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Co-Digestion of Aksu Cafeteria Waste with Cow Dung for Biogas Production and Its Fertilizer Application

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Abstract According to World atlas statistical record, about two third of the countries (Omar, Qatar, Kuwait and Saudi Arabia) still obtain the source of income from fossil fuel and its derivatives. Surprisingly, these countries solely depend on this source of energy up to 100% .So depressing that apart from its adverse effect on the economics of the countries, fossil fuel and its derivatives negative impacts on the health and the environment cannot be overlooked. Meanwhile, the use of renewable energy as a replacement for fossil fuel and its derivatives are faced by the high cost of investment for renewable energy, and high local electric energy prices. This research work evaluates the desirability of investing in renewable energy sources by making use of kitchen waste co-digested with cow dung over the use of fossil fuel and its derivatives for electricity generation.

Freshly harvested cow dung was mixed with milled kitchen waste in the ratio of 1:2 and the mixtures were dissolved in distil water to make a slurry. The slurry pH was adjusted to neutral point (pH = 7) before loading into the anaerobic digester. The digester reaction was monitored three times daily for 60 days within the mesophilic temperature ranges of 22 ^{o}C – 40 ^{o}C and pH range of 3.5 – 8.3 to obtained the biogas. Properties such as ash content, soil test and microbial count load of the substrate and digested were carried out.

Results showed that the highest volume of biogas at 54th day, after which the decelerations phase, occurred. The results of the microbial load count produced 18 x 10^4 Cfu/ml for the dilution factor of 10^{-3}. While dilution factor of 10^{-4} gave an average load count of 5 x 10^5 Cfu/ml. The ash content analysis results showed that the dry sample with initial weight of 17.0861 g and final weight of 0.176 g, respectively, eliminate inorganic and other volatile contents of 98.97%. Furthermore, the soil test of the solid residue using Zea Mays seeds showed improved growth of the crop and yielded good product.

The study concludes that co-digestion of cow dung mixed with kitchen waste could serve as a good material for production of a renewable biogas and its end product could serve as alternative conventional fertilizer.

Keywords Cow dung, kitchen waste, biogas, microbial analysis, ash content analysis, soil test

1. Introduction

The major driving force for every nation is the Energy as it is essential for social and economic development which has its usefulness across most sectors of a nation's economy. Surprisingly, most of these nations solely depend on this source of energy up to 100% (Omar, Qatar, Kuwait and Saudi Arabia) because of technology improvement. It's so sadden that apart from its adverse effect on the economics of the countries, fossil fuel negative impacts on the

health and the environment cannot be overlooked [1]. Meanwhile, the use of renewable energy as a replacement for fossil fuel and its derivative are faced by the high oil prices, high cost of investment for renewable energy, and high local electric energy prices. Biogas is a biofuel that is one of renewable sources of energy. It's a gas made by an anaerobic digestion process (biological breakdown of organic matter in the absence of oxygen) [2]. The digestion technique converts biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and crops to produce biogas. Biogas which is composed mostly of methane and carbon dioxide, alongside other components undergo four biochemical processes to be formed, which includes Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis. In this study, the production of biogas was carried out using cattle dung and kitchen waste.

Kitchen waste for example is an organic material which has been reported to have a high energy value and nutritious value for microorganisms [3]. Although, plan to turn kitchen waste into energy through different modern day technology has been possible carried out, however, optimum energy recovery and low release of energy was found economical possible through anaerobic digestion [4].

Dung, a waste product that can be obtained from animal such as domestic cattle (cows), bison (buffalo), yak and water buffalo [5]. Cattle especially, contribute to the atmospheric methane through their slurry/manure when anaerobically stored [6] . Biogas production from the manure is produced through microbial digestion of soluble lipids, celluloses, carbon-based acids, and proteins [7]. In view of these, this research work utilized the combination of kitchen waste with cow dung for biogas production.

2. Materials and Methods

2.1. Materials

Freshly harvested cow dung was obtained from a slaughterhouse in Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria Fig. 1a).

The kitchen waste was collected from the School Cafeteria of Akwa Ibom State University, Ikot Akpaden, Mkpat Enin Local Government Area, Akwa Ibom State, Nigeria (Fig. 1b). The kitchen waste was milled to achieve a particle size that will enable proper mixing and digestion process. All chemical and reagents used were of analytical grades made by GFS Chemicals, Inc., 867 McKinley Ave., Columbus OH 43223 (99.7-100%) and BDH Analar Ltd., Poole England (99%).

(a) (b)

Figure 1: Cow dung and Kitchen Waste

2.2. Methods

2.2.1. Biogas reactor (digester) design with gas collection system.

A 205 L drum of 58 x 87.5 cm was purchased and redesigned into an anaerobic digester. The drum was made of steel and in cylindrical shape for stability and better mixing of the substrate. The digester drum was painted black in order to absorb heat energy from the sun during the day [8]. The digester was perforated with three openings at the top which serves as substrate inlet, gas outlet and thermometer fixture point. A pressure gauge is provided at the side of the digester to read odd pressure generated by biogas produced in the reactor. At the bottom of the bio reactor is a

tap is fitted to collect samples of the substrate in the digester for daily experimental analysis. The produced biogas is collected first in the air-tight container with water working on the principle of water displacement system for easy measurement of the volume of biogas produced daily. The displacement system is dependent on the pressure and volume of gas produced. The base area (γ) of the displacement container was computed using Eq. (1) whereas the biogas volume was obtained as the height of the collection container above the water level and multiplied by the γ. The raw biogas collected in the water jacket setup is passed through a CO_2 purification system, an air-tight container containing activated carbon pellets to selectively adsorb carbon dioxide from the biogas. The purified biogas was passes into a gas cylinder for further use.

$\gamma = \pi r^2\{r + (h^2 + r^2)^{0.5}$ (1)

\Where

$r = 0.12m \quad d = 0.24m \quad h = 0.2m$

$\gamma = \pi(0.12)^2(0.12 + (0.2^2 + 2^2))^2 = 1.06672\ m^2$

$\beta = \gamma\ h$ (2)

$\beta = 1.06672\ h\ m^3$

Where h is the height of the gas collection container above the water level

2.2.2. Slurry preparation

The kitchen waste particle size was reduced using a hammer milling machine in order to increase its surface area for microbial activity. It was mixed with the freshly harvested cattle rumen content in the ratio of 1:1. The substrate mixture was then made into slurry by adding warm distilled water of 50 ^oC in the ratio 1:1.5 feed/water.

2.2.3. Experimental Procedure

The digester was loaded mechanically with 150 L of feed slurry. A retention time of 60 days was allowed for the experiment within 08:00 hours, 12:00 hours and 16:00 hours daily, readings were carried out and parameters determined from the biogas produced. The basicity or acidity of the digester content was measured using the pH scale to ensure the pH is within optimal conditions (6.7 to 7.99) for biogas production. The mercury-in-glass thermometer was used to monitor and measure the temperature of the digester content. The volume of biogas (β) produced was determined by measuring height of the gas holder floating over water level in the water jacket daily and calculated using Eq. 2. The anaerobic digested was stirred manually by turning the stirrer rod handle at the top of the reactor daily to ensure uniform microbial activity in the digester. The experiment continued until the volume of biogas produced reached its peak and started declining. After the retention time of 60 days, the digestate sample was collected for analysis.

2.3 Analysis of physicochemical properties of the substrate

The physicochemical properties of the substrate such as microbial analysis, ash content were carried out using the sterile method. Also soil test of the digestate will be carried out to determine the potential of the digestate as a high nutrient fertilizer for agricultural application.

2.3.1. Ash Content (%)

The method adopted by [9] was adopted with little modification. An empty crucible was fine polished and weighed. About 17 g of dried sample was weighed out and total mass of both crucible and sample calculated. The sample was transferred into the crucible which was placed into the box furnace at 600 ^oC for 4 h. The heater was allowed to cool for about 8 hours before the crucible was removed and re-weighed to determine the new weight.

The percentage of ash content (AC) of the sample was evaluated using Eq. (3).

$AC\ (\%) = \frac{\delta - \alpha}{\theta}$ (3)

Where δ= weight of crucible + ash

α = weight of crucible

θ = weight of sample to be determined in grams before ashing

2.3.2. Soil test

At the end of the retention time of sixty (60) days, the solid residue from the digester was collected and sun dried for three (3) days. The dried digestate was collected and mixed with loamy soil collected from the farm of the Department of Agricultural Engineering and placed in polyethylene bag and labeled 'soil B'. Also same loamy soil was placed in another bag and labeled 'soil A'. Both soil bags were planted with three *zea mays* seeds and placed in the greenhouse of the Department of Agricultural Engineering. During the growth period, the plant was watered and growth stages of both plants recorded. The plants were later transferred to the farm for the remainder of the growth stages until the plants reach maturity stage and yield cobs.

2.4. Microbial analysis

Empty test tubes and petri dishes were laid out and labeled; the lids of the test tubes 0 and 1 were flamed and loosened. A sterile pipette was used to transfer 1 ml of liquid from tube 0 to plate 0 and same pipette was used then to transfer 1 mil of liquid from the source culture containing the slurry separately (tube 0) to tube 1. Then the pipette was discarded, while the edge of tube 1 was flamed and then sealed. Contents of the sealed tube 1 were then mixed gently to achieve homogeneity. These steps were repeated five (5) more times moving along the chain.

After the steps had been accomplished, a conical flask containing sterilized nutrient agar was taken from the 45 ^{o}C water bath and the exterior dried. The top and neck section of the flask was then flamed. All these steps were carried out in the fume cupboard. Opening the petri dish lid a little, the nutrient agar was poured into the dilution liquid in the dish until it covers about two thirds of the area. The dilution liquid and introduced nutrient agar will be mixed by gentle swirling action and then the petri dish will be flamed.

These steps were repeated for another set of petri dishes using spread method to determine which media will have most growth between spread and pour method.

The petri dishes were left flat in the fume cupboard and set for 15 min. The dishes will then be sealed, overturned and placed in the incubator at 37 ^{o}C for 24 h.

After 24 h, the petri dishes were examined without opening the individual colonies of the dishes with dilution factors 10^{-3} and 10^{-4} of each source culture were counted using the colony counter. The results of the counting using the colony counter were recorded and the microbial load count (MLC) will be calculated using the expression in Eq. (4) below;

$$MCL\ (Cfu/ml) = \frac{A_c}{D_f I_s} \quad (4)$$

Where, A_c = average colony, D_f = dilution factor, I_s = innoculum size

3. Result and Discussions

3.1 Biogas Production

Fig. 2 (a-c) show the plots of biogas production whose readings were obtained thrice daily, while figure 2d to 2f shows a plot of average production for readings taken three times daily (morning, noon and evening). It was noted that between the first (1st) day and the third (3rd) day, volume of biogas yield was 0.01173390171 m^3 which increased to a volume of 0.01600077506 m^3 on the eleventh (11th) day. The volume production declined back to 0.01493405672 m^3 on the sixteenth (16th) day. From the twentieth (20th) day, production increased to 0.01493405672 m^3 which remained stable till the twenty-second (22nd) day. Much considerable increase was recorded from the twenty-third (23rd) day which yielded 0.01813421173 m^3 to the forty-first (41st) day yielding 0.02346780341 m^3. Exponential growth phase was found to set in from the forty-fourth (44th) day where the yielded volume was 0.02881395099 m^3 and continued increase until the fifty-fourth (54th) day when the highest volume of 0.045868888491 m^3 was recorded. Deceleration phase set in right after with the yield dropping to 0.038401860132 m^3 on the fifty-sixth (56th) day. The decline continued right up until the end of the retention time of the sixty (60) days, with a volume of 0.02560124088 m^3.

Fig. 2e shows the graph of average daily temperature recorded in the research work. From the graph, the temperature has been found to not stay within the mesophilic range (30 ^{o}C – 40 ^{o}C). This is attributed to the weather conditions of the experiment area which is having an adverse effect of production rate also. Since methane producing bacteria operate efficiently at mesophilic ranges, it affected the length of retention time for biogas production to reach peak volume and decrease. During the exponential growth phase period, the temperature of the medium was found to be between 31 ^{o}C – 42 ^{o}C, during which the highest yield of volume on the fifty-fourth (54th) day had a temperature of 39 ^{o}C. This shows that increased activities of the microbes requires considerable increase of temperature.

Fig. 2f shows that the average daily pH of the medium recorded has be found to be varying erratically between the acidic to basic range. This can be attributed to the nature of feed in the digester.

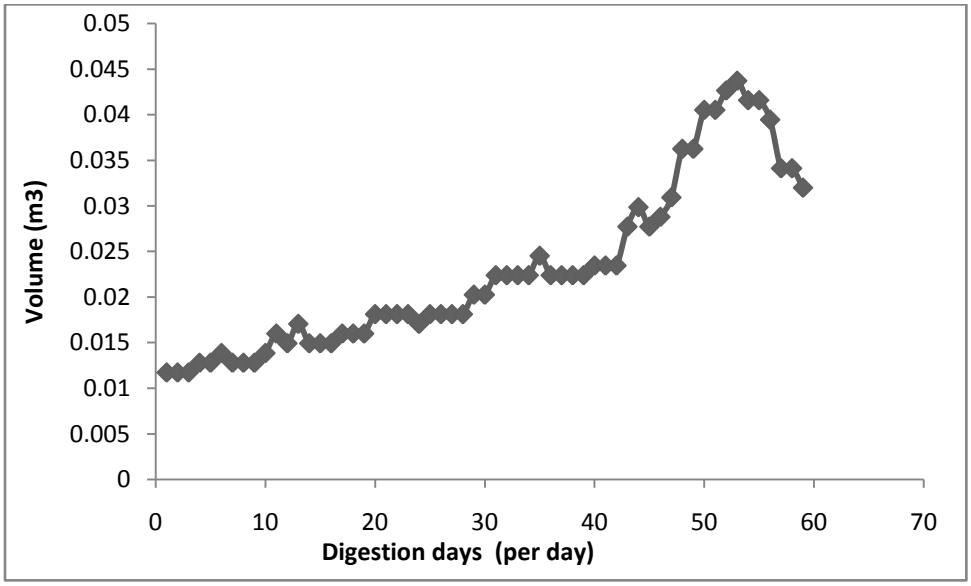

Figure 2a: Morning daily volume of biogas produced and digestion days

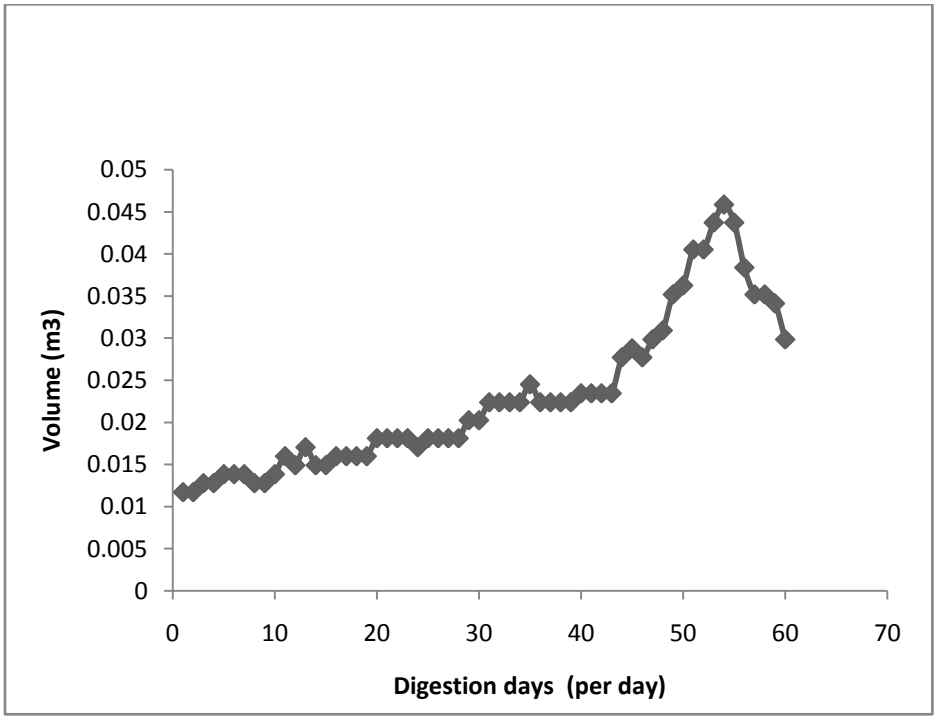

Figure 2b: Noon daily volume of biogas produced and digestion days.

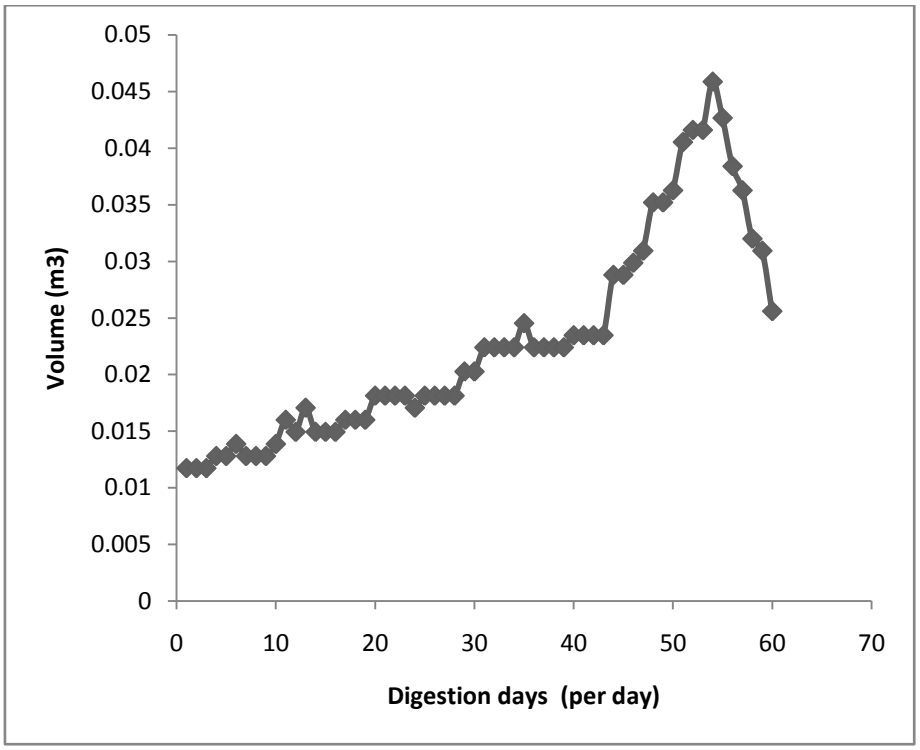

Figure 2c: Evening daily volume of biogas produced and digestion days

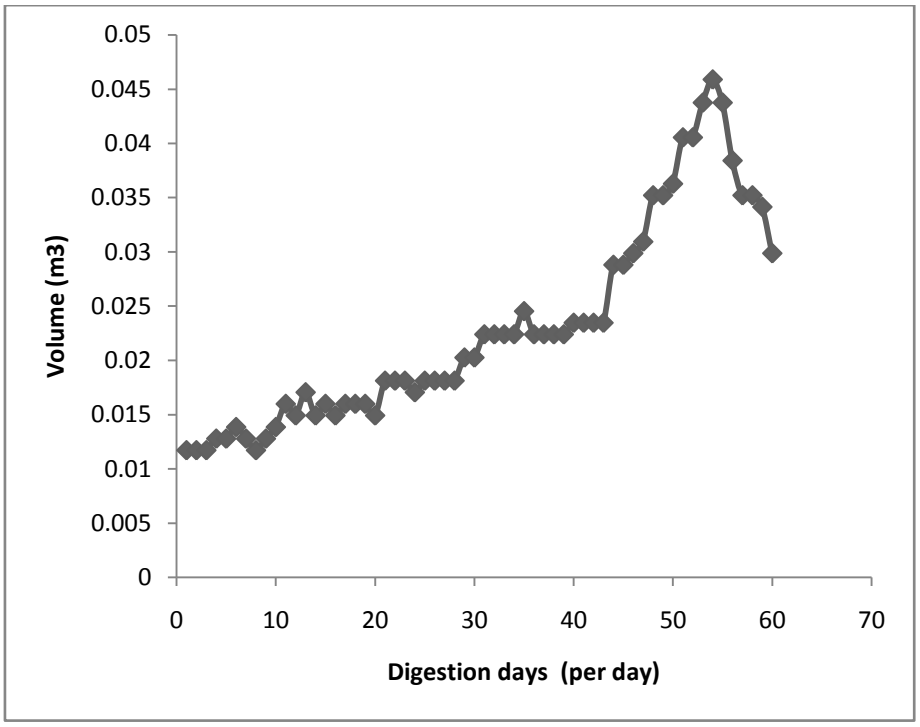

Figure 2d: Average daily volume of biogas produced and digestion days

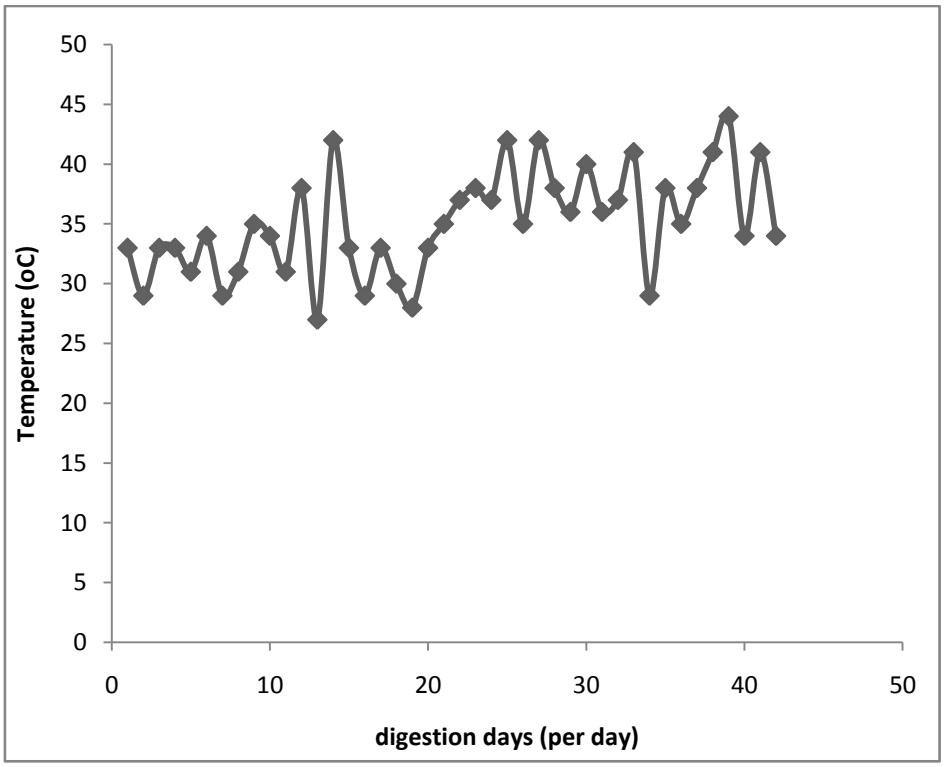

Figure 2e: average daily temperature readings and digestion days

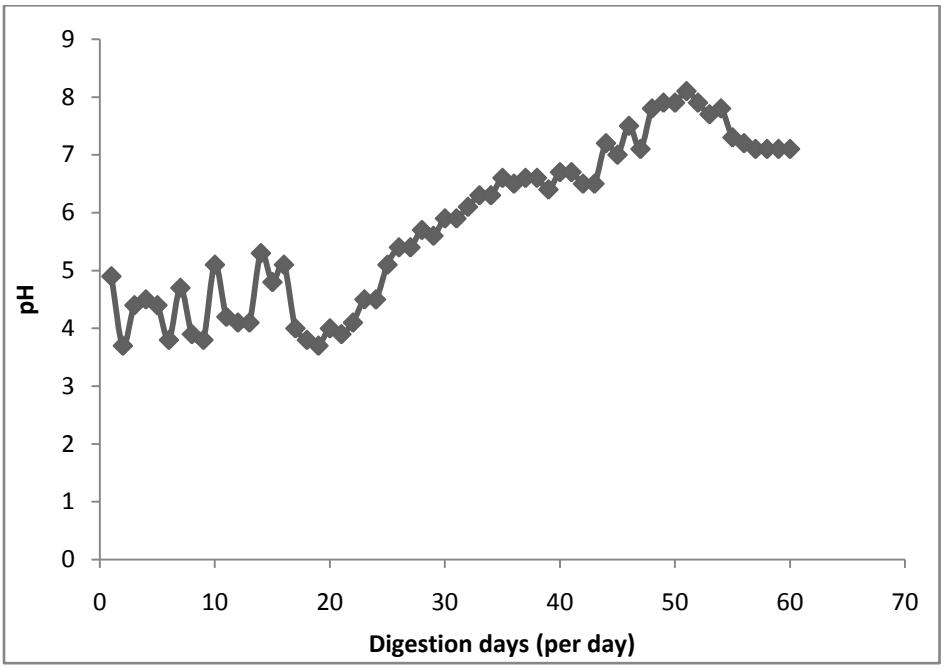

Figure 2f: Average daily pH readings and digestion days

3.2. Microbial Analysis Results

The results from the microbial analysis showed that the substrate contains the methane producing bacteria (methanogens). Also, the results showed that the spread method using for introduction of the diluent into the petri dishes containing nutrient agar before incubation showed significant microbial growth than the pour plate method.

The average microbial load count (MLC) was obtained to be 18 x 10^4 colony forming unit (Cfu/ml) for the dilution factor of 10^{-3}. While dilution factor of 10^{-4} gave an average load count of 5 x 10^5 Cfu/ml. The MLC is predicted to increase as production of biogas increases due to the growth of microbes which aids the completion of anaerobic reaction. The count decreased as volume of biogas produced reduced due to the exhaustion of substrate for the microbes, which results in the gradual death of the methane producing bacteria until the count reduces to zero.

3.3. Ash Content Analysis Results

From the ash content analysis of the substrate carried out, results showed that the dry sample with initial weight of 17.0861 g and final weight of 0.176 g, lost inorganic and other volatile contents of 98.96992292%. As the biogas production progresses to the final stages where volume produced declines, the ash content will be found to decrease further as found to be in line with [10] report.

3.4. Soil Test Results

For the soil test to show the importance of the solid residue of the digestion process as rich fertilizer, the results showed that the *zea mays* seeds planted in the loamy soil mixed with dried digestate (soil B), showed significant improvement in comparison to the other seeds planted in just loamy soil (soil A). Plant of soil B started germination from the third (3^{rd}) day of planting while plant of soil A began its germination on the sixth (6^{th}) day. This can be attributed to the increase in degree of metabolic reactions which began in soil B catalyzed by nutrients in the digestate. Other factors include soil temperature, residue on the soil surface and planting depth of the soil. Maturity stage of soil A was reached on the one hundred and twenty-third (123^{rd}) day while that of soil B was reached at one hundred and eighteenth (118^{th}) day.

This shows that soil enriched with solid residue from the anaerobic digestion process is a rich nutrient fertilizer and the application of the digestate for agriculture uses up the residue from biogas production and completes the carbon cycle.

4. Conclusions

i. The biogas production was greatly influenced by temperature, amount of slurry load and pH of the medium.
ii. For production of biogas, pH of the medium needs to progress from acidic to alkaline during production, then to neutral point when production declines.
iii. Microbial analysis was used to determine the amount of methane forming bacteria in the medium. Regular results of this analysis shows amount of microbes available for the anaerobic digestion process.
iv. Temperature of the medium was been found to be within the mesophilic range (30 ^oC – 40 ^oC) during which production took place.
v. The removal of Carbon dioxide by use of activated carbon in the purification system has been found to increase the combustibility of the biogas. This also allows compressibility of the biogas in the collector cylinder.
vi. The spread method for microbial analysis was found to have faster microbial growth than the pour method. This method allows for convenient microbial load count using the colony counter.

References

[1]. Adepoju T. F., Olatunbosun B. E., Olatunji O. M., Mayen, I. "Brette Pearl Spar Mable (BPSM): A potential recoverable catalyst for renewable source of biodiesel from *Thevetia peruviana* seed oil for sustainable development in West Africa", Energy, Sustainability and Society, (), 1-142018, Doi 10.1186/s13705-018-0164-1

[2]. Gerardi, M. "The Microbiology of Anaerobic Digesters", Waste water Microbiology Series. John Wiley & Sons, Inc. United States of America, 2003.

[3]. Suyog, V. "Biogas Production from Kitchen Waste", Department of Biotechnology and Medical Engineering National Institute of Technology, Rourkela. Pp. 8-15, 2010.

[4]. Laxman, B.K., Lana, K. L., Sunil, T. K., Prasas, L., Ram, L., Jhalak, A." Production of Biogas from Kitchen Waste", Rentech symposium compendium, Vol. 2. Number 1, 2012.

[5]. Adepoju, T. F., Babalola, R., Olatunbosun B. E., "Thermophilic Anaerobic Co-digestion of An Alkali Treated *Musa sapientum* Plant Waste (MSPW) and Cattle Dung for Biogas Production and Its Statistical Analysis: a case of response surface methodology (RSM)" *Chemistry Research Journal*,1(4): 44-53, 2016a. file:///C:/Users/User/Downloads/chemrj-2016-01-04-44-53.pdf

[6]. Meaza, M. M., Tadesse, T. K. and Yohaness, G. B., "Biogas potential from cow manure – Influence of diet", Uppsala BioCenter Master thesis. Department of Microbiology Faculty of Natural Resources and Agriculture Sciences Swedish University of Agricultural Sciences Uppsala. ISSN 1101-8151 ISRN SLU-MIKRO-EX–10/3–SE, 2010.

[7]. Yamulki, S. "Effect of straw addition on nitrous oxide and methane emissions from stored farmyard manures", Agriculture, ecosystems and environment, 112:140–145, 2005.

[8]. Adepoju, T. F., Eyibio, U. P., Olatunbosun, B. "Optimization investigation of biogas potential of *Tithonia diversifolia* as an alternative energy source in Nigeria. *International Journal of Chemical and Process Engineering Research*, 3(3): 46-55, 2016b. DOI: 10.18488/journal.65/2016.3.3/65.3.46.55 ISSN(e): 2313-0776/ISSN(p): 2313-2558.

[9]. Oni, O. O. "Optimization Investigation of Biogas Potential of Biogas Potential of *Tithonia Diversifolia* as an Energy Source in Nigeria", Final year project thesis pp. 5-16, 2015.

[10]. Owamah, H., Alfa, M. and Dahunsi, S. "Optimization of biogas from chicken droppings with *Cymbopogon citratus*" Renewable Energy, 68, 366-371, 2014.