trace amounts of methane.

Biogas technology is based on the phenomenon that when organic matter containing cellulose is fermented in the absence of air (aerobically), combustible gases but majorly (methane) is formed [4]. This technology represents one of a number of village-scale technologies that are currently enjoying a certain level of patronage

among governments and aid agencies and that offer the technological possibility of more decentralized approaches to development [5]. Biogas production is often suggested in situations where animal wastes are used as a major source of household energy [6]. The potential advantages include: The replacement of an inefficient (but traditional) fuel with a more efficient and flexible one, the recoupment of the fertilizer value of the waste, which is lost if the dung's are burned and the benefits to public health (especially in reducing eye diseases) if the cleaner, less Smokey, gas is used.

At present biogas is the most immediately practicable means for powering a conventional internal combustion engine from biomass. It tends itself to small scale on farm use and there is considerable experience with technique in a number of countries [7].

After treatment biogas approximate to pure methane with a calorific value of about 40 MJ/m<sup>3</sup>. Biogas is an attractive fuel for use in engines since it has no difficult pollutant that can damage them (like producer gas does) [8]. More also, biogas has good antiknock properties and

Table 1: Productivity of Biogas Feed Stocks

Feedstock	Gas yield per unit mass of feedstock(m <sup>3</sup> /kg)	Energy yield (MJ/kg)
Sewage sludge	0.7	6.17
Pig dung	0.5	8.11
Cattle dung	0.3	2.60
Poultry droppings	0.5	6.11
Poultry droppings and paper pulp	0.5	8.11
Gas	0.5	8.14

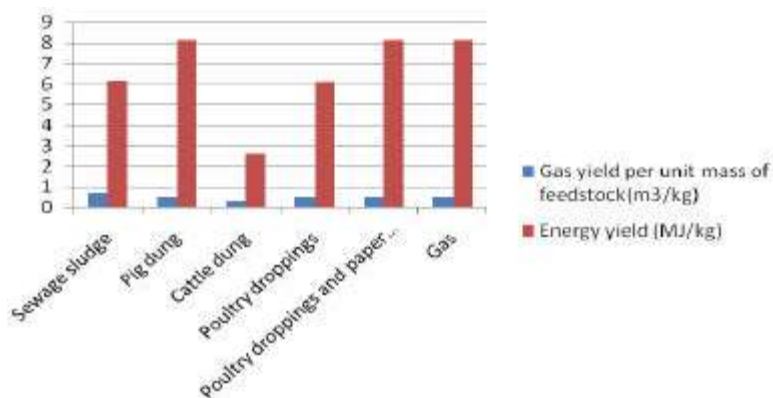


Fig. 1: Biogas various Feed stocks

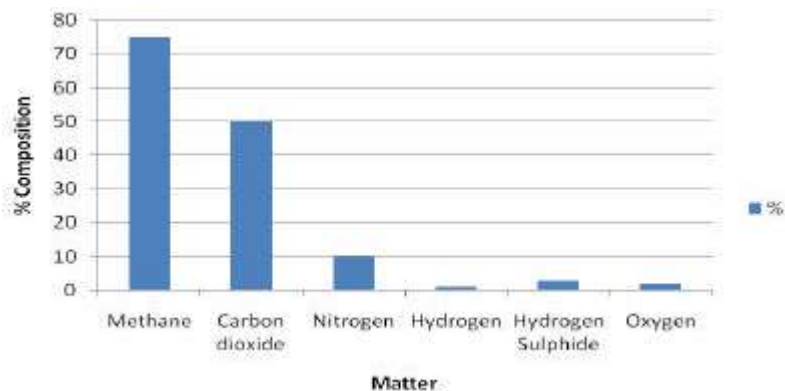


Fig. 2: Typical Composition of Agricultural Feed Stock



Fig. 3: A Typical Laboratory Sized Biogas Digester

can safely be used with high compression ratio spark ignition engines as the sole fuel [1]. An important further advantage of this process, especially in a context of irrigation company is that the digested sludge makes a good fertilizer, so that unlike the situation where when biomass is totally burnt, it is possible to return much of the original material to the land and thereby improve the soil quality and displace the use of chemical fertilizer [9].

**The Anatomy Of Biogas Generation:** Biomass that is high in moisture content such as animal manure partially decomposed green plants and food processing waste is suitable for producing biogas using anaerobic digester technology. The biogas process requires an input material (mostly agricultural waste) provided as partially composted liquid slurry with around 80 – 90 percent solid content. It is important to use materials which break down readily as highly fibrous materials like wood and straw are not easily digested by micro organism, but softer feed stocks like dung and leaves reacts well to the process. Also some feed stocks are more productive than others as indicated by (Table 1, Figure 1). For optimum performance the internal temperature of the digester needs to be maintained within the range of 25 – 35.5 degree centigrade and certainly over 25°C and within a pH range of 6.7 to 9.4. For optimum gas generation, the pH must be maintained at a reasonable alkaline condition. Four basic types of microorganism are involved in the production of biogas from agricultural feed stock (Biomass); Hydrolytic bacteria break down complex organic waste into sugar and amino acids. Fermentative bacteria then convert those products into organic acids; Acidogenic microorganism converts the acids into hydrogen, carbon dioxide and acetate. Finally, the methanogenic bacteria produce biogas from acetic acid, hydrogen and carbon dioxide. This whole process takes place in air tight chamber called a biogas digester. (Figure 2 and 3) shows the typical gas composition of agricultural feed stock and a laboratory sized biogas digester.

## MATERIALS AND METHODS

### Materials Used:

- Pineapple Peels
- Plantain Peels
- Cassava Peels:
- Sodium hydroxide (NaOH)
- Distilled Water

### Apparatus Used:

- Measuring cylinders
- Beehive for gas collection
- Infra Red thermometers
- Retort Stand
- Electronic Weighing Balance
- Biogas Digester

**Experimental:** 1.5kg of partially composted agricultural waste [500grams each of pineapple peels, plantain and cassava peels] was accurately weighed using an electronic balance and allowed to undergo partial decomposition in a compost arrangement with addition of bio enzymes and water. The partially decomposed waste was then introduced into the digester (Fig. 3). The digester was then completely sealed and then connected to the gas delivery setup (the gas was collected over water in a trough with a beehive and measuring cylinder). The experimental setup was then left for monitoring for a specific time period (Precisely 1-6 days) at an ambient condition until a decline in gas production was observed. During the period of the experiment, the temperature and volume of water displaced by gas were measure daily. The contents of the digester were continuously stirred to ensure that the molecules of gas are set in perpetual random motion. The second part of the experiment was carried out to study the effect of sodium hydroxide on biogas production. The procedure was the same as with the effects of time on biogas production, only that a solution of 1, 3 and 5% wt/wt sodium hydroxide (NaOH) was added to the partially decomposed agricultural waste before it was fed into the digester. The addition of the sodium hydroxide was aimed at studying the effect of alkaline condition on biogas generation.

## RESULT AND DISCUSSION

The amount of gas produced was monitored by measuring its volume and the average temperature daily. The digester temperature remained in the range of 27 to 35.5°C throughout the period of operation. The results obtained shows that the volume of biogas generated from the first day to the sixth day changes repeatedly. Gas generated for the first three days was quite low though an increase in production was observed daily. There was a gradual reduction in the volume of gas produced after it has reached the peak value of gas

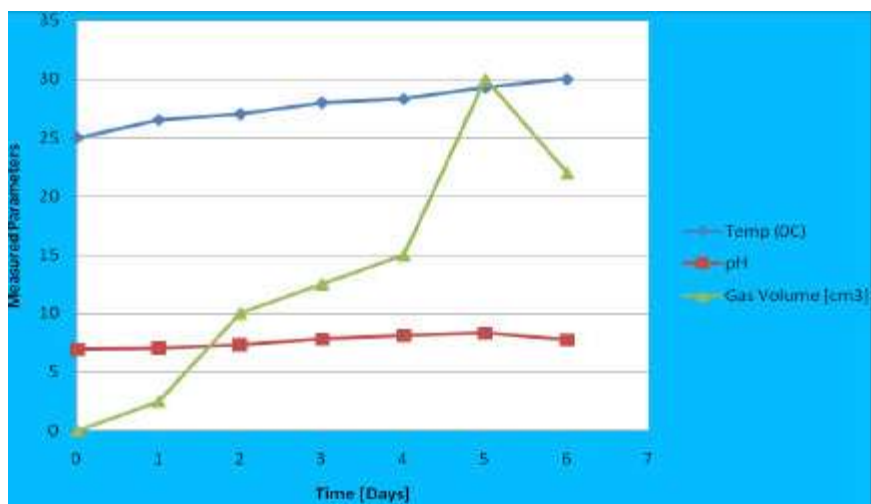


Fig 4: Biogas Production with No Addition of NaOH

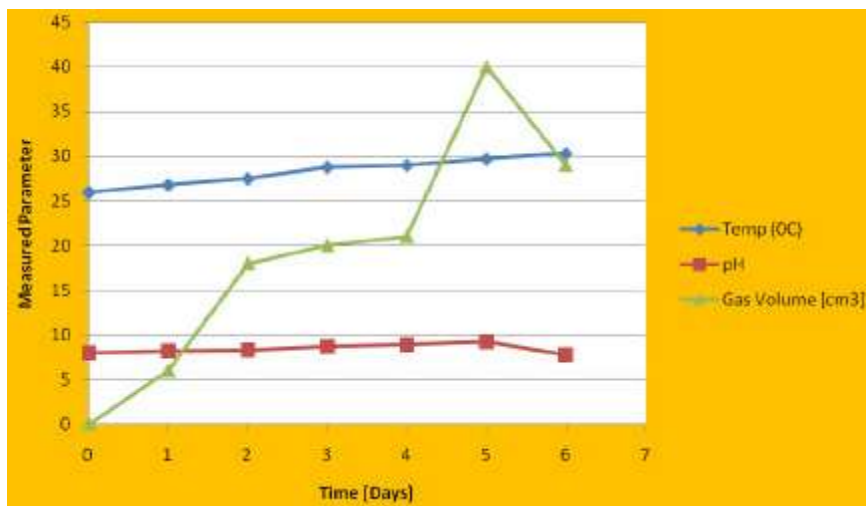


Fig 5: Biogas production with addition of 1% wt/wt NaOH

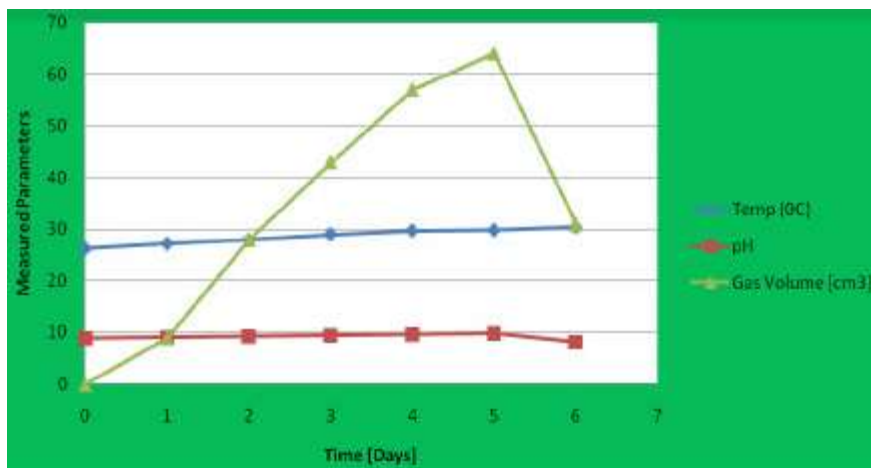


Fig 6: Biogas production with addition of 3% wt/wt NaOH

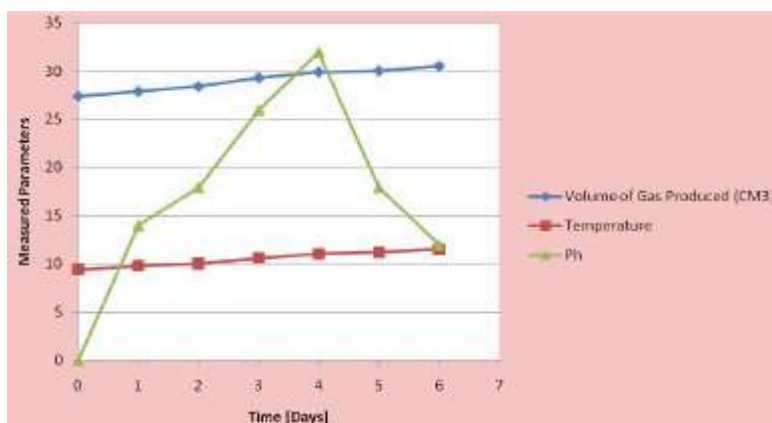


Fig7: Biogas production with addition of 5% wt/wt NaOH

Table 2: Biogas Production Without Addition of NaOH

Day	Temp (°C)	pH	Gas Volume [cm <sup>3</sup> ]
0	25.0	6.9	0.0
1	26.5	7.0	2.5
2	27.0	7.3	10.0
3	28.0	7.8	12.5
4	28.3	8.1	15.0
5	29.3	8.3	30.0
6	30.0	7.7	22.0

Table 4: Biogas Production With Addition of 3% wt/wt NaOH

Day	Temp (°C)	pH	Gas Volume [cm <sup>3</sup> ]
0	26.3	8.8	0
1	27.2	9.0	9
2	27.9	9.2	28
3	29.0	9.4	43
4	29.7	9.6	57
5	29.8	9.8	64
6	30.4	8.1	31

Table 3: Biogas Production With Addition of 1% wt/wt NaOH

Day	Temp (°C)	pH	Gas Volume [cm <sup>3</sup> ]
0	26.0	8.0	0
1	26.8	8.2	6
2	27.5	8.3	18
3	28.8	8.7	20
4	29.0	8.9	21
5	29.7	9.2	40
6	30.3	7.8	29

Table 5: Biogas Production With Addition of 5% wt/wt NaOH

Day	Temp (°C)	pH	Gas Volume [cm <sup>3</sup> ]
0	27.4	9.40	0
1	27.9	9.80	14
2	28.4	10.0	18
3	29.3	10.6	26
4	29.9	11.0	32
5	30.0	11.2	18
6	30.5	11.5	12

Table 6: Experimental Design Table (Two Way Analysis of Variance ANOVA)

S/No	% Wieght NaoH [C]	Time (Days) [T]	Treatments	Temp (°C)	pH	Gas Volume [cm <sup>3</sup> ]
1	0	0	C <sub>1</sub> T <sub>0</sub>	25.0	6.9	0.0
2	0	1	C <sub>1</sub> T <sub>1</sub>	26.5	7.0	2.5
3	0	2	C <sub>1</sub> T <sub>2</sub>	27.0	7.3	10.0
4	0	3	C <sub>1</sub> T <sub>3</sub>	28.0	7.8	12.5
5	0	4	C <sub>1</sub> T <sub>4</sub>	28.3	8.1	15.0
6	0	5	C <sub>1</sub> T <sub>5</sub>	29.3	8.3	30.0
7	0	6	C <sub>1</sub> T <sub>6</sub>	30.0	7.7	22.0
8	1	0	C <sub>2</sub> T <sub>0</sub>	26.0	8.0	0.0
9	1	1	C <sub>2</sub> T <sub>1</sub>	26.8	8.2	6.0
11	1	2	C <sub>2</sub> T <sub>2</sub>	27.5	8.3	18.0
11	1	3	C <sub>2</sub> T <sub>3</sub>	28.8	8.7	20.0
12	1	4	C <sub>2</sub> T <sub>4</sub>	29.0	8.9	21.0
13	1	5	C <sub>2</sub> T <sub>5</sub>	29.7	9.2	40.0
14	1	6	C <sub>2</sub> T <sub>6</sub>	30.3	7.8	29.0
15	3	0	C <sub>3</sub> T <sub>0</sub>	26.3	8.80	0
16	3	1	C <sub>3</sub> T <sub>1</sub>	27.2	9.00	9
17	3	2	C <sub>3</sub> T <sub>2</sub>	27.9	9.20	28
18	3	3	C <sub>3</sub> T <sub>3</sub>	29.0	9.40	43
19	3	4	C <sub>3</sub> T <sub>4</sub>	29.7	9.60	57
20	3	5	C <sub>3</sub> T <sub>5</sub>	29.8	9.80	64
21	3	6	C <sub>3</sub> T <sub>6</sub>	30.4	8.10	31
22	5	0	C <sub>5</sub> T <sub>0</sub>	27.4	9.40	0
23	5	1	C <sub>5</sub> T <sub>1</sub>	27.9	9.80	14
24	5	2	C <sub>5</sub> T <sub>2</sub>	28.4	10.0	18
25	5	3	C <sub>5</sub> T <sub>3</sub>	29.3	10.6	26
26	5	4	C <sub>5</sub> T <sub>4</sub>	29.9	11.0	32
27	5	5	C <sub>5</sub> T <sub>5</sub>	30.0	11.2	18
28	5	6	C <sub>5</sub> T <sub>6</sub>	30.5	11.5	12

production. This is due to the fact that the micro organisms responsible for biogas production have consumed a large amount of the substrate and hence subsequent drop in activity. More also the pH of the digester remains considerably within the range of 6.5 - 6.9, this also would have contributed to the lower volume of gas generated (Table 2 and Figure 4).

Moreover, when about 1000ml of 1, 3 and 5% wt/wt NaOH respectively was added to the partially decomposed waste, the result obtained shows a significant increase in volume of gas produced compared to that obtained without the addition of sodium

hydroxide. In addition, the pH of the digester content rose up a little above 7 (Table 3, 4, 5 and Fig 5, 6, 7).

**Statistical Analysis of Results Using Anova:** An experimental design was constructed bearing in mind the three principle guarding statistical analysis of data viz; Randomization, Replications and Local Control (See Table 6). Data obtained were fixed into a statistical software, (for the purpose of this analysis, MINITAB 14 was used) and a two way analysis of variance was performed to test the mean values of the gas collected, temperature and the pH at 95 percent confident limit. Result are shown below.

```
Source DF  SS  MS  F  P
Factor  2 10804.1 5402.0 60.29 0.000
Error 165 14783.3 89.6
Total 167 25587.4
```

S = 9.466 R -Sq = 42.22% R -Sq(adj) = 41.52%

```
Individual 95% CIs For Mean Based on
Pooled StDev
Level  N  Mean  StDev  +-----+-----+-----+-----
Temperature 56 28.425 1.489  ( ---*---)
pH 5 6 8.914 1.217 ( ---*---)
Gas Volume 56 20.643 16.282  ( ---*---)
+-----+-----+-----+-----
7.0 14.0 21.0 28.0
```

Pooled StDev = 9.466  
Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.05  
Critical value = 1.93

Intervals for level mean minus largest of other level means

```
Level  Lower Center Upper  ---+-----+-----+-----+-----
Temperature 0.000 7.782 11.233  ( ---*---)
pH -22.962 -19.511 0.000 ( ---*---)
Gas Volume -11.233 -7.782 0.000  ( ---*---)
---+-----+-----+-----+-----
-20 -10 0 10
```

Tukey 95% Simultaneous Confidence Intervals

All Pairwise Comparisons

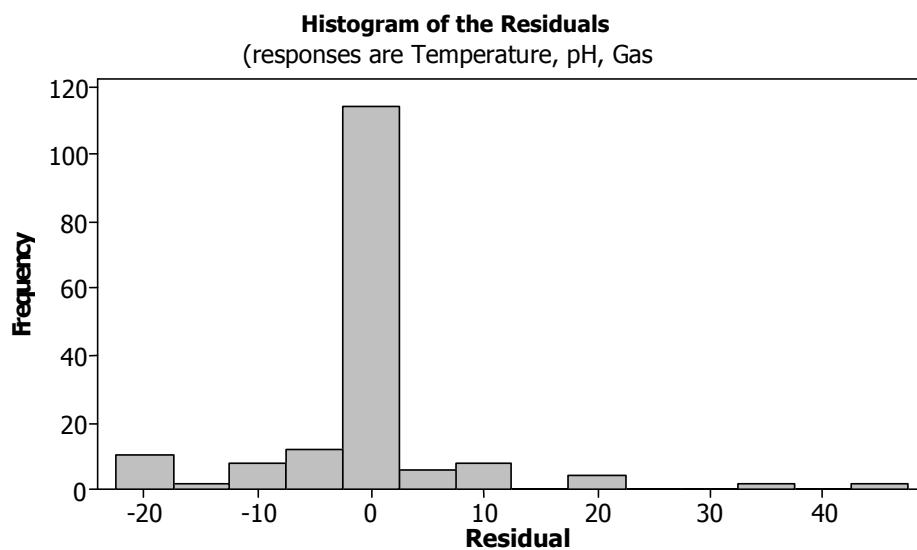
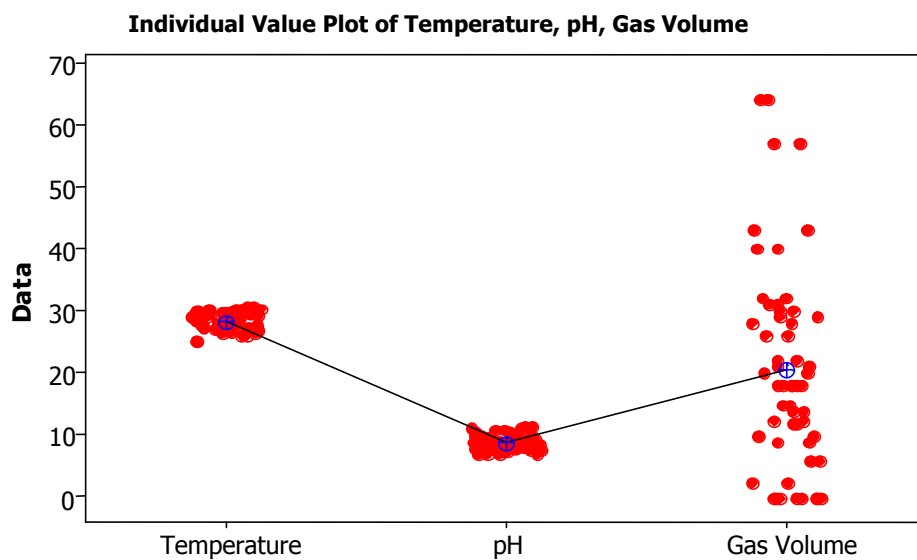
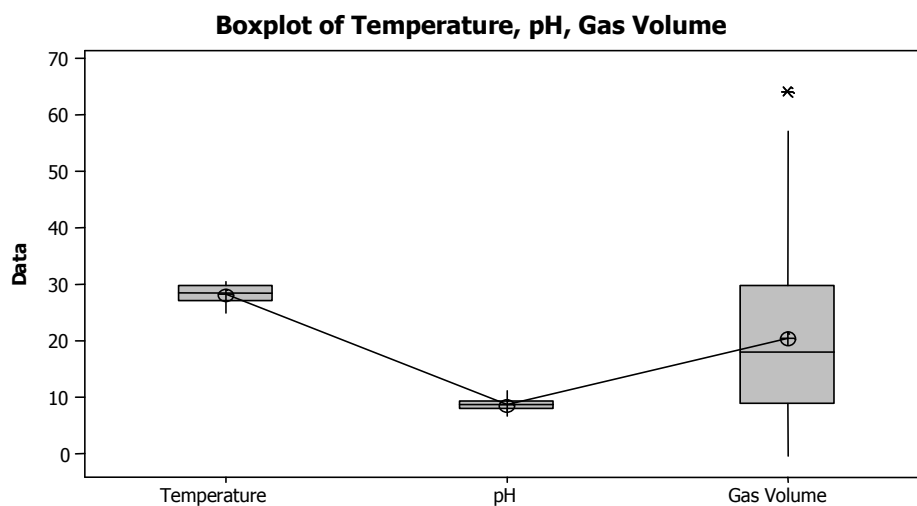
Individual confidence level = 98.06%

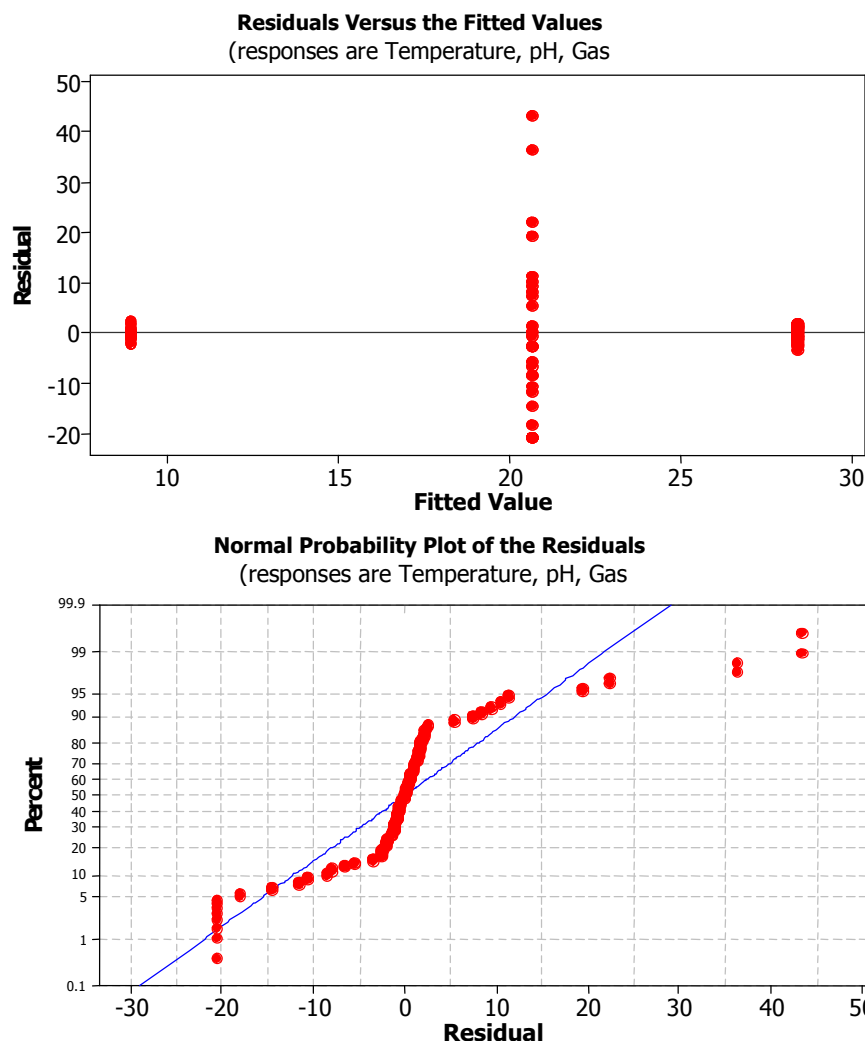
Temperature subtracted from:

```
Lower Center Upper  ---+-----+-----+-----+-----
pH -23.735 -19.511 -15.286 ( ---*---)
Gas Volume -12.007 -7.782 -3.557  ( ---*---)
---+-----+-----+-----+-----
-20 -10 0 10
```

pH subtracted from:

```
Lower Center Upper  ---+-----+-----+-----+-----
Gas Volume 7.504 11.729 15.953  ( ---*---)
---+-----+-----+-----+-----
-20 -10 0 10
```





## CONCLUSION

The results show that the addition of different strengths of caustic improved gas yield from 1 to 3% wt/wt sodium hydroxide solution, however a decrease was observed from 5% wt/wt sodium hydroxide treatment. Therefore if the pH of the system is maintained at that prevalent for 3% wt/wt caustic treatment, more gas will be produced. The statistical analysis reveals the applicability of digester as a biogas production model. The high F value of 60.29 reveal the high volume of gas generated at alkaline condition.

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