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Development of Biofertilizer from Locally Sourced Materials

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ABSTRACT

The appropriate rationing of NPK is a core problem in biofertilizer production. In this study, a 30-liter bench-scale anaerobic biodigester for biofertilizer production from solid waste was fabricated using galvanized steel sheet. About 4Kg of chicken dung, 7.5 kg of wastewater treatment sludge, and 0.5 kg of banana peel were mixed, a total of 12kg, the substrate was then mixed with water in a ratio of 1:1. (w/w) 24 kg of the slurry was fed into the biodigester. The slurry was allowed to stay for 37 days at mesophilic temperature. The pH of the digestion was between 6-7, and the temperature was within the range of 25-34^{o}C. The amount of total solid, moisture content, ash, and volatile matter of the feedstock after digestion decreases by about 31%,47%,67%, and 69%. Moreover, an increase in the amount of nitrogen content from 0.3783% to 0.6420%, phosphorous from 0.1903% to 0.2983%, and potassium from 0.1876% to 0.3153% was also observed. After digestion the biofertilizer produced has an appropriate ratio of 2:1:1. For the kinetic study, the specific growth was found to be 0.0098hr-1. Also, experimental data for microbial growth obtained from the study fitted the Monod model.

INTRODUCTION

Environmental conservation has become more and more important in recent times, and most importantly, the utilization of waste as a wealth commodity for both human and environmental benefit. The availability of solid waste such as sludge from water treatment, banana peel, and chicken dung has a great role to play in sustainable development, energy production, bio-fertilizer, and biogas production, which is a very good approach to pollution control. However, bio-fertilizers are naturally pleasant fertilizers that avert damage to the natural origin, in addition, it aid to some degree in cleaning the soil from precipitated chemical fertilizers (Raimi et al., 2021). While on the other hand, Synthetic fertilizers affect soil fertility if used for a long time, influencing the health of humans. Bio-fertilizer direct nutrient supplement inputs for plant growth which are in biological sources furthermore, the major types of bio-fertilizers are nitrogen fixing, phosphorus solubilization, potassium solubilization, zinc solubilization, and iron sequestration bio-fertilizers (Kumar et al., 2018). Moreover, it is a belief that the co-digestion of different substrates such as banana peels, plantain peels, chicken dung, sewage, and brewery sludge have produced a high yield of biofertilizer and methane by as much as 60% compared to that obtained from single substrates (Olufunmi, 2014). Various study has shown that solid waste from water treatment (sludge) and chicken dung can be used to produce bio-fertilizer(Yunus et al.,2022). Moreover, microbial biofertilizers can be developed by isolation of nitrogen fixers and potassium solubilizers from rhizosphere soil agricultural land(Kumar et al., 2018).

However, no attention has been given to the appropriate rationing of nitrogen, phosphorous, and potassium (NPK). Also, a lack of thorough characterization of feedstock may lead to a poor understanding of the properties of the feedstock which can result in improper rationing of nitrogen, phosphorous, and potassium (NPK) biofertilizer. In this research, the objectives of the study are to: formulate the ratio of feedstocks (wastewater sludge, chicken dung, and banana peel) for the

production of appropriate ratio in the blend of NPK and fabricate a bench-scale biodigester for the production of bio-fertilizer from solid waste. Characterization of the bio-fertilizer using EDXRF, proximate and ultimate analysis. Study the growth kinetic of the microbes using the Monod model.

METHODS

The Study Area

Maiduguri metropolitan area is the capital of Borno state, located in North Eastern Nigeria. and its vicinities is known for its drought, with a semi-arid climate, light annual rainfall of about 300 to 500 mm, and the average daily temperature ranging from 22 to 35°C, with the mean of the daily maximum temperature surpassing 40°C between March and June before the onset of the rains in July to September.

Raw materials collection and pre-treatment

Banana peels are collected from Gamboru market, Borno state Nigeria. The banana peels are pre-treated separated from a non-biodegradable material and washed with distilled water to remove impurities. It was sundried for 72 hours, at room temperature, chicken dung was collected at the University of Maiduguri, Faculty of Agriculture poultry farm, Borno state Nigeria. and wastewater treatment sludge is collected at Maiduguri bottling company, Borno state Nigeria.

Biodigester fabrication consideration

The biodigester operating volume is based on slurry input. The biodigester is made up of a digestion chamber, an inlet from the top, an outlet of the digestate from the bottom, and a manual stirrer that goes deep down the bioreactor, which speeds up fermentation and biogas production. The operating volume of the bio-digester (V_0) is determined based on the total volume of the digester.

The 2mm thick galvanized steel sheet was folded and welding was used to fabricate the digestion chamber, it was pressure tested before being used. It is painted black to aid the retention of heat within the wall of the digester. The site for installation of the bioreactor (University of Maiduguri, Borno state, Nigeria), has a mesophilic temperature range. According to (Onuoha et al., 2019), the mesophilic temperatures for anaerobic digestion ranges between 20 to 40°C with a digestion period of 20-40 days. In this study, the operating volume is chosen to be 80%. The operating volume is given by Equation 1.

$$V_O = S_d \times RT = (m^3) \quad 1$$

$$V_T = \frac{V_O}{0.8}\ (m^3) \quad 2$$

Where Vo is defined as the operating volume, S_d is the substrate input, and V_T total volume of the digester.

The total volume is given by Equation 3 since the hydraulic chamber is cylindrical.

$$V_T = \pi r^2 h \quad 3$$

Substrate input is given by Equation 4

$$S_d = \text{biomass (B)} + \text{water (W)} = (m^3/\text{day}) \quad 4$$

The yield of bio-fertilizer produced was determined by Equation 5

$$\frac{(\text{mass of digestates bio}-\text{fertilizer produce})}{(\text{input of the substrate})} \times 100 \quad 5$$

Figure1. Isometric view of biodigester

The specification of the biodigester is given in table 1.

Table 1. Specifications of a bench scale biodigester.

Parameter	Calculated parameter
Digester Shape	Cylindrical
Basis of bio-digester design	24 kg/ batch of substrate
Mixing ratio	1:1
Substrate input quantity (S_d)	0.024m^3
Operating Volume (V_0)	0.024m^3
Total Volume of the	0.03m^3

digester (V_T)	
Height of bio-digester (H_d)	0.42m
Radius of the bio-digester (r_d)	0.15m
Digester diameter	0.3m

Characterization of the feedstock

The feedstocks are characterized using energy dispersion x-ray fluorescence (EDXRF) and the micro Kjeldahl method

Energy dispersion x-ray fluorescence (EDXRF)

The feedstock compositions of the samples were carried out using Energy Dispersive X-ray Fluorescence (EDXRF). The sample was placed in a sample holder within the EDXRF equipment and slanted towards an angle of 450^o. The EDXRF machine was closed and the window of the EDXRF tube was opened via the shutter. The filament voltage was then fixed progressively to 40 kV and the current to 20 mA. A drift detector (silicon) was used to detect the secondary X-rays (X-ray detector) and to record the spectrum. Then, the individual element was presented in percentages.

Kjeldahl method

Determination of total nitrogen from chicken dung, banana peel, and wastewater sludge was done using the automatic micro-Kjeldhal method. Digestion: 1.0g of the sample was weighed in triplicate, together with a blank, and set in digestion flasks. About 3.0g of copper catalyst mixture (96%) anhydrous sodium sulfate, 3.5% copper sulfate, and 0.5% selenium dioxide) were added to each of the flasks tailed by 20mL concentrated sulphuric acid. The mixture was heated on the micro-Kjeldahl digestion unit at a temperature of 250^{0}C for two hours. At non-stop pending until a clear solution is obtained. After cooling, the digest was filtered and then made up to 100mL with distilled water. 20 mL of the diluted digest was pipetted into distillation flasks and used in the distillation and titration. The total organic nitrogen was calculated using Equation 6.

$$\%N = \frac{Ti \times N \times Td}{Ms \times V} \times 100 \qquad 6$$

Where, Ti = Titre value, NE = mg nitrogen equivalent to molarity of acid, TVd = total volume to which digest was diluted, Ms = mass of sample (g) and Vd = volume of digest distilled, and N = T Nitrogen.

Mixing Ratio

After the characterization of each feedstock, the composition of each element given in table 2 in percentage is converted to mg/kg. In chicken dung, 89680 mg/4kg of nitrogen, 17976 mg/4kg of phosphorous, and 30968 mg/4kg of potassium. Similarly, in wastewater treatment sludge, 12 mg/7.5 kg of nitrogen, 27150 mg/7.5 kg phosphorous, and 353.25 mg/7.5 kg potassium. Additionally, 1110 mg/0.5kg of banana peels, 557.6 mg/0.5kg phosphorous, and 13712mg/0.5 kg potassium. The total composition of nitrogen, phosphorous, and potassium in 12kg is 90802 mg, 45683 mg, and 45033 mg. The 12 kg of the substrate is then mixed with water in an equal ratio of 1:1 (w/w) which gives a total of 24kg of the slurry. The new concentration of nitrogen, phosphorous, and potassium is given as: 3783.64 mg/l nitrogen, 1876.385 mg/l phosphorous, and 1903.48 mg/l potassium. Therefore, the equivalent of the above in percent is as follows: 0.378 % nitrogen, 0.1876% phosphorous, and 0.1903 % potassium.

Biofertilizer characterization

Similarly, the biofertilizer produce after digestion was characterized using EDXRF, micro Kjeldahl method, and proximate and ultimate analysis.

Proximate Analysis

The proximate analysis was conducted before and after digestion. The proximate analysis was conducted based on the procedure outlined in European standard EN15148-2009.

Ultimate analysis

The ultimate analysis is a quantification method that determined carbon, nitrogen, sulfur, hydrogen, and oxygen.

Determination of carbon

1g of sample was weighed and subjected into a 500 mL conical flask and 10 ml of 1M $K_2Cr_2O_7$ solution was added and mixed well. Concentrated H_2SO_4 (20mL) was added and the flask with the content was twirled 3 times and let to stand for 30 minutes till the reaction attained completion. Distilled water (200mL) was added into the flask to dilute the suspension, 10mL of 85% H_3PO_4 and 1ml of Diphenylamine indicator were added and back titrated with 0.5M Ferrous Ammonium Sulphate

solution, till the color flashed from violet via blue to bright green as the endpoint. The volume of the Ferrous Ammonium Sulphate was recorded. A similar procedure was carried out to obtain a blank titre value (i.e. without a sample). Equation 7 is used to calculate carbon content.

$2Cr_2O_7^{2-} + 3C + 16H^+ \longrightarrow 4C^{3+} + 8H_2O + 3CO_2$

The percentage (%) of total organic carbon in the sample was calculated thus,

$$R=\frac{(V_1-V_2)m\times 0.003\times 100\times C}{W} \quad 7$$

Where,

W - Weight of Sample

V_1 - Blank Titre value

V_2 - Titre value of the Sample

M- Morality of $K_2Cr_2O_7$ (Here it is 1M)

C - Correction Factor (1.334)

Hydrogen and Oxygen

The hydrogen and oxygen are calculated as reported by (Aliyu et al., 2020) using Equation 8.

Hydrogen Content (%) = [(0.036 FC) + 0.086 (VM –0.1 A) – (0.0035 M^2) (1 – 0.02 M)] 8

Where, FC =fixed carbon content (%), VM = percentage volatile matter (%) A = ash content (%) and M = moisture content (%). Fixed carbon (%)=100-% of moisture content+% of ash+% of volatile matter.

Study of growth kinetics of microbes

Estimation of microbial Population in the slurry was determined using colony forming unit (X), on nutrient agar. The bacterial concentration was determined according to (Khan et al., 2021) by serial dilution using the pour method, the dilution is set by partying 1ml of the sample into 9ml of distilled water for the first dilution. Then 1 mL of 1st dilution was taken and mixed with 9 mL of distilled water for 2nd dilution. Equally, the same technique was applied to prepare the 3rd, 4th, 5th, and 9th dilutions. Nutrient agar is used as media for bacterial growth. It is prepared by taking 14g of the media agar and mixing thoroughly with 500 ml of deionized water. Which is then autoclaved for 50 minutes at 121°C and 0.16MPa, 20ml of the mixture was poured into the petri dish. Then, for the growth of microbes, 1 mL of each of the ninth dilutions prepared was spread evenly over the Petri dishes and allowed to solidify, which is then placed in an incubator at 37°C for 24 h. This is done in triplicate for better accuracy. Thus, the colony forming unit (X) is calculated using equation 9.

$$CFU(X) = \frac{\text{Colony Forming Unit} \times \text{Dilution factor}}{\text{volume platted}} \quad 9$$

The Monod equation is used to study the growth kinetic of microbes, Monod equation is given by Equatio10.

$$\mu = \frac{\mu_{maxS}}{K_{s+S}} \quad 10$$

where μ_{max} is the maximum growth rate, μ is the specific growth rate and X is cell concentration, and S is the substrate concentration.

Initial Substrate concentration was determined using Equation 11.

$$S_o = \frac{\text{mass of feedstock}}{\text{volume of water}} \quad 11$$

The substrate concentration was determined using experimental values of X using Equation 12.

$$S_E = S_o - \frac{(X-X_o)}{Y} \quad 12$$

Where, X_o is initial cell concentration, S_E is S experimented and Y is yield.

$$Y=\frac{X_0}{S_o} \quad 13$$

A predictive value of X known as $X_{predicted}$ was obtained using several guess to obtain the K value using excel solver by regression using Equation 14.

$$X_P = \frac{X_{o\ exp(Kt)}}{1-\frac{X_o}{X_\infty}[1-exp(Kt)]} \quad 14$$

Where $X_\infty = X_o + YS_o$ 15

The value of X predicted from Equation 14 was used to obtain the value of S predicted.

$$S_P = S_0 - \frac{X_P - X_0}{Y} \quad 16$$

Using the Monod equation the value of μ as well as S was determined using Equation 17.

$$\mu = \frac{\mu_{max} S_M}{K_S + S_M} = K\left(1 - \frac{X_P}{X_\infty}\right) \quad 17$$

17

Assuming K = μ_{max} and Customizing Equation 17 for S_M as seen in Equation 18.

$$S_M = \frac{K_S}{X_P}(X_\infty - X_P) \quad 18$$

Bacterial identification

Bacterial identification was carried out, using serial dilution on nutrient agar, MacConkey agar, and Eosin Methylene blue agar. The individual colonies obtained were subjected to morphological, gram staining, and biochemical test.

RESULTS AND DISCUSSION

Feedstock Characterization

Energy dispersion x-ray fluorescence (EDXRF) and micro Kjeldahl method were carried out on each of the three different feedstock (chicken dung, banana peel, and wastewater sludge) which gives the elemental composition of each sample. The elemental compositions are presented in Table 2.

Table 2. EDXRF and Kjeldhal analysis of feedstocks

Chicken dung		Banana peel		Sludge	
Element	Composition (%)	Element	Composition (%)	Element	Composition (%)
Fe	0.0811	Fe	0.0196	Fe	0.1028
Cu	0.0005	Cu	0.0001	Cu	0.0004
Ni	0.0004	Ni	0.0019	Ni	0.0490
Zn	0.1223	Zn	0.0086	Zn	0.0004
Al	0.0302	Al	0.0016	Al	0.0247
Mg	0.0259	Mg	0.0161	Mg	0.0937
Na	0.0271	Na	0.0118	S	0.0413
S	0.1072	S	0.0490	P	0.3620
P	0.4494	P	0.1115	Ca	0.2021
Ca	0.5815	K	2.7424	K	0.0047
K	0.7742	Ca	0.1948	Mn	0.0014
Mn	0.0062	Mn	0.0206	Rb	0.0004
Rb	0.0077	Pb	0.0840	Sr	0.0005
Si	1.2600	Rb	0.0087	Br	0.0054

Chicken dung contains a high amount of nitrogen content of 2.24%, among all animals, faces chicken dung has high nutrient contents as reported by (Amanullah et al., 2010). Also, the banana peels contain high potassium content of 2.74% which is similar to (Hassan et al., 2018). Similarly, wastewater sludge contains high phosphorous content 0.362 % as reported by (Shiba & Ntuli, 2017). In their study Akpan et al., (2019) nitrogen content in banana peel was found to increase by 98% after digestion. Similarly, phosphorous content in the banana peel was found to increase by 45% after digestion, and potassium content was also found to increase by 62%. Also, in a study conducted by Alfa et al., (2014) the co-digestion of chicken dung and cow dung in a ratio of 1:1 the nitrogen content increased by 79% after digestion.

Therefore, as stated earlier, in this study, about 4kg of chicken dung, 7.5 kg of wastewater treatment sludge, and 0.5kg of banana peel were mixed with water in an equal ratio of 1:1 (w/w). The total nitrogen, phosphorous, and potassium composition in the 24kg of slurry is 0.378%, 0.190%, and 0.188%. The nitrogen content is expected to increase by 70-80% as reported in the literature, similarly for the potassium and phosphorous.

Proximate Analysis Before and After Digestion

The proximate analysis is used in the analysis of biological materials. The component of proximate analysis includes moisture content, ash, and totally solid and volatile matter. The proximate analysis of the slurry before digestion and after digestion is given in table 3 below.

Table 3. Proximate analysis of slurry and the digestate

Component	Before digestion (%)	After digestion (%)
Moisture content	69 .0	37 .0
Ash content	12.00	4.00
Total solid	26.60	18.0
Volatile matter	16.0	5.00

The moisture content is the amount of water present in a sample. 69% accounted for the amount of moisture content before digestion and 37% after digestion is as a result of moisture content present in the wastewater treatment sludge and chicken dung. Also, the decrease in moisture content is a result of vapor formation in the biodigester. The temperature of the digestion process is between 25-35^{o}C, at this temperature, it is the belief that vaporization does take place, and the vapor formed is collected together with the biogas in form of moisture.

In his study, Menta (2020) found that the volatile matter and total solid content of the co-digestion of banana peel and poultry dung before digestion in a mixed ratio of 25% banana peel and 75% poultry dung Before digestion, the total solid was found to be 24.5% and 20.8 % volatile matter after digestion the total solid was found to be 17.4 % and the volatile matter to be 14.8 % the less decrease in the volatile matter and total solid as reported was as a result of high fiber present in the banana peel. In this study, the co-digestion of banana peel, wastewater sludge, and chicken dung. The banana peel content is only 0.5 kg of 24 kg of the slurry which is very less in the slurry, this means that the slurry contains less fiber which resulted in a high decrease in the amount of the volatile matter after digestion. Also, the decrease recorded in the total solid and volatile matter after the digestion process is a consequence of the removal of organic carbon in form of methane (CH_4) and carbon dioxide (CO_2). Moreover, the decrease observed in the volatile matter and total Solids (TS) after digestion is a result of the effectiveness of the system and the retention time (37 days) together with the level of nitrogen content in the poultry waste. This is similar to (Okwu et al., 2020). Additionally, the decrease in ash content shows that carbon is been consumed.

Ultimate analysis

The ultimate analysis is a quantification method that gives information on carbon, oxygen, nitrogen, sulfur, and hydrogen. Table 4 shows the summary of the ultimate analysis.

Table 4. Summary of ultimate analysis of digestate (biofertilizer).

Element	Composition (%)
Nitrogen	0.64
Carbon	16.0
Sulphur	0.28
Hydrogen	2.10
Oxygen	49.5

The carbon and nitrogen content of the biofertilizer after digestion was found to be 0.64% and 16%. With carbon to nitrogen ratio (C/N) of 25:1. Which is within the acceptable range of 20-30 for biogas and biofertilizer production as a report by (Kiewtniewska & J.Tys, 2014; Meegoda et al., 2018; Owamah et al., 2014) nally, C/N ratio disturbs the production of methane (CH_4) without having any effect on the production of carbon dioxide (Co_2), also, it does not affect the digestion process, the digestion process takes place at the greatest promising rates. While the 0.28 % sulfur content recorded after digestion, which is higher compared to the amount of sulfur present in the feedstocks might be a result of bond breakage and bond formation during the digestion process. Moreover, the 2.10% hydrogen in the digestate might be a result of methane formation and the reduction in moisture content.

Biofertilizer characterization

The biofertilizer produce after digestion is characterized using EDXRF and the micro-Kjeldahl method. Table 5 shows EDXRF and Kjeldahl analysis of the digestate.

Table 5. EDXRF and micro Kjeldahl analysis after digestion.

Element	Composition (%)
Fe	0.27271
Cu	0.00046
Ni	0.05510
Zn	0.01595
Al	0.08776

Mg	0.14220
S	0.20820
P	0.29830
Ca	0.20680
K	0.31530
Mn	0.00785
N	0.6420

After digestion, the increase in the amount of nitrogen content from 0.378% to 0.642% is a result of organically bound nitrogen and organic matter present in banana peel, chicken dung, and wastewater treatment sludge similar to (Akpan et al., 2019; Alfa et al., 2014). Also, the increase in phosphorous from 0.1903% to 0.298% and potassium from 0.1876% to 0.315% might be due to the large release of organically bonded phosphorous and potassium present in chicken dung, banana peel, and wastewater treatment sludge. Additionally, the presence of microelements such as Fe, Cu, Ni, Zn, Al, Mg, and Ca, these microelements are essential to plant nutrients needed in trace amounts. The biofertilizer yield was 87%.

Biogas Production

The product of anaerobic digestion of organic waste consists of carbon dioxide, hydrogen sulfide, moisture, digestate (biofertilizer), and biogas (Hassan & Abdulsalam, 2017). The volume of biogas produced during the digestion process is recorded daily. Figure 2 shows the plot of biogas produces daily.

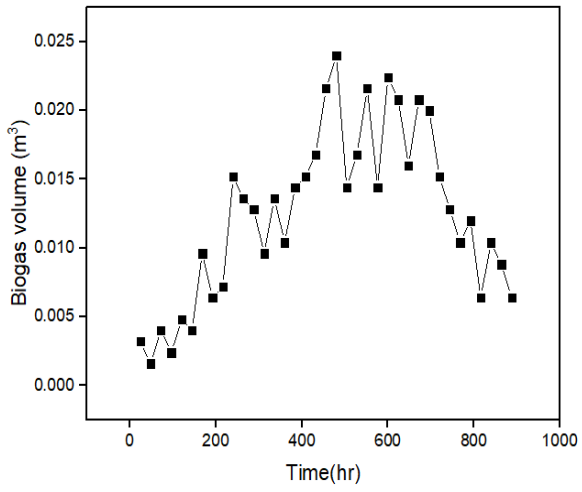

Figure 2. Biogas volume agianst time

Biogas production is proportional to the microbial growth curve. In this study, the total volume of biogas produced by anaerobic co-digestion of chicken dung, banana peel, and wastewater treatment sludge is 0.46 m^3. The highest biogas production was obtained on the 20th day with a volume of 0.024 m^3 at a temperature of 34 ^oC and a pH of 7.2. while the least volume of biogas was obtained on the 2nd day of the digestion. This is similar to studies by (Ramalan, 2020). Moreover, there was a significant increase in biogas production from the 7th day to the 20th day. This shows an exponential growth increase in methanogens. Therefore, most literature report, that generally, biogas production increased from the beginning, and as the days progressed, it reached a peak value in a given time and may tend to decrease after maximum gas generation. This is due to the decrease in the microbial population.

Temperature and pH in biogas production

The pH and temperature during the digestion process is within the optimum pH condition for anaerobic digestion between 6-7 at mesophilic temperature (20-40 ^oC) as reported by (Abdulkarim et al., 2019; Hamouda et al., 2016; Hassan & Abdulsalam, 2017; Menta, 2020; Onuoha et al., 2019).

Effect of pH

The pH from the 2nd day to the 5th day is acidic, this is due to the activities of acidogenic bacteria (acid formers) that have the ability of degrading organic matter and produce volatile fatty acids this is similar to (Eze, J. and Onwuka, 2007). While the change in pH from acidic to neutral recorded from the sixth day is due to the conversion of volatile fatty acid produced by acid formers to methane by bacteria (methanogens), these bacteria are responsible for the production of methane. Furthermore, a significant increase in biogas production was observed on day sixth day, this is similar to studies conducted by (Eze, J. and Onwuka, 2007; Harikishan, S. and Sung, 2003; Okwu et al., 2020). Moreover, the fluctuation in pH between 6 and 7.5 is a result of Volatile Fatty Acid (VFA) concentration, and the ability of methanogens to convert them into methane. This is similar with studies conducted by (Meegoda et al., 2018; Menta, 2020). Figure 3 shows the plot of pH against time (days).

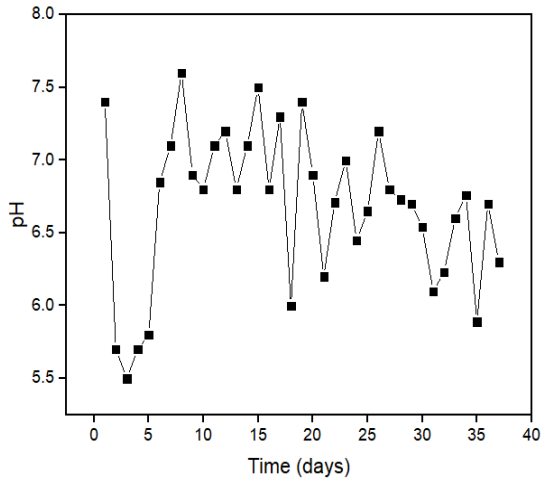

Figure 3. The plot of pH against Time (days).

Effect of Temperature

Additionally, it is an established fact that temperature is one of the key vital parameters in the anaerobic digestion process. Most methanogens are lively between 25-40 ^{o}C (mesophilic range) (Onuoha et al., 2019). It was seen from figure 4, the temperature of the process is between the mesophilic range (20-40 ^{o}C), which is similar to (Alfa et al., 2014; Onuoha et al., 2019). Therefore, the entire temperature of the process falls in within the mesophilic range. Figure 4 shows a plot of temperature against time (days). Moreover, it is common knowledge that chemical reactions occur faster at higher temperatures. As the temperature rises, molecules move faster and collide more vigorously, greatly increasing the likelihood of bond cleavages and rearrangements.

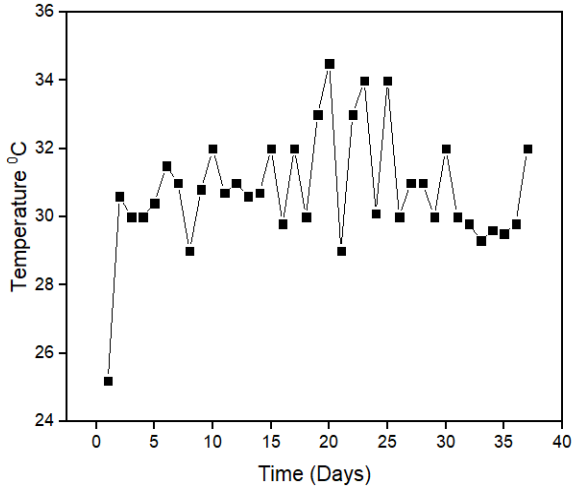

Figure 4. The plot of temperature against time (days)

Kinetic Study of Microbial Growth

A kinetic study of microbial growth was carried out using Monod model Figure 5 shows the plot of colony forming unit on nutrient agar against time and substrate concentration.

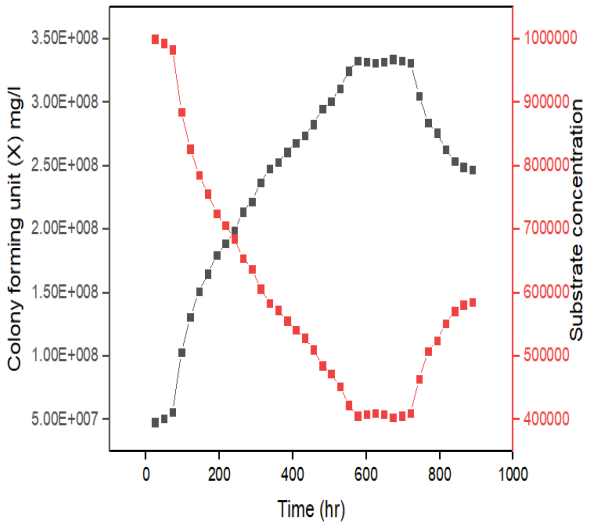

Figure 5. Microbial growth curve and substrate concentration.

The microorganism present in the biodigester follows the microbial growth curve as presented in figure 5. Also, it was observed that there is no significant increase in microbial population from the first day to the third day (lag phase). As reported by (Strigul et al., 2005) when microorganisms are subjected from one surrounding to another, they naturally observed a state of lag in growth before they begin to multiply. All over this time, the microorganisms transformed their physiological state to take advantage of their new surroundings and begin to multiply. In this study, the microorganism experiences a lag phase of three days. A significant increase in microbial population was observed from the 4th day to the 25th day (growth phase). Also, a stationary phase for the bacteria was observed from the 27th day to the 33rd. A decrease in the population from the 30th day to the 37th day (death phase). It is also observed that the degradation of organic matter depends on the growth of microorganisms. For the substrate concentration, the substrate concentration is inverse of the microbial growth curve. That is, as the microbial population increases the substrate concentration decreases. This shows that the substrate is been consumed by the microorganism.

Monod model practices a precise proper approximation of the batch growth process when

describing microbial kinetics. Therefore, since the Monod model deals only with the growth phase, the value of μ obtained from the above equation and S is plotted which describes the Monod plot. A plot of the growth phase against substrate obtained from the Monod equation is described in figure 6.

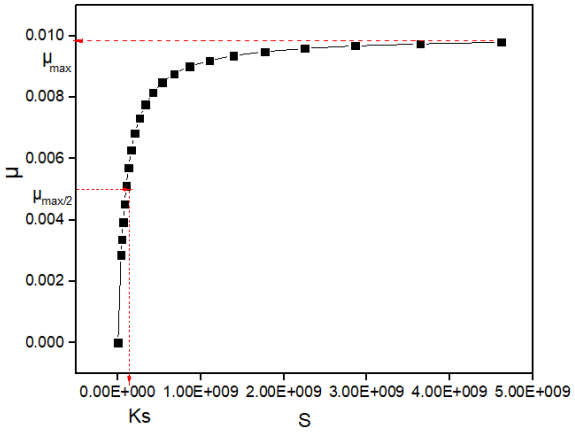

Figure 6. Plot of μ against S

From the above plot the maximum growth rate of 0.0098 hr^{-1}. Which approximately conforms with the earlier assumption made that $k = \mu_{max}$ k is gotten as 0.01 by regression analysis. Ks is the substrate utilization constant, mathematically equivalent to the substrate concentration. The specific growth rate of microorganisms decreases if the substrate concentration is decreased and vice versa.

Identification of Bacteria

The presence of gram-positive bacteria *(Bacillus)* and gram-negative bacteria *Pseudomonas* and *Clostridium* were confirmed after digestion. The species of *clostridum* are reported to be *nitrogen* fixers while, species of *pseudomonas* and *bacillus* are phosphorous and potassium solubilizes this is by (Hassan & Abdulsalam, 2017). It is reported in the literature that these microorganisms contributed to the yield of biogas since biogas technologies have been found to commonly apply natural anaerobic consortia of microbes.

CONCLUSION

A 30-liter bench scale anaerobic biodigester for biofertilizer production from solid waste (wastewater sludge, banana peels, and chicken dung) using a 2mm thick galvanized steel sheet. Was used effectively for the production of biofertilizers. The feedstocks were characterized with EDXRF and micro Kjeldhahl method and also, the biofertilizer has an approximate NPK ratio of 2:1:1 which can be compared with inorganic fertilizer (20:10: 10). Moreover, after digestion the presence of microelements such as Fe, Cu, Ni, Zn, Al, Mg and Ca and the species of *Clostridium, pseudomonas,* and *bacillus* further testified the quality of the biofertilizer. The kinetic study of the microbial growth using the Monod equation shows that the experimental data has fitted Monod with a maximum growth rate of 0.0098 hr^{-1}. Therefore, this study shows that the appropriate ratio of biofertilizer can be obtained and at the same time biogas. Moreover, biofertilizer and biogas production when generated in commercial quantity can provide an alternative source of sustainable energy, that can serve as a means of waste management and its disposal problems. The following are recommended:

1. Possibilities of heating the biodigester using solar energy or radiation.
2. Development of software for appropriate rationing of NPK from waste/local sources.
3. Applying nanotechnology additives to improve methanogenesis activity.

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