Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

(Research Article)

Check for updates

Improving biogas yield via poultry droppings doped with plantain peels

Mabel K [1,*], Amabogha B [2] and Adepoju T. F [1]

[1] *Department of Chemical Engineering, Faculty of Engineering, Delta State University of Science & Technology Ozoro, Delta State, Nigeria.*

[2] *Department of Chemical Engineering, Faculty of Engineering, Federal University Otuoke, Bayelsa State, Nigeria.*

Global Journal of Engineering and Technology Advances, 2023, 15(03), 038–050

Publication history: Received on 15 April 2023; revised on 03 June 2023; accepted on 06 June 2023

Article DOI: https://doi.org/10.30574/gjeta.2023.15.3.0094

Abstract

This research work investigates biogas production from poultry droppings mixed with plantain peels and poultry droppings without plantain peels and its statistical analysis using Microsoft excel and a four factor response surface methodology (RSM). Chemical and proximate compositions of digestate were carried out with the aids to determine the potential use for agricultural purposes. Result obtained from poultry droppings mixed with plantain peels and poultry droppings without mixing with plantain peels indicates the maximum biogas yield as 3.06 x 10^{-2} and 2.42 x 10^{-2} m^3/day respectively. Analysis of variance of regression equation shows the coefficient of determination (R^2) of 99.67% and 99.98% respectively. Ambient, slurry, gas layer and interface between slurry and gas layer temperatures were measured during the fermentation process and were found to be within the mesophilic temperature range. Chemical and proximate compositions of the digestates show that it could be used as replacement for biological fertilizers. Therefore, it can be concluded that mixing plantain peels with poultry droppings increased the biogas volume.

Keywords: Plantain peels; Poultry droppings; Biogas; Statistical analysis; Microsoft Excel; Chemical; Proximate composition

1. Introduction

As a result of global warming occurred via the released of toxic chemical by fossil fuel usage, the world has been subjected to constant domestic and human health risks. The more the use of fossil fuel increases, the more the mortality rate increase. Report shows that averagely, more than 8 million died in 2018 [1]. Given Nigeria's high reliance on non-renewable energy sources and its dense population, the harmful consequences of these fossil fuels grow more pronounced with rising daily usage. However, the use of renewable and clean energy as a replacement for fossil fuel and its derivatives is constrained by the high cost of refining fossil fuel, petroleum, and its related products as a result of volatile oil prices and the policies of oil-producing nations. These factors plead for the issue of fossil fuels as key energy sources to be quickly addressed in order to prevent an economy from having no dependable energy supply for its socioeconomic growth. According to [2], the oil industry in Nigeria, which generates 85% of the country's revenue, is very important to the country's economy. To lessen reliance on non-renewable resources, alternative energy sources have been identified and are currently being used throughout the majority of the world. These alternative fuels have been determined to have better qualities than fossil fuels due to their clean combustion, cheaper production or acquisition costs, lack of negative environmental effects, and lack of health risks for people [3]. An eco-friendly form of fuel is biogas. It is a gas created by the biological decomposition of organic material without the presence of oxygen, a process known as anaerobic digestion. Four biochemical processes take place during anaerobic digestion: hydrolysis (complex carbohydrates, fats, and proteins are first hydrolyzed to their monomers by exoenzymes and bacterial cellulose), acidogenesis (monomers are further decomposed into short-chain acids like acetic acid, propionic acid, butyric acid, and valeric acid), acetogenesis (these short-chain acids are converted into acetate, hydrogen, and carbon

* Corresponding author: Mabel, K

dioxide), and methane[4]. Additionally, a lot of home, industrial, and agricultural waste that contains nitrogen, phosphorus, and potassium is produced every day all over the world and has a difficult time being dumped. Plantain peels are a home waste with high potassium and phosphorus content that are present as mineral compositions with high calorific and nutritional qualities. The majority of the time, these wastes are thrown or dumped in landfills, where they represent a risk to public health and result in illnesses. They encourage the growth of rodents, flies, mosquitoes, and other disease-carrying vectors, which give off an unpleasant odor and methane, a significant greenhouse gas that contributes to global warming, and they cause surface and groundwater contamination through leachate[5]. Within the same constrained management, the nutrient content of poultry droppings, which are a mixture of animal excrement and bedding materials like sawdust, etc., varies [6]. Poultry droppings have a higher percentage of biodegradable organic materials than the manure from any other livestock, which anaerobic digestion can handle to its fullest [3]. In light of these, this study combined and compared the use of plantain peels combined with chicken droppings for the production of biogas.

2. Material and methods

2.1. Materials

Fresh plantain peels was collected at the eatery and was washed with distilled water to remove adherent dirt, and was oven dried to constant weight, milled into smaller sizes for easy microbial actions [7].

Poultry droppings were obtained from Hadebs farm, Kilanko, Offa garage, Ilorin, Kwara State, Nigeria. All chemical and reagents used were of analytical grades with no further purification and includes, distilled water, activated carbon pellets, ferric chloride, sodium hydroxide, H_2SO_4 and N_aSO_4 and were obtained from Finlab Nig. Ltd.

2.2. Methods

2.2.1. Biogas reactor design with gas collection system

The digester was constructed and run by the methods used by [3] and [8] with little alterations. A 205 L methane reactor with shape implemented for proper mixing was made from galvanized steel because of its strength and durability in acid and basic environments. Different holes were bored on the lid of the digester for the slurry inlet, the insertion of temperature sensors and the gas outlet. For positive retainability of heat and running digestion, the digester was placed above the ground level. The digester made up of rotatable stirrer was made of outlet for digestate and the inlet for the slurry. The gas collection delivery system was via water displacement method collection. The height displayed by the column gas accounted for the biogas volume. The base area of gas collector and biogas volume was computed using Eq. (1) and (2):

$$B_{AC} = \frac{\pi D^2}{4} \dots\dots\dots\dots..(1)$$

Where D= diameter of gas holder, B_{AC} = Base area of gas collector

$$B_V = B_{AC}\ X\ H \dots\dots\dots..(2)$$

Where H = height of the gas in the cylinder

2.3. Slurry preparation

The substrates of poultry droppings mixed with plantain peels, and poultry droppings only were mixed with distilled water using the ratio 1 kg of feedstock: 2 kg of water: 1 kg of plantain peels (1:2:1) in a reactor, since thermal pretreatment removes pathogen also improves dewatering performance and reduces viscosity of the digestate with subsequent enhancement of digestate handling, the slurry was thermally pretreated at temperature of 50 °C. The pH of the slurry was checked in order to know the degree of acidity of the slurry. $NaOH_{(aq)}$ was added to the slurry of poultry droppings mixed with plantain peels to reduce its acidity from 5.4 to 7.21 and H_2SO_4 was added to the slurry of poultry droppings to increase the pH to 7.21 for neutral medium, to help organism adaptation during anaerobic digestion.

2.3.1. Experimental procedure

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 [8]. The slurry was allowed to occupy two-third of the digester space leaving height of 29.1 cm as space for gas production. The slurry 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 manually stirred daily through a stirrer attached to the digester for uniformity of the microbial activities in the digester daily at 9 am, 1 pm and 5 pm, respectively. The gas was collected through water displacement method and the fermentation process was monitored for 50 days. During this period, daily ambient, slurry, interface between slurry and gas and gas layer temperatures were monitored, the pH of the digestate and the height of the biogas holder were measured daily.

2.3.2. Desulphurification

The desulphurification tank contains activated carbon pellets and ferric chloride to selectively adsorb carbon dioxide and hydrogen sulfide from the biogas. Due to the percentage composition of CO_2 in biogas, it lowers the calorific value of biogas produced [9] Biogas with reduced CO_2 content burn with a bright luminous flame [10]. Hence, the raw biogas collected was allowed to pass through a desulphurification tank so as to remove CO_2 and H_2S.

2.3.3. Statistical Analysis by Microsoft Excel with Linear Regression and correlation

Microsoft Excel Version 2013 was used to plot the graphs of biogas volume against the period of digestion (50 days). Linear regression model and correlation was used to evaluate the regression parameters βo (intercept) and β1 (slope), [2], respectively and ANOVA Table was prepared.

2.3.4. Correlation of temperature with biogas volume by RSM

Central Composite Optimal Design (CCOD) was employed to correlate the relationship among the temperatures and biogas volume. Five-level-four-factors (ambient, slurry, gas layer, and interface temperatures) design was applied, the central point was increased by 2 step-lengths, and the central point per groups was increased by a step length while the run per HTC axial group was also increased by 2 step length. Chosen alpha spherical 2 with K>5 = 1.41421 with face centered 1, 50 experimental runs were generated. This included 16 factorial points, 14 axial points, and 20 central points to provide information regarding the interior of the experimental region, making it possible to evaluate the curvature effect. Selected factors for biogas volume relationship were ambient temperature, X_1 (T_{amb}), slurry temperature, X_2 (T_{slurry}), interface temperature, X_3 (T_{int}), and gas layer temperature, X_4 (G_{lt}. The quality of the fit of the model was evaluated using test of significance and analysis of variance (ANOVA). The fitted quadratic response model is described by Eq. (3).

$$\beta = \vartheta_0 + \sum_{i=1}^{k} \vartheta_i X_i + \sum_{i=1}^{k} \vartheta_{ii} X_i^2 + \sum_{i<j}^{k} \vartheta_{ij} X_i X_j + \varepsilon \ldots \ldots \ldots (3)$$

Where:

β is response factor (biogas volume), ϑ_o is the intercept value, ϑ_i (i= 1, 2, k) is the first order model coefficient, ϑ_{ij} is the interaction effect, and ϑ_{ii} represents the quadratic coefficients of X_i, and ε is the random error.

2.4. Chemical and proximate analyses of the digestates

Chemical and proximate compositional analysis of the substrate and digestate such as, ash content, carbon content, nitrogen content, calcium, pH, phosphorus, potassium, and C/N ratio were carried out using method already adopted by [3].

3. Results and discussion

3.1. Volume of biogas

Biogas production occurred in a constructed biogas plants called anaerobic digestion [11], and was measured for 50 days. In order to get a higher biogas yield, the substrate contained high quality and biodegradable organic matters from which methane concentration produced was in higher percentage [12]. The height of digester and biogas volume were measured daily in the afternoon. From Table 1, it was observed that the volume of biogas was slow at the beginning, increased on the 17th day and decreased on the 20th day and maintained a steady increase till the 35th day before maintaining a constant yield to the end of the digestion process in a batch anaerobic digestion. Biogas production rate in batch condition is directly proportional to specific growth rate of methanogenic bacteria in the bio-digester [13].

Observations show that, when plantain peels was mixed poultry droppings, the rate of biogas production was increased which agrees with [15] and [16].

Table 1 Daily readings of biogas volume and height of digester

		Poultry droppings mixed with plantain peels		**Poultry droppings**	
Date	**Cross sectional area (m^2)**	**Height (m^2)**	**Biogas volume (m^2) x 10^{-2}**	**Height (m^2)**	**Biogas volume (m^2) x 10^{-2}**
1	1.07	1.94	2.07	1.33	1.42
2	1.07	2.01	2.15	1.42	1.51
3	1.07	2.03	2.17	1.42	1.52
4	1.07	2.11	2.25	1.50	1.6
5	1.07	2.14	2.28	1.54	1.64
6	1.07	2.17	2.31	1.56	1.66
7	1.07	2.02	2.16	1.42	1.52
8	1.07	1.97	2.1	1.45	1.55
9	1.07	2.02	2.16	1.41	1.5
10	1.07	1.99	2.13	1.39	1.48
11	1.07	2.17	2.31	1.57	1.67
12	1.07	2.15	2.28	1.54	1.64
13	1.07	2.21	2.36	1.61	1.72
14	1.07	2.14	2.28	1.53	1.63
15	1.07	2.16	2.3	1.56	1.66
16	1.07	2.08	2.22	1.48	1.58
17	1.07	2.86	3.05	2.27	2.42
18	1.07	2.87	3.06	2.27	2.42
19	1.07	2.86	3.05	2.26	2.41
20	1.07	2.87	3.06	2.26	2.41
21	1.07	2.05	2.19	1.42	1.52
22	1.07	2.05	2.19	1.42	1.52
23	1.07	2.04	2.18	1.43	1.53
24	1.07	2.05	2.19	1.44	1.54
25	1.07	2.17	2.31	1.56	1.66
26	1.07	2.17	2.31	1.56	1.66
27	1.07	2.16	2.3	1.57	1.67
28	1.07	2.17	2.31	1.57	1.67
29	1.07	1.95	2.08	1.35	1.44
30	1.07	1.95	2.08	1.33	1.42
31	1.07	2.13	2.27	1.53	1.63

32	1.07	2.17	2.31	1.55	1.65
33	1.07	2.08	2.22	1.48	1.57
34	1.07	2.21	2.36	1.61	1.72
35	1.07	2.87	3.06	2.26	2.41
36	1.07	2.81	3	2.26	2.41
37	1.07	2.87	3.06	2.27	2.42
38	1.07	2.77	2.96	2.25	2.4
39	1.07	2.87	3.06	2.27	2.42
40	1.07	2.80	2.99	2.26	2.41
41	1.07	2.87	3.06	2.26	2.41
42	1.07	2.87	3.06	2.25	2.4
43	1.07	2.81	3	2.27	2.42
44	1.07	2.87	3.06	2.26	2.41
45	1.07	2.91	3.1	2.26	2.41
46	1.07	2.87	3.06	2.27	2.42
47	1.07	2.87	3.06	2.27	2.42
48	1.07	2.92	3.11	2.26	2.41
49	1.07	2.87	3.06	2.27	2.42
50	1.07	2.87	3.06	2.26	2.41

3.2. Temperature variations and pH

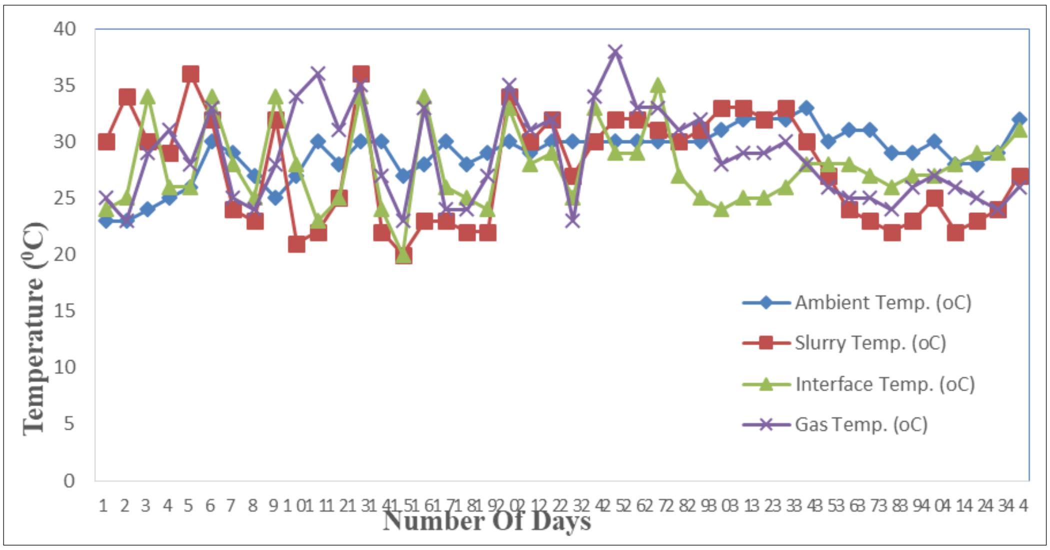


Figure 1a Graph of temperature variations poultry droppings without plantain peels

The temperature variations for the morning, afternoon and evening of the fermentation process of poultry droppings mixed with plantain peels and poultry droppings without mixing with plantain peels. The plots of temperature versus days are shown in Figure 1a and 1b. It was observed that throughout the duration of the digestion process, the temperature was found to be within the mesophilic range (30 °C – 40 °C) and could be attributed to the weather conditions of the experiment area which encouraged digestion [14]. During the exponential growth phase period, the temperature of the ambient, slurry, interface and gas layer was found to be between 20 to 30 °C, 18 to 29 °C, 19 to 31°C and 19 to 34 °C respectively. The plot of pH against the weeks of digestion process is shown in Figure 2. The weekly pH recorded was found to vary erratically between the acidic to basic range [18], which was attributed to the nature of feed in the digester. pH of the digestion changes progressively from acidic to alkaline during the process of biogas production [14]. To maintain the C/N level of the digester, substrates of poultry droppings were mixed with plantain peels [19].

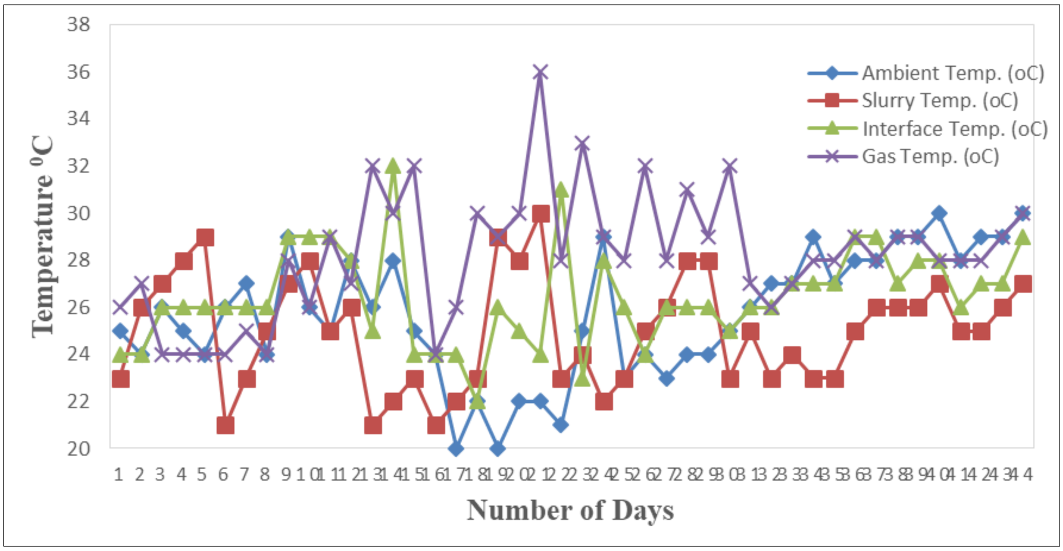


Figure 1b Graph of temperature variations for poultry droppings with plantain peels

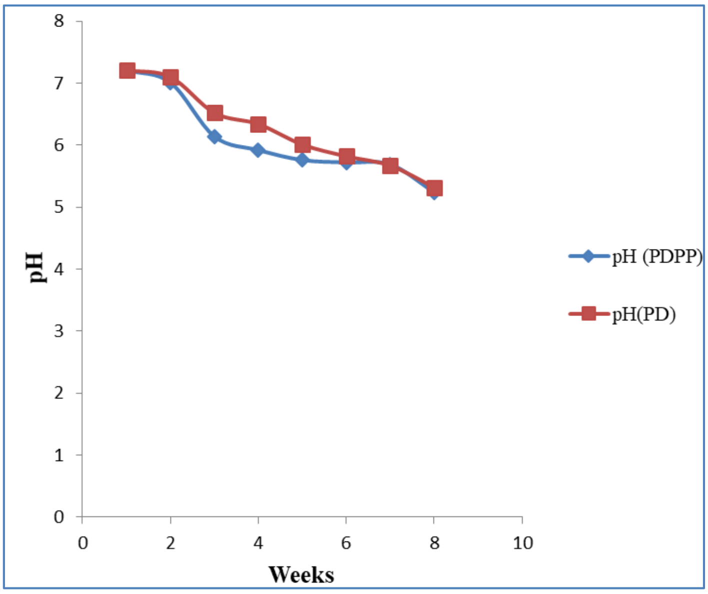


Figure 2 Weekly pH of poultry droppings mixed plantain peels (PDPP) and poultry droppings (PD) against number of weeks of the digestion period

3.3 Statistical analysis

3.3.1 Statistical analysis of biogas produced using Microsoft Excel 2013.

The Statistical Analysis results of linear regression model and correlation was carried out. The input model variable was the number of days while the output variable was the volume of biogas produced. Table 1 shows the total sum of the square (SST) which is a measure of the total variability of the biogas volume of poultry droppings mixed with plantain peels and poultry droppings only, was obtained as 8.34×10^{-4} and 11.26×10^{-4}, the SSR called the regression sum of square, which measures the total variability of the fitted values was obtained as 4.19×10^{-4} and 4.33×10^{-4}. The SSE (sum of square error) which is the measure of the unexplained variability was obtained as 4.14 x 10^{-4} and 4.14 x 10-4 respectively. To obtain the degree of freedom for the ANOVA, the parameters are the number of digesters while the number of experiments is the number of days for the digestion process. The probability values obtained are less than 0.05 which explains that the regression and correlation model terms are significant.

Table 2 ANOVA for linear regression model and correlation for poultry droppings mixed with plantain peels and poultry droppings

Source	**DF**		**Sum of square (10^{-4})**		**Mean square (10^{-4})**		**F value**		**Prob>F**
	PDPP	PD	PDPP	PD	PDPP	PD	PDPP	PD	PDPP&PD
Model	1	1	4.19	4.34	4.19	4.34	46.56	48	< 0.0001
Error	48	48	4.14	4.14	0.09	0.09			
Total	49	49	8.34	8.48					

3.3.2 Statistical analysis by Response Surface Methodology (RSM)

Statistical analysis of poultry droppings mixed with plantain peels

Table 3a Test of significance for every regression coefficient

Source	**Term df**	**Error df**	**F-value**	**p-value**	
Whole-plot	2	4.94	1999.85	< 0.0001	Significant
X_1	1	4.21	43.26	0.0023	
X_1^2	1	5.92	3962.87	< 0.0001	
Subplot	12	24.20	458.65	< 0.0001	Significant
X_2	1	27.15	0.4456	0.5101	
X_3	1	27.15	0.9296	0.3435	
X_4	1	27.15	32.61	< 0.0001	
$X_1 X_2$	1	27.15	10.11	0.0037	
$X_1 X_3$	1	27.15	7.93	0.0090	
$X_1 X_4$	1	27.15	0.4043	0.5302	
$X_2 X_3$	1	27.15	0.6683	0.4207	
$X_2 X_4$	1	27.15	6.94	0.0138	
$X_3 X_4$	1	27.15	74.47	< 0.0001	
X_2^2	1	24.84	2501.46	< 0.0001	
X_3^2	1	24.84	1538.76	< 0.0001	
X_4^2	1	24.84	1538.76	< 0.0001	

Table 3b Summary of regression values

Std. Dev.	**0.0284**	**R^2**	**0.9967**
Mean	2.56	Adjusted R^2	0.9951
C.V. %	1.11		

Design Expert 12.0.3.1 software was employed to evaluate the coefficients of the full regression model equation and their statistical significance. Graph can provide a visual method to observe responsive value and to test parameter level relation. Figure 3 shows the 3-Dimentional response surface plots representing the effect of temperatures on the biogas volume. Results show that there were perfect interactions between the selected variables and the volume of biogas produced, it was noticed that the mutual effects between slurry with ambient temperatures, interface with slurry temperatures indicated superiority over other factors. Table 2 shows the test of significance for every regression coefficient. The results showed that the p-values of the model terms were significant, i.e. $p< 0.05$. In this case, the two linear terms (X_1, X_4), the four cross-products (X_1X_2, X_1X_3, X_2X_4, X_3X_4 where the terms X_1, X_2, X_3 and X_4) and the four quadratic terms (X_1^2, X_2^2, X_3^2 and X_4^2) were all remarkably significant model terms at 95% confidence level except X_2, X_3,X_2X_3, and X_1X_4. However, all other model terms were more significant than X_2X_4. In order to minimize error, all the coefficients were considered in the design. Table 4.6b shows the analysis of variance of regression equation model. The model F-value (subplot) of 458.65 with error df of 24.20 implied the model was significant. The data obtained fitted best to a quadratic model. It exhibited low standard deviation of $2.28 \times 10^{-5}$and high "R-Squared" values. The coefficient of determination (R^2) was 99.67%, R-Sq. (adj.) was found to be 99.51% and all p-value coefficients were less than 0.1, which implied that the model proved suitable for the adequate representation of the actual relationship among the selected factors. These values revealed that this regression was statistically significant; only 0.033% of total variations were not explained by this regression model. Meanwhile, the R^2 indicated a high consistency between the experimental values and the predicted values. The final equation was done in terms of actual factors for the central composite optimal design response surface quadratic model is expressed in Eq. (4).

$$\begin{aligned} Y\,x10^{-2}\,(\mathrm{m}^3) = {} & -23.08531 + 0.658030X_1 + 0.107524X_2 + 0.618295X_3 + 0.440287X_4 - 0.000456X_1X_2 \\ & + 0.001076X_1X_3 + 0.000199X_1X_4 - 0.000104X_2X_3 - 0.000275X_2X_4 - 0.002399X_3X_4 - 0.012542X_1^2 \\ & - 0.001691X_2^2 - 0.009429X_3^2 - 0.006312X_2^2 \ldots\ldots (4) \end{aligned}$$

Statistical analysis of poultry droppings

Table 4a Test of significance for every regression coefficient

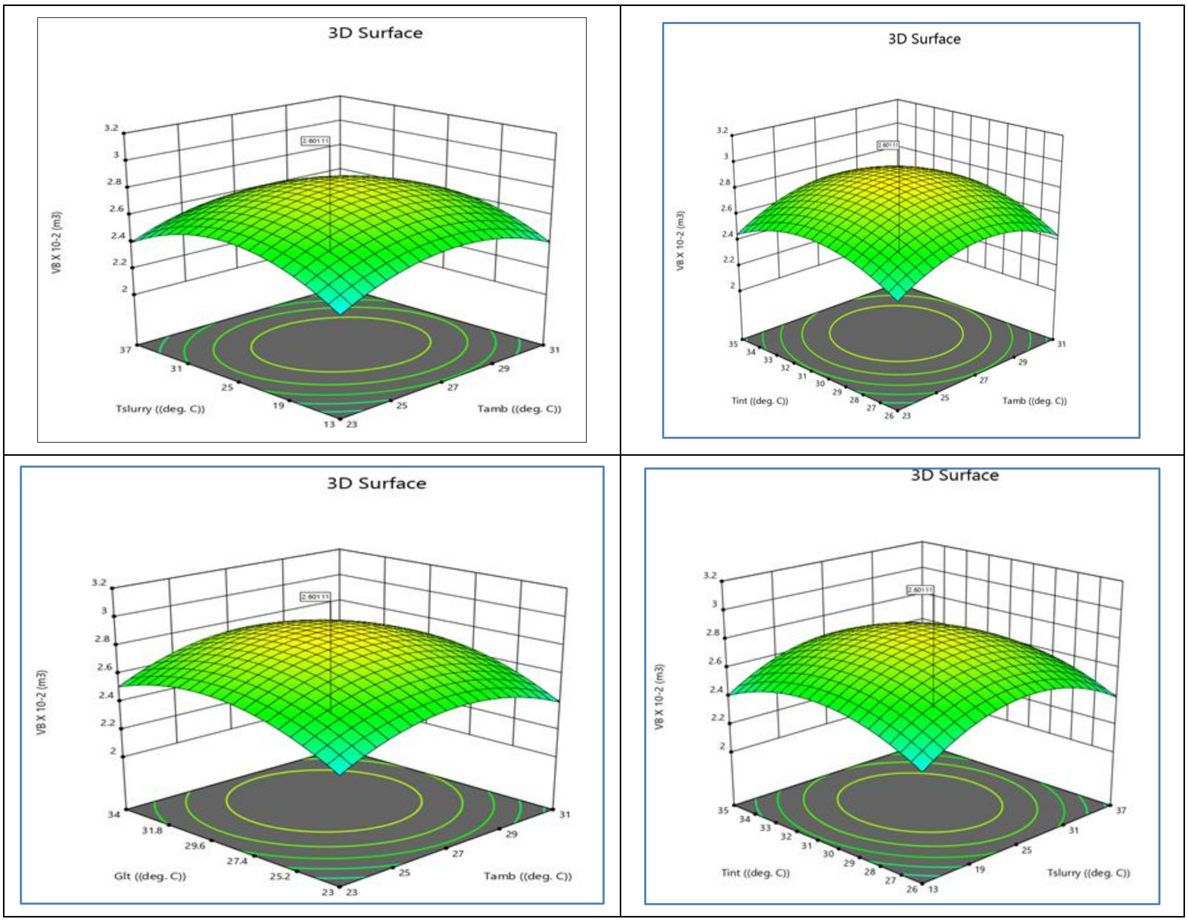
Source	Term df	Error df	F-value	p-value	
Whole-plot	2	8.03	23648.14	< 0.0001	significant
X_1	1	7.30	553.22	< 0.0001	
X_1^2	1	8.90	46760.63	< 0.0001	
Subplot	12	27.71	5160.50	< 0.0001	significant
X_2	1	30.20	1.27	0.2677	
X_3	1	30.20	38.57	< 0.0001	
X_4	1	30.20	674.43	< 0.0001	
$X_1 X_2$	1	30.20	231.40	< 0.0001	
$X_1 X_3$	1	30.20	80.80	< 0.0001	
$X_1 X_4$	1	30.20	0.4781	0.4946	
$X_2 X_3$	1	30.20	5.893E-29	1.0000	
$X_2 X_4$	1	30.20	68.85	< 0.0001	
$X_3 X_4$	1	30.20	883.99	< 0.0001	
X_2^2	1	25.03	32938.41	< 0.0001	
X_3^2	1	25.03	20340.21	< 0.0001	
X_4^2	1	25.03	20077.09	< 0.0001	

Table 4b Summary of regression values

Std. Dev.	**0.0078**		**R^2**	**0.9998**
Mean	1.92		Adjusted R^2	0.9997
C.V. %	0.4048			

Design Expert 12.0.3.1 software was employed to evaluate and determine the coefficients of the full regression model equation and their statistical significance. A graph can provide a kind of visual method to observe responsive value and to test parameter level relation. Figure 4 shows the 3-Dimentional response surface plots representing the effect of temperatures on the biogas volume. Table 3 shows the test of significance for every regression coefficient. The results showed that the p-values of the model terms were significant, with p< 0.05. In this case, the three linear terms (X_1, X_3, X_4), the four cross-products (X_1X_2, X_1X_3, X_2X_4, X_3X_4) and the four quadratic terms (X_1^2, X_2^2, X_3^2 and X_4^2) were all remarkably significant model terms at 95% confidence level except for X_2, X_2X_3, and X_1X_4 that were non sigificant with very low F-value. However, X_1^2 with the highest Fmodel = 46760.30 is the most significant model term, but all other model terms were more significant than X_3 with Fmodel value = 38.57. In order to minimize error, all the coefficients were considered in the design. The model F-value (subplot) of 5160.50 with error df of 27.71 implied the model was significant. The data obtained fitted best to a quadratic model. It exhibited low standard deviation of 0.0078 and high "R-Squared" values. The coefficient of determination (R^2) was 99.98% while the R-Sq. (adj.) was found to be 99.97% and all p-value coefficients were less than 0.1, which implied that the model proved suitable for the adequate representation of the actual relationship among the selected factors. These values revealed that this regression was statistically significant; only 0.02% of total variations were not explained by this regression model. Meanwhile, the R^2 indicated a high consistency between the experimental values and the predicted values. The final equation in terms of actual factors for the central composite optimal design response surface quadratic model is expressed in Eq. (5).

$$Y\,x10^{-2}(\mathrm{m}^3) = -25.24207 + 0.901922X_1 + 0.361055X_2 + 0.398216X_3 + 0.299190X_4 - 0.001209X_1X_2 + 0.000844X_1X_3 + 0.000051X_1X_4 - 1.52896\mathrm{E}-16X_2X_3 - 0.000330X_2X_4 - 0.001396X_3X_4 - 0.016655X_1^2 - 0.005801X_2^2 - 0.006367X_3^2 - 0.003905X_2^2 \;\ldots\ldots\ldots\ldots\ldots(5)$$



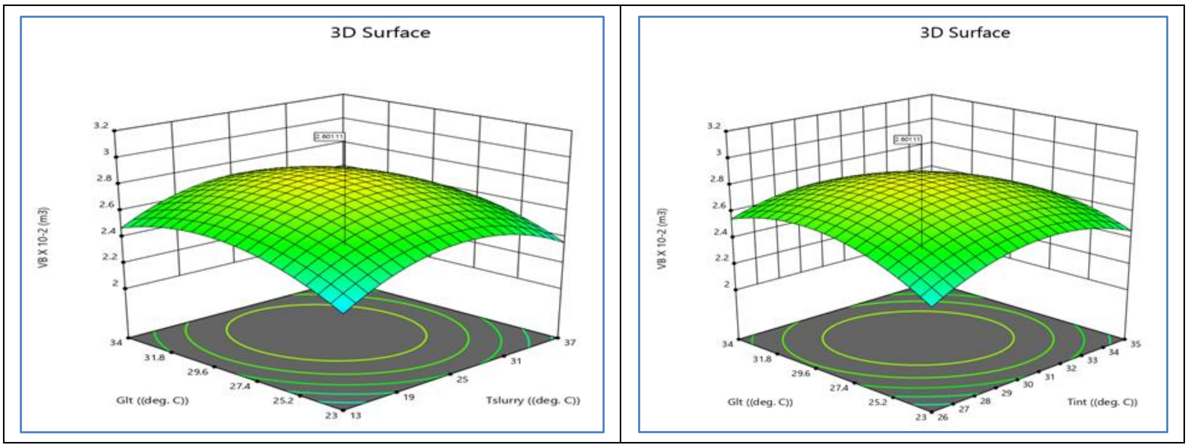
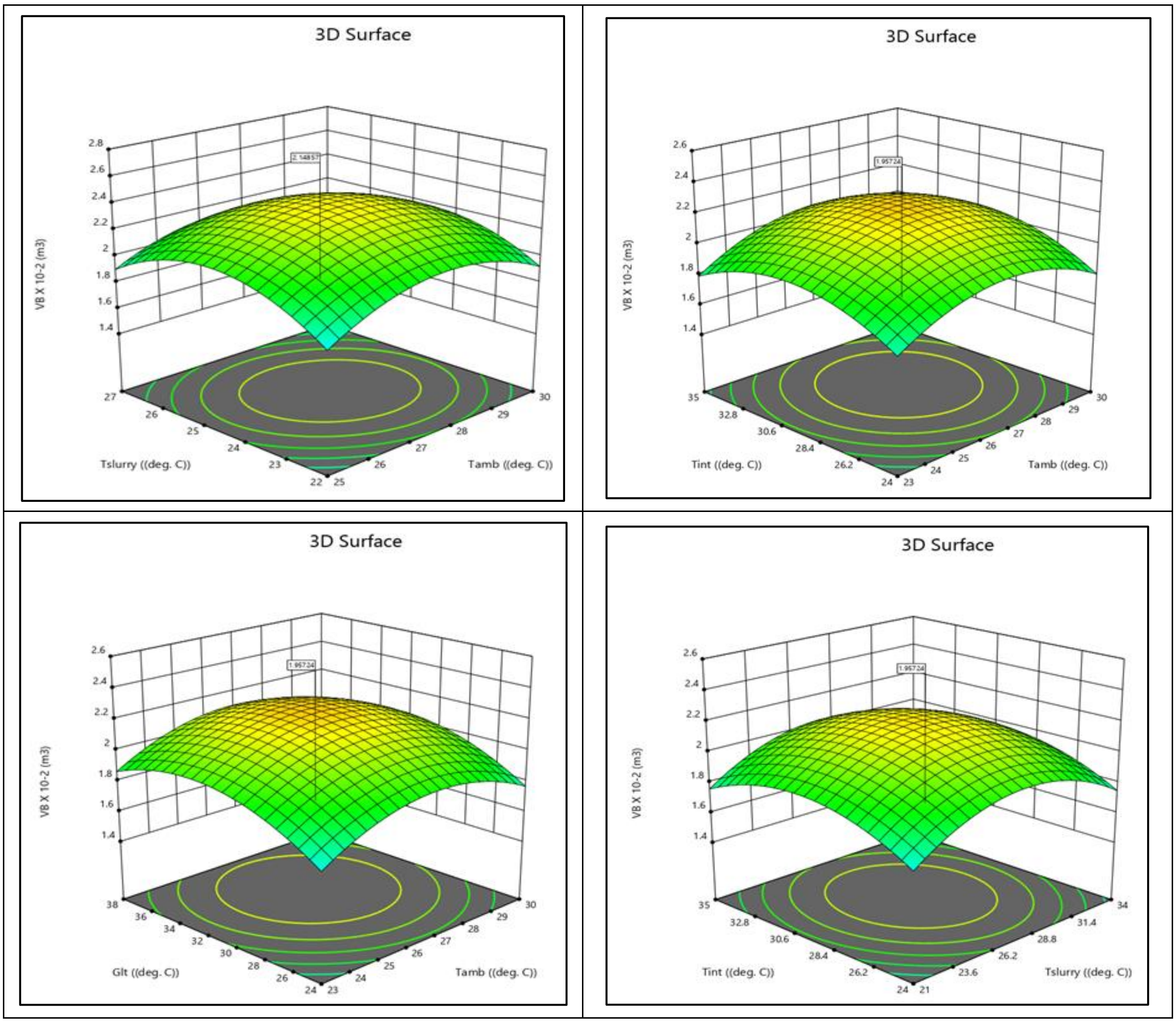


Figure 3 3-D plots of the interaction between temperatures on volume of biogas produced of poultry droppings mixed with plantain peels



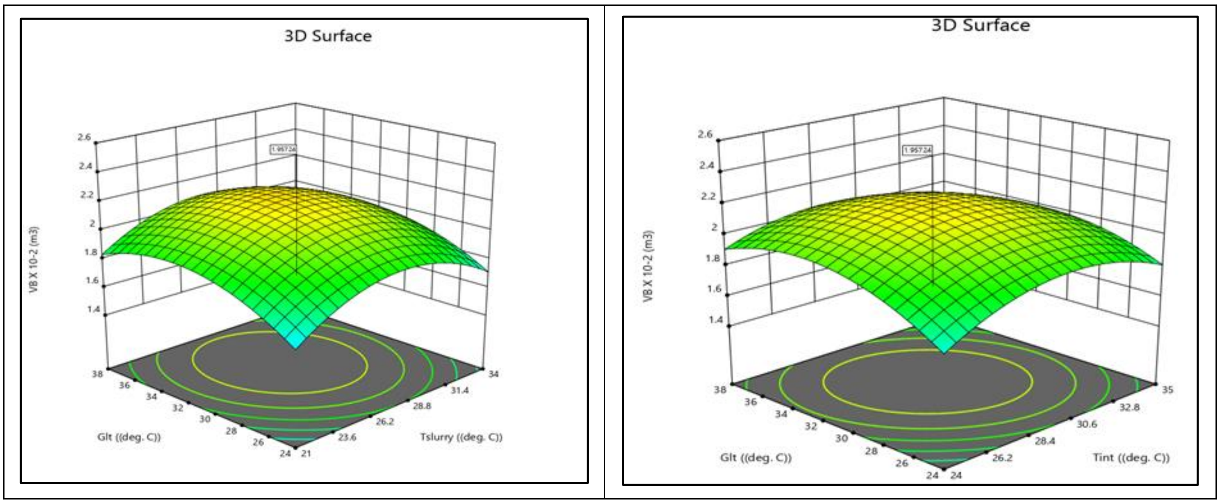


Figure 4 3-D plots of the interaction between temperatures and volume of biogas produced from poultry droppings

3.4 Chemical and Proximate Analysis of the Digestate for PDPP and PD

Table 4 shows the chemical and proximate analysis of the digestates after the anaerobic digestion shows the percentage variation. Chemical and Proximate analyses 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. Poultry droppings have a higher potential for organic manure compared with plantain peels because of its higher ash content. However the high values of nitrogen, phosphorus and potassium in the digestate indicates that the end product is useful for fertilizer application. The weight sample of 0.165 g of the digestate for each of the digester was used in the determination of the proximate analyses results. From the results, it was observed that the digestate of poultry droppings mixed with plantain peels has the highest value of pH, C, N, C/N, P, K, and ash content compared with when it was not mixed with plantain peels. The values of NPK from the digestate of poultry droppings mixed with plantain peels and poultry droppings without mixing with plantain peels (6.23, 32.41, 4.51) and (6.01, 29.57, 4.31), respectively which makes it applicable for fertilizer applications and agrees with [16]. Reduction of size of the plantain peels helps the digestion rate to be faster [17], and was within the mesophilic temperature range.

Table 5. Chemical and Proximate Analysis of the Digestate

Digestates	pH	C (mg/LC)	N (mg/LN)	C/N	P (mg/LP)	K (mg/LK)	Ca (mg/LCa)	Ash (%)
PDPP	7.92	72.01	6.23	4.8:1	32.41	4.51	34.02	24
PD	7.85	70.11	6.01	4.8:1	29.57	4.31	32.23	22

Where PDPP is poultry droppings mixed with plantain peels and PD is poultry droppings.

4 Conclusion

Biogas production from poultry droppings mixed with plantain peels and poultry droppings only and their statistical analysis were carried out and the following conclusions were drawn:

- The highest experimental daily biogas volume was 3.06×10^{-2} and 2.42×10^{-2} obtained was on the eighteenth day (18th day) of the digestion process.
- Results show that more biogas volume was produced when poultry droppings were mixed with plantain peels.
- The temperatures of the slurry, ambient, interface and gas layer measured during the fermentation period were within the mesophilic temperature ranges (30-40°C).
- Chemical and proximate analyses of the digestate shows that poultry droppings mixed with plantain peels and poultry droppings only improved organic manure for agricultural production.
- The statistical analysis by RSM predicted values were validated using 95% confidence level; the R-squares were all above 90% with adjusted R-square in close agreement with it.

Compliance with ethical standards

Acknowledgments

Authors acknowledge the effort of the owners of Poultry Hadebs farm, Kilanko, Offa garage, Ilorin, Kwara State and the technicians of Finlab Nig. Ltd, Kwara State Nigeria.

Disclosure of conflict of interest

The authors declare no conflicts of interest.

Funding

This work received no fund from University, Private organization or Government body.

References

[1] https: //www. hsph.harvard.edu/c-change/news/fossil-fuel-air-pollution-responsible-4-1-in-dealth-worldwide/: retrieved on May 15th, 2023.

[2] Energy Information Administration. http//www.eia.doe.gov/emeu/cabs/usa.html. November, 27, 2015.

[3] Adepoju, T. F., Olatunbosun, B.E., Olawale, O. (2016). Statistical Analysis of Biogas Production from Co-digestion of Cornstalk with Goat Dung using a One Factor Design. Chemistry Research Journal, 1(4):1-10. ISSN: 2455-8990 CODEN (USA):CRJHA5.

[4] Ademisoye, O. B. (2015). Biogas Production from Plantain Plant Wastes with Cattle Dung and its optimization. Final Year Project Thesis: 18-33.

[5] Suyog, V. (2010). Biogas Production from Kitchen Waste. Department of Biotechnology and Medical Engineering National Institute of Technology, Rourkela. P 8-15.

[6] Sharpley, A., Slaton, N., Tabler, T. J., Van Devender, K., Daniels, M., Jones, F. and Daniel. T., Nutrient Analysis of Poultry Litter. Agriculture and Natural Resources, 2009; FSA9529-PD-6-09N.

[7] Adepoju, T.F., Oni, O.O., Dahunsi, S.O., 2015. Optimization investigation of biogas potential of Tithonia diversifolia as an alternative energy source. IJCPR. (In press).

[8] Karki, A., 2002. From Kitchen Waste to Biogas: an Empirical Experience. In: Biogas and Natural Resources Management.

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

[10] Antoniraj, (2015). Mini Bio-Gas Plant Using Food Waste Decomposable Organic Material and Kitchen Waste. Online at: http://m.instructables.com/id/Bio-gas-planr-using-kitchen- waste/Accessed on 9/1/2016.

[11] Yohaness, M. T. (2010). Biogas potential from cow manure – Influence of diet. Uppsala BioCenter Master Thesis 2010:3 Department of Microbiology Faculties of Natural Resources and Agriculture Sciences Swedish University of Agricultural Sciences. ISSN 1101-8151 Uppsala ISRN SLU-MIKRO-EX–10/3–SE.

[12] Mursec, P., Vindis, B., Janzekovic, M., Cus, F. (2009).The impact of mesophilic and thermophilic anaerobic digestion on biogas production. Journal of Achievements in Materials and Manufacturing Engineering, 36(2).

[13] Nordberg A. Edstrom M. Co-digestion of Energy Crops and the Source-Sorted Organic Fraction of Municipal Solid Waste. Water Science Technology.2005; 52: 217-222.

[14] Ukonu, C. U. (2011). Optimization of Biogas Production Using Combinations of Saw Dust and Cow Dung in a Batch Anaerobic Digestion Bioreactor. School of Postgraduate Studies Department of Biochemistry University of Nigeria, Nsukka.

[15] Azadeh Babaee, Jalal Shayegan, Arus Roshani (2013).Anaerobic slurry co-digestion of poultry manure and straws: Effect of organic loading and temperature. Journal of Environmental Health Science and Engineering, 11(1), 15.

[16] Ojolo, S.J., Dinrifo, R.R., Adesuyi, K.B., 2007.Comparative study of Biogas Production from five substrates. Advanced Material Research Journal.18 (19):519-525.

[17] Uzodinma, E. O., Ofoefule A. U. and Enwere N. J. (2011).Optimization of Biogas fuel Production from Blending Maize Bract with Biogenic waste. American Journal of Food and Nutrition.1 (1):1-6.

[18] Ntengwe, F. W., Jovo N., Kasali L. G., and Witika, L.K. (2010). Biogas production in cone-closed floating-Dome batch digester under tropical conditions. International Journal of Chemical Technology Research. 2(1): 483-492.

[19] Zaher, U., Li, R., Jeppsson, U., Steyer, J.P. and Chen, S., (2009). GISCOD: General Integrated solid waste co-digestion model. Waste Research. 43: 2717-2727.