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Effect Of Temperature On Biogas Yields Using South-South Nigeria As A Case Study

P.O. Ebunilo, E. K. Orhorhoro, V. Oboh, P. U. Onochie

Department of Mechanical Engineering,
National centre for Energy & Environment
University of Benin, Benin City, Nigeria
Ejiroghene Kelly Orhorhoro correspondence, +234 8064699781
Email: Patrick.ebunilo@uniben.edu; kelecom@yahoo.com; onochieuche@yahoo.com

Abstract: This research work is aimed at investigating the effect of temperature on biogas yields using South-South Nigeria as a case study. 42.3Kg of biomass (kitchen biodegradable wastes) was mixed with water in ratio of 1:2 to form slurry which was charged into biogas digester. Digestion was allowed to take place for a period of four months; two (2) months with continuous rainfall and another two (2) months of dry season without rainfall. Performance analysis was carried out based on biogas yields and anaerobic digester parameters (i.e. temperature, pH-scale and pressure). Within a period of sixty two days (i.e. two months) of continuous rainfall, a total of ten (10) evacuations and 3.41Kg of biogas yields were obtained while a total of eighteen (18) evacuations and 7.53Kg of biogas yields were obtained during dry season at a shorter retention period. This show that the higher the mesophilic temperature, the higher the rate of evacuation and the shorter the retention period. Considering the fact that South-South Nigeria experiences more rainfall throughout the year which leads to drop in mesophilic temperature and on the other hand affect biogas yields, proper insulation of bio-digester and use of plastic digester will be preferable especially for a higher mesophilic temperation to be attained.

Keywords: Domestic Wastes, Biogas Yields, Mesophilic Temperature, Retention Period, Evacuation Rate and South-South Nigeria

INTRODUCTION

South-South Nigeria experiences more of rainfall throughout the year (Akinsanola & Ogunjobi, 2014) and this lead to drop in mesophilic temperature. The optimum mesophilic temperature for the digestion process is between 36°C-37°C (Mattock, 1984). In general, the higher the temperature inside the digester, the less time required for complete digestion of organic materials (i.e. more production of biogas) since more methanogenic bacteria are upon substrate and also more destruction for diseases causing microbes (EREC, 2002). There are three ranges of temperature at which digestion process can be occurred (Mattocks, 1984), and these ranges are:

1. Low temperature range (psycrophilic bacteria range): less than 20°C
2. Medium temperature range (mesophilic bacteria range): ranged between 20°C and 45°C
3. High temperature range (thermophilic bacteria range): from 45°C to 70°C

According to FAO/CMS (1996), the optimum temperature for the digestion process is 35°C. The temperature inside the digester should be stable, since the methanogenic bacteria are highly sensitive toward changes and variations of temperature inside the digester especially at high temperature ranges (39.4°C-51.7°C) where the productivity of the biogas dropped significantly, while it drops gradually at low temperature range (EREC, 2002). That is, a sudden or fast temperature changes reduces the production of biogas or may stop its production, so temperature monitoring is essential especially for biogas plants working at high temperature range. The most fascinating feature of any civilized society is the availability of energy for domestic, agricultural and industrial purposes (Bande, 2004). The energy problem of Nigeria is rampant across the entirely country and thus many of the energy decisions have to be coordinated between all levels of government (Julia et al, 2008). A more serious problem is our increasing population culminating in high energy demand and a limited fasted depleting energy resource which has resulted in severe energy crisis (Sambo, 2005). The energy industry in Nigeria has severe environmental ramifications, mostly in the form of both pollution and deforestation (Lukman, 2003). The available energy sources in Nigeria are woods, fossil fuels, coal, petroleum, natural gas, hydro etc, (Twinder and Weirs, 1986). The cost of energy for domestic, commercial and industrial uses in Nigeria has risen astronomically in the past few years following the liberalization and reform of the oil industry and the energy sector as a whole (Sambo, 2005). This calls for serious measures and adequate policies in perfecting utilization, exploration and exploitation of our energy sources and pursuit of new alternative energy sources and its conservation. The biogas technology is one of such systems and has been found to be cost effective and environmentally sound (Brown, 2003). It is defined as ecology oriented form of appropriate technology based on degradation of organic materials under suitable and stable temperature to produce a combustible mixture of methane gas known as biogas leaving behind slurry known as bio fertilizer (Bande, 2004). Furthermore, using of waste biomass to produce energy can reduce the use of fossil fuels, reduce greenhouse gas emissions and reduce pollution and waste management problems (Vetter et al., 1990; Marshall, 2007; Inderwildi and King, 2009, Ebunilo et al., 2015). ECN (1997) pointed out that by 2020, the equivalent of 19 million tonnes of oil will be available from biomass, of which 46% will be from biomasses majorly municipal solid wastes, agricultural residues, farm waste and other biodegradable waste streams. Biomass represents a continuously renewable potential source of methane and thus offers a partial solution to the eventual prospects of fossil fuel depletion. In addition, biomass can be economically converted to biogas at a variety of scales and thus can be tailored to supply local, regional and nationwide biogas needs. Though Nigeria has a huge biogas potential but full utilization has not been achieved. The continuous rainfall in South-South Nigeria has brought

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about drop in mesophilic temperation and this has a resulting effect on biogas yields. There is a need to investigate the effect of temperature on biogas yields and to achieved the said aim, this research work was conducted during rainy season whereby a poor mesophillic temperature is recorded and during dry season where optimum mesophilic temperature can be achieve. This research work was conducted within a period of four months, two months (2) of continuous rainfall and another two months of dry season where rainfall was not recorded.

MATERIALS AND METHODS

MATERIALS

The following materials were used in this research work: Biogas gas mild steel digester with temperature and pressure gauge attached, pH meter, scrubber, weighing scale, manual compressor, gas bottle and rubber hose. Figure 1 shown the experimental set up.

Figure 1: *Experimental set up*

METHOD

The biogas digester was pressure test for gas leakage. Collected biomass was cut into pieces to increase its surface area, and then mixed with water in ratio of 1:2. The mixture is finally charged into the biogas digesters and made air tight. The digester content was stirred several times per day with the aim of mixing the substrates inside the digester for efficient biogas generation. The continuous stirring prevents the formation of swimming layers and it can as well bring the micro-organisms (MOs) in contact with the feedstock particles. The pressure and temperature readings are taken daily while the pH reading is taken at each biogas evacuation. The gas generated is purified and compressed into a 7kg gas bottle made of mild steel material with the help of manual compressor. Before each evacuation, the initial mass of the gas bottle and the final mass after the gas is transferred are noted. The quantity of biogas generated is calculated by subtracting the initial mass of the gas bottle from the final mass of the gas bottle.

That is:

$M_{GE} = M_F – M_I$

Where;

M_{GE} = Mass of gas evacuated

M_F = Final mass of the gas bottle

M_I = Initial mass of the gas bottle

RESULTS AND DISCUSSION

RESULTS

The results obtained with continuous rainfall for a period of two (2) months and a period of two (2) month of dry season without rainfall is shown in Table one (1) and Table two (2) respectively.

P_D = Pressure reading of biogas digesters in dry season

T_D = Temperature reading of biogas digester in dry season

P_R = Pressure reading of biogas digesters in rainy season

T_R = Temperature reading of biogas digester in rainy season

M_{GE} = Mass of biogas evacuated = $M_F – M_I$

M_F = Final mass of gas bottle

M_I = Initial mass of gas bottle

$F_{EV(R)}$ = Frequency of evacuation for rainy season

$F_{EV(D)}$ = Frequency of evacuation for dry season

Table1: *Results obtained for a period of continuous rainfall (i.e. Drop in Mesophilic Temperature)*

DAY S/N	DIGESTERS READINGS				
	P_R (Bar)	T_R (^{0}C)	pH (m)	REMARKS	M_{GE} (Kg)
1	0.00	26	-	No gas	-
2	0.00	24	-	No gas	-
3	0.00	26	-	No gas	-
4	0.00	23	-	No gas	-
5	0.00	21	-	No gas	-
6	0.00	25	-	No gas	-
7	0.00	27	-	No gas	-
8	0.00	26	-	No gas	-
9	0.00	20	-	No gas	-
10	0.00	25	-	No gas	-
11	0.00	27	-	No gas	-
12	0.00	29	-	No flame	-
13	0.00	26	-	No flame	-
14	0.45	22	-	No flame	-
15	0.55	26	-	No flame	-
16	0.58	26	-	Yellow flame	-
17	0.69	28	-	Yellow flame	-
18	0.78	27	-	Blue flame	-
19	0.92	25	-	Blue flame	-
20	0.85	25	0.58	Blue flame	0.23
21	0.53	24	-	Blue flame	-
22	0.63	28	-	Blue flame	-
23	0.75	28	-	Blue flame	-
24	0.64	26	-	Blue flame	-
25	0.81	27	0.61	Blue flame	0.38
26	0.51	27	-	Blue flame	-
27	0.62	29	-	Blue flame	-
28	0.69	28	-	Blue flame	-
28	0.88	26	0.62	Blue flame	0.36
29	0.58	28	-	Blue flame	-
30	0.63	24	-	Blue flame	-
31	0.88	25	0.62	Blue flame	0.41
32	0.55	24	-	Blue flame	-
33	0.58	30	-	Blue flame	-
34	0.65	26	-	Blue flame	-
35	0.88	29	0.63	Blue flame	0.37
36	0.58	27	-	Blue flame	-

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37	0.63	28	-	Blue flame	-
38	0.64	25	-	Blue flame	-
39	0.88	28	0.63	Blue flame	0.44
40	0.51	25	-	Blue flame	-
41	0.62	28	-	Blue flame	-
42	0.73	29	-	Blue flame	
43	0.82	28	0.63	Blue flame	0.43
44	0.51	25	-	Blue flame	-
45	0.55	26	-	Blue flame	-
46	0.62	25	-	Blue flame	-
47	0.65	27	-	Blue flame	-
48	0.80	29	-	Blue flame	-
49	0.82	25	0.66	Blue flame	0.27
50	0.45	22	-	Blue flame	-
51	0.55	29	-	Blue flame	-
52	0.65	25	-	Blue flame	-
53	0.77	24	-	Blue flame	-
54	0.85	29	0.66	Blue flame	0.30
55	0.52	26	-	Blue flame	-
56	0.55	27	-	Blue flame	-
57	0.57	28	-	Blue flame	-
58	0.60	27	-	Blue flame	-
59	0.63	24	-	No flame	-
60	0.67	28	-	No flame	-
61	0.78	30	-	No flame	-
62	0.81	29	0.66	No flame	0.22

Table 2: *Results obtain for dry season (i.e. Improved Mesophilic Temperature)*

DAY S/N	DIGESTER READINGS				
	P_D (bar)	T_D (^0C)	Ph (m)	REMARKS	M_{GE} (Kg)
1	0.00	36	-	No gas	-
2	0.00	37	-	No gas	-
3	0.00	35	-	No gas	-
4	0.00	36	-	No gas	-
5	0.53	37	-	No flame	-
6	0.59	36	-	Yellow flame	-
7	0.66	38	-	Yellow flame	-
8	0.69	34	-	Blue flame	-
9	0.77	37	-	Blue flame	-
10	0.86	35	-	Blue flame	-
11	1.00	36	-	Blue flame	-
12	0.95	36	0.61	Blue flame	0.49
13	0.55	37	-	Blue flame	-
14	0.68	38	-	Blue flame	-
15	0.79	36	-	Blue flame	-
16	0.88	35	0.68	Blue flame	0.47
17	0.60	37	-	Blue flame	-
18	0.78	35	-	Blue flame	-
19	0.92	36	0.68	Blue flame	0.50
20	0.60	35	-	Blue flame	-
21	0.85	34	0.69	Blue flame	0.45
22	0.56	35	-	Blue flame	-
23	0.88	37	0.71	Blue flame	0.47
24	0.57	37	-	Blue flame	-
25	0.68	36	-	Blue flame	-
26	0.86	36	0.71	Blue flame	0.46
27	0.55	38	-	Blue flame	-
28	0.86	36	0.71	Blue flame	0.43
29	0.65	36	-	Blue flame	-
30	0.81	35	0.71	Blue flame	0.37
31	0.64	36	-	Blue flame	-
32	0.80	37	0.71	Blue flame	0.36
33	0.60	37	-	Blue flame	-
34	0.76	34	-	Blue flame	-
35	0.87	36	0.72	Blue flame	0.47
36	0.79	37	0.72	Blue flame	0.36
37	0.62	37	-	Blue flame	-
38	0.88	36	0.72	Yellow flame	0.48
39	0.59	36	-	Blue flame	-
40	0.84	36	0.72	Blue flame	0.43
41	0.77	37	0.72	Blue flame	0.30
42	0.67	36	-	Blue flame	-
43	0.96	36	0.73	Blue flame	0.48
44	0.67	35	-	Blue flame	-
45	0.90	36	0.73	Blue flame	0.47
46	0.62	36	-	Blue flame	-
47	0.73	33	0.73	Blue flame	0.34
48	0.68	34	-	Blue flame	
49	0.65	29	0.73	Blue flame	0.20

DISCUSSION

The performance analysis of average pressure reading for rainy and dry season is shown in Table three (3). The average pressure at each evacuation showed that pressure reading during dry season (good mesophilic temperature) was higher in comparison to rainy season (bad mesophilic temperature).

Table 3: *performance analysis of average Pressure at each evacuation*

S/N	P_R (Bar)	P_D (Bar)
1	0.69	0.76
2	0.67	0.73
3	0.68	0.77
4	0.70	0.73
5	0.67	0.72
6	0.68	0.70
7	0.67	0.71
8	0.66	0.73
9	0.65	0.72
10	0.64	0.74
11	-	0.79
12	-	0.75
13	-	0.72
14	-	0.77
15	-	0.82
16	-	0.79
17	-	0.68
18	-	0.67

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This simply shown that continuous rainfall has huge negative impact on biogas yields since the pressure build up is as a function of improved mesophilic temperature which resulted into good biogas yields. Also, improved average pressure value during dry season shown that hydrolysis, fermentation and methanogensis processes were faster when compared to rainy season. Table four (4) shows the average temperature reading for rainy and dry season at each evacuation.

Table4: *Performance analysis of average Temperature at each evacuation*

S/N	T_R	T_D
1	25.20	36.08
2	27.20	36.50
3	27.50	36.00
4	25.67	34.56
5	27.25	36.00
6	27.00	36.33
7	27.00	37.00
8	26.17	35.50
9	25.00	36.50
10	27.38	35.67
11	-	37.00
12	-	36.50
13	-	36.00
14	-	37.00
15	-	36.00
16	-	35.50
17	-	34.50
18	-	31.50

Good average mesophilic temperature readings at each evacuations were recorded in the dry season and this accounted for higher biogas yields at a short retention period unlike in the rainy season where biogas yields is not only poor (i.e.3.78Kg), but it took long time for digestion of substrates. Therefore, the drop in temperature prolongs digestion hence the higher the retention period. The comparative analysis of frequency of evacuation for both rainy and dry season is shown in Table five (5).

Table 5: *Comparative analysis of frequency of evacuation*

S/S/NN	FREQUENCY OF EVACUATION			
	$F_{EV(R)}$	M_{GE}(Kg)	$F_{EV(D)}$	M_{GE}(Kg)
1st	20	0.23	12	0.49
2nd	5	0.38	4	0.47
3rd	4	0.36	3	0.50
4th	3	0.41	2	0.45
5th	4	0.37	2	0.47
6th	4	0.44	3	0.46
7th	4	0.43	2	0.43
8th	5	0.27	2	0.37
9th	5	0.30	2	0.36
10st	8	0.22	3	0.47
11th	-	-	1	0.36
12th	-	-	2	0.48
13th	-	-	2	0.43
14th	-	-	1	0.30
15th	-	-	2	0.48
16th	-	-	2	0.47
17th	-	-	2	0.34
18th	-	-	2	0.20
Σn	**62**	**3.41**	**49**	**7.53**

During rainy reason, a retention period of sixty two days (i.e. two months) and a total of eleven (10) evacuations were recorded. However, that was not the case during dry season when the research work was conducted in absent of rainfall. The evacuation was not only frequent but retention period was shorter (i.e. 49 days). This shows that substrates digestion was faster during dry season (i.e. good mesophilic temperature). Also, frequency of evacuation during rainy season was not as prolong as the case of continuous rainfall (rainy season). The pH values obtained at each evacuation for dry season was better than the values obtained for continuous rainfall (rainy season), the better pH values during dry season enhanced better biogas yields. Chrish (2013) recommended a pH range of 6-8 while Niji-Qin (1993) pointed out that pH range of 7.0-7.4 will bring about optimum biogas yields.

CONCLUSION

The results of the analysis shown that for a period of two (2) months of continuous rainfall, biogas yields was hugely affected when compare to the yields during dry season when better mesophilic temperature can be achieve. The parameter analysis confirmed that throughout the period of two (2) months of continuous rainfall (i.e. drop in mesophilic temperature), the temperature and pressure readings were lower in comparison to the values obtained in dry season (i.e. good mesophilic temperature) and this affected the quantity of biogas yields (i.e. 3.41Kg for rainy season and 7.53Kg for dry season). In summary, the biogas yields rate during dry season (i.e better mesophilic temperature) is twice the quantity obtained during rainy season (drop in temperature). Besides, good mesophilic temperature increase rates of digestion and in the process reduces retention period. On the other hand, poor mesophilic temperature reduces digestion rate and consequently prolong retention period. Therefore, for a better biogas yields proper insulation of bio-digester and use of plastic digester will be preferable especially for a higher mesophilic temperation to be attained in South-South Nigeria.

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