

A Preliminary Investigation into the Effect of Ambient Temperature on Biogas Generation using Cow-Dung from Afaka-Kaduna for Household Cooking

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Abstract - This paper presents an exploratory investigation of the feasibility of generating biogas from the surplus cow-dung available in Afaka, Kaduna for possible use as an alternative renewable environmentally friendly cooking fuel in pursuant of the Kyoto Protocol which Nigeria is a signatory. The investigation was carried out in a continuous mode operated VACVINA type bio digester charged with cattle slurry and specifically the effect of ambient temperature on the slurry temperature and the pH was monitored alongside biogas yield over a retention time of 21 days. Within this period, ambient temperature varied between 26^oC and 30^oC while the variation in slurry temperature was between 29^oC and 32^oC and the pH value fluctuated between 6.1 and 7.0. The results showed that ambient temperature rise tends to increase the slurry temperature and pH value. However, towards the end of the retention days, there was slight drop in pH value. The gas generated was low but deflected the pressure gauge at 8mmHg and 2mmHg in the first and second week of the experiment and none in the third week. Despite the low gas yield, this result demonstrates that the cow-dung in Afaka can be a viable alternative cooking fuel to fossil fuels used presently.

Keywords – Cow dung, ambient temperature, slurry temperature, pH value, biogas

I INTRODUCTION

Nigeria is blessed with abundant and diverse energy sources comprising of renewable and non-renewable sources. However, this huge energy potentiality has not been exploited effectively and efficiently to cater for the ever increasing energy needs. The energy consumption pattern in Nigeria has been shown to be in the industrial, transport, commercial, agricultural and household sectors of the economy with the household sector accounting for about 65% [1] of the total energy. Accordingly, the major energy consumption pattern in Nigeria households includes cooking, lighting and use of electrical appliances and cooking alone constitute 91% [1].

Of all the energy resources available in the country, fuel wood, kerosene, liquefied petroleum gas (LPG) and electricity have been identified as the major forms of cooking [2]. Among all these forms, fuel wood remains the most favorite partly because of its accessibility, convenience, tradition and vegetation distribution [3]. In spite of its choice as the most convenient form of cooking, its use has been associated with public health issues, rapid deforestation and desertification, soil erosion, biodiversity loss and flooding [4,5]. Furthermore, kerosene, LPG and electricity are petroleum derived and the issues with petroleum are its finite nature, increase in prices and inadequate supply. There is,

therefore, the need to develop and make available alternative energy source that is efficient, cheap and environmentally friendly.

Biogas is a combustible gas mixture produced by the anaerobic digestion (AD) of biomass by bacteria and takes relatively short time to be generated. The available biomass for the production of biogas in Nigeria include water lettuce, water hyacinth, animal dung, cassava leaves, urban refuse, solid waste, agricultural residues and sewage [6]. Typical composition of biogas is given in [7].

Several factors influence biogas generation, these include bio digester temperature (slurry temperature and ambient temperature), pH value of the slurry, loading rate, carbon/nitrogen ratio, nature and type of feedstock, hydraulic retention time, agitation and volatile fatty acids. Each of these factors influence AD in a unique way providing the necessary and right conditions for the bacteria responsible for the breaking down of the feedstock to act. AD is strongly affected by temperature [8, 9] as it increases the metabolic and growth rates of chemical and biochemical reactions within the tolerances of the bacteria. Furthermore, methanogenic bacteria are more sensitive to changes in temperature than other organisms present in the digester because other groups of organisms in the bio digester such as acetogens grow faster and achieve catabolism even at low temperatures [9]. Two conventional operational temperatures levels Mesophilic and Thermophilic for ADs have been reported in literature which are determined by the species of methanogens in the digesters [10]. It was also revealed in [10] that Mesophilic operational level takes place optimally around 30°C to 38°C corresponding to ambient temperatures of 20°C and 45°C while mesophiles which are the primary bacteria present operates 35°C for optimum biogas generation. For thermophilic, digestion takes place optimally around 49°C to 57°C or at elevated temperatures up to 70°C and thermophiles are the primary organisms present. A third temperature level, Psychrophilic, was identified to operate between 4°C and 15°C [8]. However, there are exceptional cases where ADs functioned in temperature conditions less than 10°C. For example in Tongliang China biogas is generated between 6°C-10°C though with insufficient gas yield [11]. It is

worth noting here that the temperature of Kaduna falls within the mesophylic range, thus suitable for biogas generation.

pH influence biological reactions significantly. Also, most micro-organisms grow best under neutral pH conditions, since other pH adversely affect metabolism altering the chemical equilibrium of enzymatic reaction or by actually destroying enzymes and methanogenic bacteria have been adjudged the most sensitive to pH [12]. Low pH can cause the chain of biological reaction in digester to cease [12].

In a related study, in determining the effect of pH on the value of gas produced from cowpea, cassava peelings, the pH value of the digester slurry was disclosed to be an important indicator of methane organic performance [13]. The use of pH value alone to check the digester environment was and that gas can be produced between pH of 6.6 – 7.6 with the highest production achieved at pH 7.0 and 7.2. It was equally observed that beyond these pH limits, digestion proceeds with less efficiency. The pH can be checked periodically during fermentation as rapid change in pH can result due to fluctuation in temperature or loading rate which may result in rapid production and Volatile acid capable of inhibiting methanogenesis.

The objective of this paper therefore is to determine the effect of the variation of ambient temperature on the slurry temperature and pH value in VACVINA Model bio digester with different retention times, fed with wet cow-dung from Afaka community in Kaduna with the view of possible generation of biogas as a prospective environmentally friendly cooking fuel within the community.

II Study Area

Study area, Kaduna, is situated at latitude 10° 31' 20.06" North, longitude 7° 26' 17.81" East and 616 meters elevation above sea level [14] with two distinct seasons, rainy season and dry season from April to October and November to March, respectively. The vegetation extends from guinea savanna in the southern part of the state to the sudan savanna in the northern part [15]. This experiment was carried out in the month of May which is in the raining season with an average high and low

temperatures of 32.6⁰C and 22⁰C respectively, and an average precipitation of 125mm [C].

III. MATERIALS AND METHOD

The materials used for this study include an already existing VACVINA type bio digester, Coleparmer thermocouple digital meter model 8500-40, Bokang CE 0197 pressure meter, JeanWay 3020 pH meter, thermometer, a semi automatic weighing balance serial no. 8206 and wet cow-dung. The wet cow-dung was obtained from a Fulani Settlement in Afaka, Kaduna. About 15kg of the wet dung was diluted with water in the ratio 1:5. The resulting slurry was thoroughly stirred in a drum and then charged into the bio digester fitted with a pressure gauge. The top cover was properly sealed and made air tight. From the next day onwards measurements of the ambient temperature, slurry temperature and pH commenced and was carried out daily everyday at 1400hrs over a period of 21 days (3 weeks) using thermometer, thermocouple and pH respectively. The pressure of gas yield was also monitored using the pressure gauge. The set up of the experiment is as illustrated in figure 1.



Fig 1: Experiment set up.

IV. RESULTS AND DISCUSSION

The results of the weekly variation of slurry temperature and pH with the ambient temperature over 21 days retention time are presented per week and shown in figures 3,4 and 5 respectively.

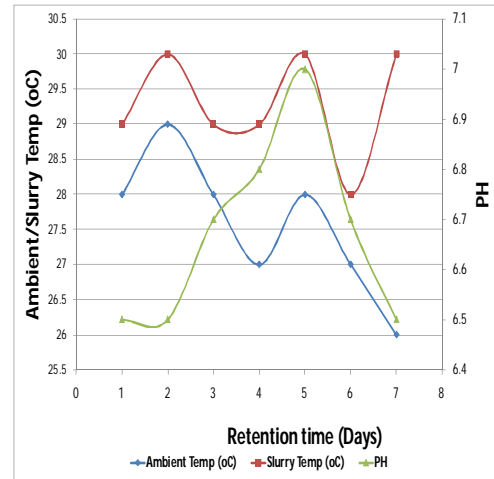


Fig 2: Plot of the Variation of Ambient Temperature and pH versus Retention Time for week one

From figure 2, it was observed from the ambient temperature curve that, the minimum temperature and maximum temperature occurred in 7th and 2nd days, respectively. The curve depicts a rise and a sharp drop in temperature. However, within the digester a minimum slurry temperature of 28⁰C was recorded on day 6th day and maximum of 30⁰C on the 2nd, 5th and 7th days. Generally ambient temperature fluctuated between 26⁰C and 29⁰C while the slurry temperature fluctuated between 28⁰C and 30⁰C. The observable trend is that as the ambient temperature increases the slurry temperature also increases depicting the heating up of the slurry. While on the other hand, the pH remained constant for first and second days. However, there was a sudden rise on the 5th day and fall on the 7th day from 7.0 and 6.5, respectively on the pH scale.

The result for week 2 is shown below:

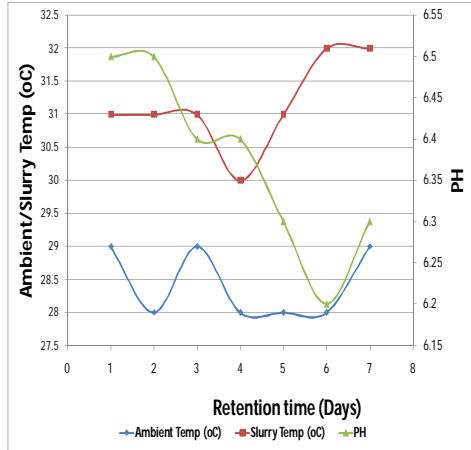


Fig 3 : Plot of the Variation of Ambient Temperature and pH versus Retention Time for week 2

For week 2 the ambient temperature varied between 28^oC and 29^oC while the slurry temperature varied between 30^oC and 32^oC. Even though this ambient variation is similar to that of week 1, the slurry temperature attained was higher than that of week 1. However, the pH fluctuated between 6.2 and 6.5 lower in value than that of week 1. In all, there was an appreciable increase in slurry temperature of +2^oC and an increase of average of 0.3 for pH.

The result for Week 3 is shown below:

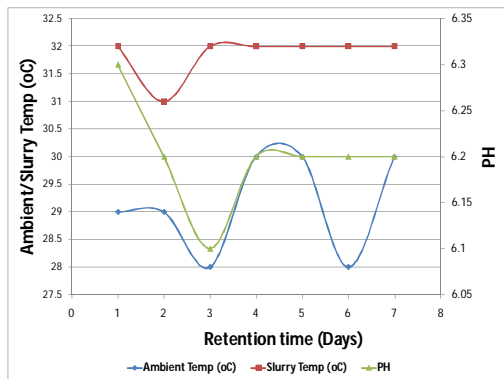


Fig 4 : Plot of the Variation of Ambient Temperature and pH versus Retention Time for week 3

The graph shows a variation of ambient temperature between 28^oC and 30^oC while slurry temperature oscillated between 31^oC and 32^oC. However the curve pattern depict a constant slurry temperature from the 3rd to 7th day, whereas the pH value fluctuated between 6.1 and 6.3 indicating further drop with respect to week 2

Hence, it was deduced that, ambient temperature varied between 26^oC and 30^oC while slurry temperature oscillated between 29^oC and 32^oC, over a retention period of 21 days. From this, there was an increase of +3^oC and +2^oC in ambient temperature and slurry temperature respectively, indicating an appreciable effect. This trend is in agreement with the findings of [9] and [14] although, during the experimentation, the optimum mesophilic temperature of 35^oC was not attained. This may not be unconnected to the season (rainy season) because ambient temperatures are generally low during this season. Furthermore the possibility of water seeping into the biodigester is not ruled out. However, pressure gauge records of 8mmHg and 2mmHg for week 1 and 2, respectively which implied that gas had actually been generated. Indeed, for week three very slight deflection of pressure gauge was observed. It was generally observed that the shape of the curves of ambient and slurry temperature from figure 2, 3, and 4 is somewhat sinusoidal, suggesting a mutual relationship between the two parameters. As mentioned earlier, the conducive pH values for biogas generation is between 6.6 –7.6 with highest production at pH scale of 7.0 and 7.2 [11]. The pH range deduced is 6.1 – 7.0. The lowest pH value of 6.1 was observed in week 3, and this may be attributed to the very low gas yield, from the aforementioned pressure records. This condition is definitely not suitable for methanogenic bacteria activities. However, the range for week 2, is 6.2 – 6.5 indicating a drop from the previous week. The trend of the pH variation with gas yield was in agreement with [12].

V CONCLUSION AND RECOMMENDATION

A preliminary investigation into the feasibility of generating biogas from Afaka in Kaduna was carried out, though emphasis was on the variation of the slurry temperature and pH, and monitoring of gas yield generation. The result of the investigation reveals that ambient temperature rise increases the slurry temperature and so also the pH. However, the pH was observed to have dropped in the second and third week of this investigation. Nevertheless, gas yield corresponding to 8mmHg and 2mmHg in the first and second weeks respectively were recorded with very little yield in the third week. Generally,

even though gas yield was low, the result show that biogas generation from the cow-dung is feasible. However this experiment cannot be said to be void of human errors for which further work is recommended specifically an extra investigation to be conducted considering all of the other factors that could affect biogas yield Perhaps if other factors such as concentration of volatile fatty acids, carbon/ nitrogen ratio, even the addition catalyst (CaOH) etc would have stabilized the pH and increased biogas yield.

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