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Statistical Analysis of Biogas Production from Co-digestion of Cornstalk with Goat Dung using a One Factor Design

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Abstract This study investigates biogas production from co-digestion of cornstalk with goat dung and its statistical analysis. Physicochemical analysis of substrate and digestate were also carried out as well as microbial count load analysis. Result shows highest experimental biogas yield of 4.7×10^{-2} m^3, temperature of 38^{o}C on 29th day. The predicted biogas yield by the model was 4.44 x 10^{-2} m^3, temperature of 37.7 °C on 29.0895th day. Using the optimum condition of 29.0895th day to load two digesters, an average biogas yield of 4.216 x 10^{-2} m^3 and mesophilic temperature of 37 ^{o}C was attained, which was well within the range predicted by the model. Analysis of variance (ANOVA) of regression equation shows that the coefficient of determination R^2 of 73.34% and 55.60% were obtained for biogas and temperature during the analysis. The temperature of the slurry was found to be within the mesophilic temperature ranges (30-40 ^{o}C). The pH of the slurry decreased from 7.95 to 7.55 in the space of 4 weeks. Physicochemical analysis of substrate and digestate varies. Hence, it can be concluded that alkali treated dried cornstalk (ATDCS) with goat dung is a good waste material for biogas production and the by-products or spent slurry of this process could also be used as fertilizer or improved organic manure for agricultural production.

Keywords alkali treated dried cornstalk (ATDCS), goat dung, biogas, statistical analysis, physicochemical properties, microbial count load.

Introduction

Biogas is a metabolic product of anaerobic (absence of air) digestion and it is produced from the mixture of carbon dioxide and methane with mixture of some other elements such as H_2S, but in small quantities. Methane, which is the needed gas, is a colorless gas with blue burning, used for cooking, heating, and lighting [1]. Biogas is a clean, efficient, and renewable source of energy, which can be used as a substitute for other fuels in order to save energy in rural areas, and the whole country at large [2]. In anaerobic digestion, which is regarded as waste treatment method, is a technique of production of clean-renewable energy in the absence of oxygen, converting it into a methane and carbon dioxide mixture. The slurry from the digester after the gas is being generated can be used as fertilizers because it is rich in ammonium and other mineral components necessary for plant's growth. This shows that even in the waste conversion, the obtained digestate is useful, leaving zero waste [3]. However, for optimum performance of anaerobic digestion, suitable conditions such as pH, temperature, mixing, substrate, C/N ratio, Hydraulic retention time (HRT), and Organic landing rate, have to be established to keep the microorganisms in balance and also keep them in check. A neutral pH is best suitable for biogas production, since most of the methanogens grow at the pH

range of 6.7–7.99. Most acids forming microorganisms grow under mesophilic conditions, however, for methanogens, a higher temperature is favorable [4]**.** Too much mixing stresses the microorganisms and without mixing foaming occur, which will alter the rate of biogas production negatively. Methane-forming microorganisms grow slowly, with a doubling time of around 5–16 days. Therefore, the hydraulic retention time should be at least 10–15 days, unless these bacteria are entrapment. The substrate should be slowly digested, otherwise easily degradable substrates may cause a sudden increase in acid content, which is not a desired material. The carbon and nitrogen (C/N) ratio on the other hand should be around 16:1–25:1 [5]. Significant change (increase or decrease) of C/N ratio affects the production of biogas. The amount of raw materials fed per unit volume of digester capacity is organic loading, thus if the digester is overfed, acids will accumulate and methane production will be inhibited, likewise, if the loading rate is lower, there will be less gas [6].

Crop residues are precious commodity, although, human efforts to produce ever-greater amounts of food leave their mark on our environment, but should never be considered as waste [7]. Its numerous competing uses are for feed, fodder, and fuel. Residues have assimilated a large amount of solar energy, and this energy equivalent of crop residues is estimated to about 2 barrels of diesel or 18.6 x 10^9 J/MG of dry biomass [8]. It is because of its high energy value that crop residues as biofuels are considered an alternative to fossil fuel [9]. Although in the recent years, the use of cereal grains as feed has increased, estimated that between 1982 and 1994, the global use of cereal grain as livestock feed increased at the rate of 0.7% annually [10]. Nigeria being an agricultural based economy produces huge amounts of residues such as corn stalks, rice and wheat straws, cotton wastes, barley residues, biogases to mention but view. However, the energy potential accessible by these crop residues is yet to be exploited in spite of increasing interest in production of biogas worldwide.

Goats, like cattle, play a significant role in the socio-economic livelihoods and food security of smallholder farmers through sale, slaughter, and provision of milk, skins and manure for cropping and in various socio-cultural ceremonies [11]. Though use of manure alone has been noted to generally produce less than optimum yields [12], its use increases yields and can avoid total crop failure, also its value for maintaining and improving the productivity of the soil has been recognized from antiquity [13]. The animals are the only source of draught power and of the dung, the only fuel available, which is therefore very valuable. Major nutrient component and chemical compositions of some livestock manure and goat manure are listed in Table 1.

The main purpose of this study was to optimize biogas production from the synthesis of cornstalk mixed with goat dung. Additional objective is to determine the physicochemical properties of the substrate and digestate as well as the microbial activities.

Table 1: Nutrient content of some livestock manure

Manures	**N**	**P_2O_5**	**K_2O**
Cow and Buffalo	13.8	6.1	4.3
Poultry (Broiler)	22.7	15.3	16.2
Pig	17.4	7.1	9.5
Goat and Sheep	20.5	23.8	24.6

Materials and Methods

Materials

Partially Dried Corn stalk (PDCS) was collected from Landmark University farm while the goat dung was collected from Cattle Farm in Landmark University Teaching and Research Farm, Omu-Aran, Kwara State, Nigeria. The collected PDCS were dried in an oven at temperature80 ^oC for 20 min for easy grinding. The dried cornstalk is aligning in plant crop residue; the methanogens (bacteria) cannot digest or process this substance easily, and hence, the chemical pretreatment was done to make the substrate suitable for digestion and loading. Chemical treatment was carried out by treating dried cornstalk with 1% NaOH in a tightened polymeric bag to prevent air from entering for 7 days to increase biogas production during anaerobic digestion [14]. After 7 days, alkali treated dried cornstalk (ATDCS) was mixed with a fresh goat dung, at a 1:1 w/w ratio, and then milled to semi-fine particles using a Delmar R175A diesel engine hammer mill machine to increase its surface area for microbial action [15]. The milled ATDCS with goat dung called substrate were collected in a cleaned bucket for further processing.

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%) and supplied by EQUILAB Nig. Ltd.

Methods

Biogas digester design with gas collection system

A 25 L cylindrical shape biogas digester of dimension 50 cm x 25 cm wasconstructed using galvanized steel, due to its strength and durability in acid and basic environments. Three different holes were bored on the lid of the digester for the slurry inlet, the thermometer insertion and the gas outlet. The cylindrical shape was adopted to enhance better mixing and stability. The digester was air tight, painted black and placed above ground level where it was exposed to sunlight for easy absorption. The major unit of the digester is the stirring unit at the top of the digester while, at the bottom of the digester, there is a tap for the slurry outlet.

A 12 L gas holder tank of height 27 cm and diameter 25 cm was also fabricated from thin sheet metal and used to collect and store the biogas. Rubber hose was used to connect the digester to the gas collection system through the water displacement method. The volume of biogas was measured through the height displaced by the gas via the liquid column. The digester and gas holder was designed, built and operated by the methods used by Karki, (2002) and Fountoulakis *et al*. (2008) with slight modifications [16-17]. The base area of gas collector as well as the biogas volume was computed using Eq. (1) and Eq. (2):

$$Base\ area\ of\ gas\ collector = \frac{\pi r^2}{2} = \frac{\pi D^2}{4} \quad (1)$$

Where D = diameter of gas holder tank = 25 cm = 0.025 m

$A = \frac{3.142 \times 25^2}{4}$ = 490.94 cm^2 = 0.04904 m^2

$$Volume\ of\ biogas\ \ (m^3) V = A\ \times h \quad (2)$$

Where h = height of gas collector (m)

Slurry preparation

For preparation of slurry, the substrate (milled ATDCS with goat dung) was mixed with distil water in a ratio 1:1 w/w in a reactor mix bucket (Fig. 1), and the slurry was thermally pretreated using the method earlier stated by Adepoju *et al*. (2015) [15]. Thermal pretreatment has been said to lead to pathogen removal and also improves dewatering performance and reduces viscosity of the digestate with subsequent enhancement of digestate handling [18]. Since pH plays an important role when considering the growth of microbial life during digestion, a neutral pH is best suitable for biogas production, since most of the methanogens grow at the pH range of 6.7–7.99. The pH of the slurry was checked using a pH meter and was found to be 7.95, which was well within the range earlier reported for growth of microbial life [19].

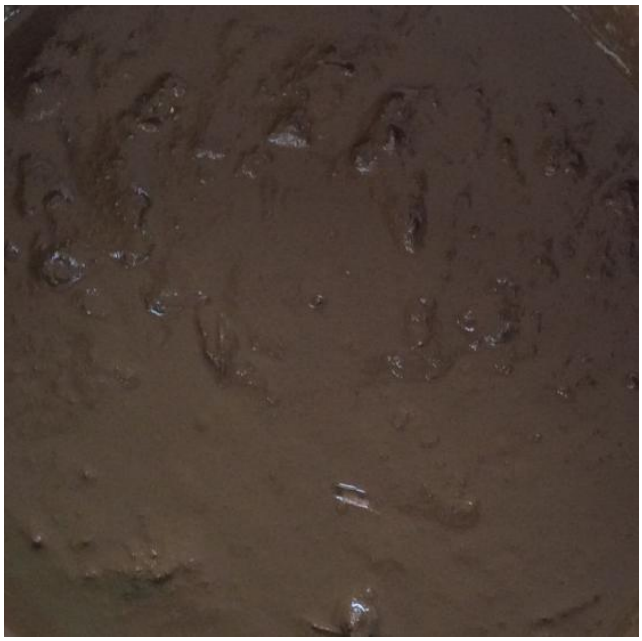


Figure 1: The slurry

Experimental Set Up

Before feeding the digester, the rubber hose connecting the gas outlet from the digester to the gas holder was disconnected, such that the gas outlet was left open. This was done to prevent negative pressure build-up in the

digester. The slurry was fed into the digester through the inlet and was sealed to prevent air from getting into the digester and gas from escaping. The slurry was allowed to occupy three-quarter of the digester space leaving a clear height of about 8.30cm as space for gas production. The inflow was directed downward to cause the solids to accumulate at the bottom of the tank for easy removal after digestion. The contents of the digester were gently and manually stirred daily through a stirring rod attached to the digester. The gas was collected by water displacement method and the fermentation process was monitored for a period of 30 days, after which the digestate sample was collected for analysis. During this period, daily ambient temperature within the mesophilic temperature range and the height of the gas holder were measured. Daily biogas volume produced was computed based on above-mentioned Eq. (2).

Statistical Analysis of Daily Biogas Yield and Daily Temperature

In order to analyze the data obtained for daily biogas produced and daily temperature, Stat-Ease\Design-Expert 8.0.3.1\DX8.exe" was used. Response Surface Methodology (RSM) with a one factor design was adopted since the input factor is one (day), the model setting was set to be quadratic with center point adjusted to 24 which yielded 30 experimental runs. The experiment was randomized to minimize the effects of unexpected variability in the experimental responses (biogas volume and temperature). The model, sequential model sum of square, lack of the fit test, the R-square, adjusted R-square, the RMSE values and ANOVA for response surface quadratic model were used. Meanwhile, the predicted biogas yields and the predicted temperature were twofold validated, and the optimum yields were recorded.

Physicochemical Properties of the Substrate and Digestate

Physicochemical properties of the substrate and digestate were carried out, this includes ammonia nitrogen, total phosphate, total alkalinity, pH, aluminium, potassium, iron, total copper, magnesium, calcium, zinc, dissolve oxygen (DO), total nitrogen ash, carbon, nitrogen, phosphorus, conductivity, total solids, ash content, and volatile solidswere carried out. Detailed procedures of some of the analysis were described below:

Ash Content (%)

An empty crucible was fire polished in a muffled furnace and allowed to cool in a desiccator containing calcium chloride for 20 min and then weighed. About 2.0 g of dried sample (substrate/digestate) was weighed out into the crucible and transferred into a muffle furnace at 650 ^{o}C for 3 h. The crucible was removed from the furnace, placed in desiccator and then allowed to cool and then re-weighed to get the final weight. The percentage of ash content of the sample was calculated using Eq. (3):

$$Ash\ \% = \frac{X-Y}{W} \times 100 \quad (3)$$

where, X = weight of crucible + ash, Y = weight of crucible

W = weight of sample to be determined in grams before ashing.

Phosphorous Content

5 ml aliquot of the soil extract was pipette into a 25 ml volumetric flask and distilled water of 10 ml was added. 4 ml of reagent of phosphorus standard solution was added and made up to volume with distilled water. The blue colour was allowed to develop for 15 min and remain stable for 24 h. Phosphorus content in solution was then determined using Jenway Spectrophotometer at 660 mμ.

Kjeldahl Nitrogen

A representative sample was prepared and 1g was weighed to an accuracy of 0.1 mg into a digestion tube. Two kjeltabs were added (5 g Na_2SO_4 and 1 g $CuSO_4.5H_2O$ and Selenium). 12 ml of concentrated H_2SO_4 was carefully added and shook to wet the acid with the sample. The exhaust system was attached to the digestion tubes in the rack and the water aspirator was set to full effect. The rack was loaded with exhaust into a preheated digestion block (420 ^{o}C) and contained within the exhaust head. After 5 min, the water aspirator was turned down until the acid fumed. Digestion was continued until all samples were clear with a blue/green solution (normally after 30-60 min). The rack of tubes was removed with exhaust still in place and put in the stand to cool for 15 min. 80 ml of de-ionized water was carefully added to the tubes. The steam valve on the Kjeltec 1002 was opened and distilled for approximately 4 min. At the end of the distillation cycle the steam valve was closed and the distillate was titrated with standardized HCl until the blue/grey end point was achieved and the volume of acid consumed in the titration was recorded. Kjeldahl nitrogen was estimated using Eq. (4):

$$KN = \frac{(T-B)\times N\times 14{,}007\times 100}{weight\ of\ sample\ (mg)} \quad (4)$$

where, T = titration volume for sample (ml), B = titration volume for blank (ml), N = normality of acid, molar weight of Nitrogen = 14.007

Total Alkalinity

1 ml of the sample (substrate and digestate) was diluted with 9 ml of distilled water and then inserted into the tube-hole of the apparatus and covered. Blank test of distilled water was then run and Total alkalinity was determined. This procedure was also used to determined ammonia nitrogen, total phosphate, total solids, aluminium, potassium, copper, iron, magnesium, calcium, zinc and dissolve oxygen.

Microbial Activities Test of Substrate and Digestate

Test tubes and empty 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 to transfer 1 ml of liquid from the source culture containing the substrate and digestate separately (tube 0) to tube 1 and the pipette was then discarded. The edge of tube 1 was flamed, then sealed and the content was homogeneously mixed gently. These steps were repeated 5 more times moving along the chain for each source culture. At the end of this process, a conical flask of sterilized nutrient agar was taken from the 45 °C water bath, where it had been kept just above setting temperature. The outside of the conical flask was dried and the top and neck area were then flamed, all these steps were carried out in the flame cupboard. By slightly opening each petri dish lid, the nutrient agar was poured into the dilution liquid already in the Petri dish, until it covered about two thirds of the area (although this is not critical). The nutrient agar was mixed with the dilution liquid by a gentle swirling action, then the edge of the conical flask was flamed and this step was then repeated for the remaining Petri dishes. The Petri dishes were left in flame cupboard to set for 15 min, and then sealed, inverted, and placed in the laboratory incubator at 37 ^{o}C for 48 h, Petri dishes were then examined without opening. The individual colonies of Petri dishes with dilution factors 10^{-5} and 10^{-6} 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 was calculated using Eq. (5);

$$Microbial\ load\ count\ \left(\frac{Cfu}{ml}\right) = \frac{No\ of\ colony}{dilution\ \ factor} \times 10\ ml \quad (5)$$

Results and Discussion

Daily Biogas Production

Table 2 shows the results of daily biogas production which was taken 2.00 pm every day for duration of 30 days. Observation shows that for the 1st and 2nd day, there was a constant gas volume production of 2.7× 10^{-2} m^3, a drop in volume of biogas on the 3rd day, and a significant increase by 26.58 % was observed between 4th and 9th day, however, there was 15 % further decrease in biogas volume between the 9th and 11th day.

Table 2: Volume of biogas yield per day (m^3/day) with temperature

Day	Volume of Biogas Yield Per Day (m^3/day)	Temperature (^{o}C)
1	0.027297	30
2	0.027297	32
3	0.026623	32
4	0.026623	33
5	0.0271285	32
6	0.0271285	34
7	0.026286	35
8	0.0267915	36
9	0.0337	33
10	0.033026	37
11	0.028645	38
12	0.029319	35
13	0.029319	36
14	0.03033	36
15	0.028308	36
16	0.029656	38
17	0.029319	39
18	0.028308	34
19	0.028308	35
20	0.0278025	39
21	0.028308	35
22	0.03707	33

23	0.0352165	34
24	0.034374	30
25	0.032015	38
26	0.029656	36
27	0.040103	37
28	0.042125	40
29	0.0470115	38
30	0.0402715	35

A significant increase was then observed on the 22nd day with a volume of 3.7×10^{-2} m^3 of biogas production. The highest biogas volume was computed on 29th day with a value of 4.7×10^{-2} m^3, while the least volume of biogas production was observed on 7thday with a production of 2.62×10^{-2} m^3. Dar and Tandon (1987), attributed the higher biogas yield to the alkali treated dried cornstalk (ATDCS) with goat manure at a 1:1 w/w ratio, while Fulford *et al.* (1998), attributed it to the low carbon-nitrogen ratio. Observation shows that biogas production was slow at the beginning and slightly slow at the end period. Biogas production rate in batch condition is directly proportional to specific growth rate of methanogenic bacteria in the bio-digester [14, 20].

Daily Temperature Variation

Also in Table 2 also shows the results of daily temperature reading. It was observed that throughout the duration of the digestion process, the temperature range from 30 and 40 ℃. Although, there are three temperature ranges selected for different bacteria. The pyschrophilic range is less than 30℃, mesophilic is between 30−40 ℃, and thermophilic is between 50 and 60℃. Anaerobic bacteria are most active in themesophilic and thermophilic range [3]. The temperature ranges obtained in this study shows that the thermophiles deliver a lower quality effluent and frequent energy to maintain the higher temperature [21].

Weekly pH Variation

Since, pH plays an important role when considering the microbial life growth during digestion, anaerobes prefer a pH close to neutral, in the range of 6.8-7.2, a neutral pH is best suitable for biogas production, since most of the methanogens grow at the pH range of 6.7–7.99.Observation on weekly pH variation during anaerobic digestion in this study shows a pH of 7.95 at the end of first week, a drop slight drop in pH (7.80) at the end of second week, further drop was noticed by the end of third week (7.67), and a significant drop was observed on the fourth week (7.55). Observation on the pH in this study could be attributed to the nature of the feed within the digester [2, 22-24]. Garba, (1996), reported that optimum biogas production is achieved when the pH value in the digester is between 6 and 7 [25]. Furthermore, Vicenta *et al*. (1984) reported that low pH value inhibits methanogenic bacteria and methanogenesis [26].

Statistical Analysis by Response Surface Methodology (RSM)

Data obtained from the experiment in Table 2 was analyzed using the RSM. Table 3 shows the significance results for every regression coefficient for both biogas and temperature. The results showed that the p-value of the model terms were significant, i.e. $p < 0.05$. In this case, the quadratic and the cubic terms were significant for biogas whereas, only the quadratic term is significant for temperature at 95% confidence level. To minimize error, all the coefficients were considered in the design. Table 4 and 5 shows the analysis of variance (ANOVA) of the regression equation. The model F-values obtained for both gas and temperature implied a high significant for the regression model [27]. The goodness of the fit of model was checked by coefficient of determination (R^2). The R^2 of 73.34 % and 55.60 % obtained for biogas and temperature, indicated that the sample variation were attributed to the independent factor (Day).

Table 3: Test of Significance for Every Regression Coefficient

Biogas					
Source	Sum of Squares	Df	Mean Square	F-Value	p-value
Day	2.214E-006	1	2.214E-006	0.26	0.6118
Day^2	1.055E-004	1	1.055E-004	12.57	0.0015
Day^3	5.593E-005	1	5.593E-005	6.67	0.0158
Temperature					
Source	Sum of Squares	Df	Mean Square	F-Value	p-value
Day	8.29	1	8.29	2.18	0.1531
Day^2	23.72	1	23.72	6.24	0.0200
Day^3	11.07	1	11.07	2.91	0.1013

Table 4: Analysis of Variance (ANOVA) of Regression Equation

		Biogas			
Source	Sum of squares	df	Mean Square	F-value	p-value
Model	6.003E-004	3	2.001E-004	23.85	< 0.0001
Residual	2.182E-004	26	8.392E-006		
Cor Total	8.185E-004	29			
R-Squared = 73.34%, R-Sq.(adj) = 70.27%, predicted R-Sq. = 60.80%, Adeq Precision = 17.706					
		Temperature			
Source	Sum of squares	df	Mean Square	F-value	p-value
Model	109.43	6	18.24	4.80	< 0.0026
Residual	87.37	23	3.80		
Cor Total	196.80	29			
R-Squared = 55.60%, R-Sq.(adj) = 44.02%, predicted R-Sq. = 25.03%, Adeq Precision = 8.833					

Table 5: ANOVA for Response Surface Quadratic Model for Intercept.

		Biogas			
Factors	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.029	1	7.941E-004	0.028	0.031	-
Day	1.142E-003	1	2.224E-003	-3.429E-003	5.713E-003	6.30
Day^2	5.893E-003	1	1.662E-003	2.477E-003	9.310E-003	1.00
Day^3	8.222E-003	1	3.185E-003	1.676E-003	0.015	6.30
		Temperature			
Factors	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	37.21	1	0.78	35.59	38.83	-
Day	-3.89	1	2.63	-9.34	1.56	19.53
Day^2	-22.47	1	8.99	-41.07	-3.87	64.65
Day^3	16.70	1	9.78	-3.54	36.94	131.31
Day^4	52.54	1	23.32	4.30	100.78	393.97
Day^5	-9.77	1	8.09	-26.51	6.97	64.63
Day^6	-34.50	1	15.91	-67.41	-1.59	164.05

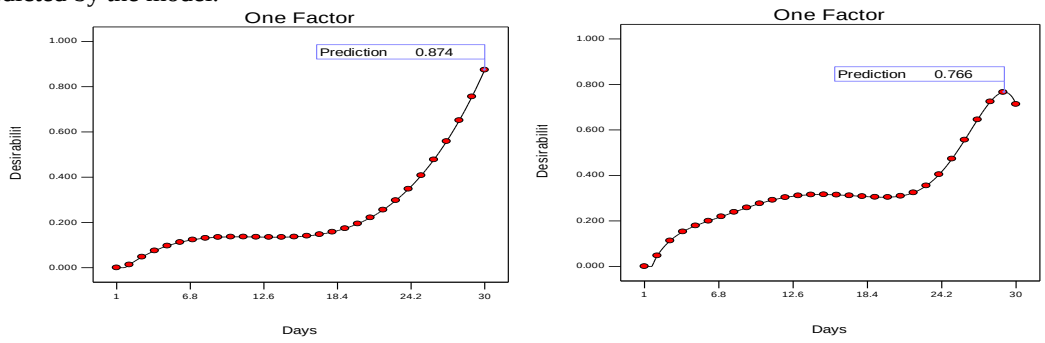
The value of adjusted determination coefficient for both biogas and temperature was also high, supporting a high significant of the model [28] and all p-values coefficients were less than 0.0001, which implied that the model is suitable for the adequate representation of the actual relationship in the selected variable. The lack-of-fit term obtained for biogas and temperature were not significant relative to the pure error. Adequate precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The values (17.706, 8.833) obtained in this study indicates an adequate signal.This model can be used to navigate the design space. The final equations in terms of actual factor for the response cubic (biogas) and sixth (temperature) model are expressed in Eqns. (1) and (2).

$$Biogas\ Volume\ (m^3) = 0.024616 + 1.15366\text{E} - 003(\text{Day}) - 9.73782\text{E} - 005(Day^2) + +2.69697\text{E} - 006\ (Day^3) \quad (1)$$

$$Temperature\ (o_C) = 26.06226 + 4.81510(\text{Day}) - 1.29444(Day^2) + 0.17162\ (Day^3) - 0.011007\ (Day^4) + 3.29964\text{E} - 004(Day^5) - 3.71191\text{E} - 006(Day^6) \quad (2)$$

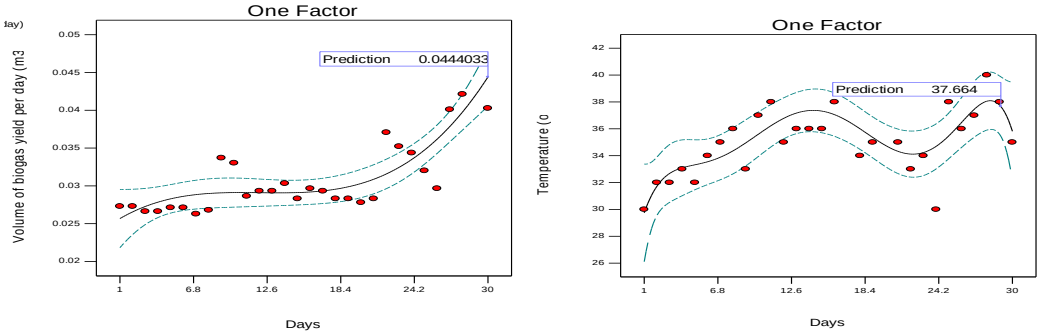
In general, the desirability plot is a graphical representation of the regression equation for the optimization of the reaction variable. Fig. 2(a-b) described the desirability prediction point for both biogas and temperature while Fig. 3 (a-b) shows the plots of biogas volume against day with predicted point, and temperature against day with predicted point. The optimum condition predicted by the model was biogas volume 4.44 x 10^{-2} m^3, temperature of 37.7 ^oC at 29.0895 day. Using the optimum condition of 29.0895 (29 days, 2 h, 9 min) day to load two digesters, an average

biogas volume of 4.216 x 10^{-2} m^3 and mesophilic temperature of 37 ^oC was attained, which was well within the range predicted by the model.



(a) (b)

Figure 2: Desirability prediction point for both biogas and temperature



(a) (b)

Figure 3: Plots of biogas volume, temperature against day with predicted points

Physicochemical Properties of Substrate and Digestate

Physicochemical properties of substrate and digestate were determined using a digital photometer. An effective way of finding the availability of the amount of nutrients accessible for bacterial action during digestion is through the determination of the total solids of the wastes. Table 6 shows the physicochemical properties of the substrate and digestate before and after the anaerobic digestion, based on remarks, total alkalinity, aluminium, potassium, iron, total copper, zinc, dissolved oxygen (DO), total nitrogen, carbon, nitrogen, phosphorous, conductivity, total solid and volatile solid, shows remark S's, which explains an increase in values of substrate and digestate after the anaerobic digestion. Meanwhile, ammonia nitrogen, total phosphate, pH, calcium, magnesium and ash content shows remark D's, a decrease after anaerobic digestion. This observation is in line with what was earlier reported [29]. The high disparity in total solids and volatile solids in this study after anaerobic digestion are within the ranges earlier reported for biogas production. The amounts of methane to be produced depend on the quantity of volatile solids present in the waste and their digestibility. Higher ash content also corresponds with higher volatile solids content. Goat dung has a higher potential for organic manure due to its ash content. The little variation obtained in conductivity shows that the substrate and digestate are good energy carrier. Furthermore, the increased in values of nitrogen, phosphorus and potassium (NPK) in the digestate indicate that the end product will be good for fertilizer application.

Microbial Analysis Results

The presence of methane producing bacteria called methanogens in substrate and digestate arose the needs for microbial load count analyses. The results shows substrate account for 5.2×10^{-2} Cfu/ml, inoculums contains 8.4×10^{-3} Cfu/ml while digestate account for 5.8×10^{-2}Cfu/ml. The increase in microbial load count for digestate during the digestion of substrate was due to growth of the microbes that aided the completion of the anaerobic reaction as well as biogas production during the digestion.

Conclusion

Biogas production from Co-digestion of cornstalk with goat dung and its statistical analysis was carried out and the following conclusions were drawn:

i. The highest experimental daily biogas volume obtained was 4.7×10^{-2} m^3 on 29^{th} day.
ii. The temperature of the slurry was within the mesophilic temperature ranges (30-40 ℃).
iii. The pH of the slurry dropped from 7.95 to 7.55 in the space of 4 weeks.
iv. The optimum condition predicted by the model was biogas volume 4.44 x 10^{-2} m^3, temperature of 37.7 ^oC at 29.0895^{th} day. Using the optimum condition of 29.0895 (29 days, 2 h, 9 min) day to load two digesters, an average biogas volume of4.216 x 10^{-2} $m^3$and mesophilic temperature of 37 ^oC was attained, which was well within the range predicted by the model.
v. The R^2 of 73.34% and 55.60% obtained for biogas and temperature, indicated that the sample variation were attributed to the independent factor (Day).
vi. Physicochemical analysis substrate and digestate showed that alkali treated dried cornstalk (ATDCS) with cattle dung is a good waste material for biogas production.
vii. The increase in values of nitrogen, phosphorus and potassium (NPK) in the digestate indicate that the end product will be good for fertilizer application.

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