Original Research Article

TEMPERATURE EFFECT ON BIOGAS PRODUCTION FROM CO-DIGESTION OF FOOD WASTE, POTASH AND COW DUNG

ABSTRACT

Temperature influence on biogas production from co-digestion of substrate (food waste, potash and cow dung) was investigated. Different concentrations of the substrate (4% to 12%) were mixed and loaded into the anaerobic digesters to produce biogas. Results of temperature effects on the biogas volume indicated that as the days of production increased, the temperature in the digesters increases and the volume of the biogas produced also increased. For digester B1 to B5, the temperature increase ranged from 10.1 to 44.5^{o}C while the volume of the biogas produced increased from 11.3 to 25.9; 15.3 to 30.9; 10.1 to 34.5; 18.5 to 36.0 and 18.8 to 36m^3/day for digesters B1, B2, B3, B4 and B5 respectively. For digesters B6 to B9, the temperature increase ranged from 20.6 to 48.4^{o}C while the volume of the biogas produced increased from 22.1 to 40.2; 20.6 to 41.5; 24.9 to 42.0 and 24.2 to 42.5m^3/day for digesters B6, B7, B8 and B9 respectively. A total 17859.6m^3 of biogas was generated for a period of 90 days. Average temperature ranges from 29.30 ± 3.00 ^{o}C for digester B1 (4 % concentration of sample) to 41.46 ± 4.33 ^{o}C of digester B8 (11 % concentration of sample). This result was further clarified from the Analysis of variance and multiple comparisons of the temperature which revealed that digesters B5, B8 and B9 had no significant difference among them. The correlation of temperature and volume of biogas generated by each digester revealed that temperature significantly influenced the quantity of biogas generated at P= 0.01 and r = 0.760 (B2G), r = 0.740(B3G), r = 0.721(B6G) and r = 0.650(B8G) showing relationship were significant and had a high relationship between temperature and the substrates.

Keywords: Food waste, temperature, Substrate, Cow dung

1 INTRODUCTION

There is now a worldwide concern about both energy use and pollution. The extraction and use of crude oil have reached unsustainable levels. As a result, research has centered on creating renewable energy sources [7]. Biofuels, which are derived from biomass, are sustainable and renewable forms of energy. All of the Earth's biotic (plant and animal) stuff is collectively referred to as "biomass." Bioenergy production, then, is the process of amassing biomass like trees, crops, or dung and converting it into usable forms of energy like electricity, heat, or motion [7]. Biogas is a combination of carbon dioxide and methane that can be produced from the anaerobic digestion of the organic component of practically any form of biomass. This is an environmentally friendly energy option. Leachates from dump sites, annoyance impacts like flies, stench, aesthetic effects, and vermin like birds and rats can all result from poorly managed organic wastes, which litter the environment. It's possible that leachate could contaminate the groundwater and soil below. Methane (CH4), the biogas component with the highest energy density, is the most vital.
As a significant portion of municipal garbage, food scraps include biodegradable chemicals that can be co-digested with animal manure to increase biogas production [5]. In addition to

commercial kitchens and dining establishments, households can also be a source of food waste. Methanogens are microorganisms often only present in the digestive system, however they can be found in animal manure (slurries from bovine dung, pig manure, poultry, etc.). In the absence of oxygen, the metabolism of these methanogens results in the production of methane. When organic matter is digested anaerobically, one of the major byproducts is biogas. In the absence of oxygen, microorganism colonies breakdown organic molecules in a biological process known as anaerobic digestion. Temperature, pH, the carbon to nitrogen ratio, and a host of other parameters all have a role in the success or failure of anaerobic digestion of organic compounds. The primary variable in biogas production is temperature. Maximum biogas production occurs when temperatures are high enough to support the anaerobic activities that drive waste decomposition. Maximum efficiency in an aerobic digestion system is most affected by the reactor's operating temperatures. Different types of microbes thrive in one of three temperature ranges. Psychrophilic organisms thrive at temperatures between 10 and 20 degrees Celsius (or less than 30 degrees Celsius), mesophilic organisms thrive at temperatures between 30 and 40 degrees Celsius (or slightly more than 50 degrees Celsius), and thermophilic organisms thrive at temperatures between 50 and 60 degrees Celsius (or more than 60 degrees Celsius) [8]. At temperatures between the mesophilic and thermophilic, anaerobic bacteria thrive [2]. High or low temperatures have a negative effect on anaerobes, which can slow down or stop the entire anaerobic digestion process [9]. Potash is an alkaline metal that can be utilized as a catalyst [9]. It also works well as an oxidizer. The purpose of this investigation is to measure how temperature affects the amount of gas produced during the co-digestion of food waste, cow dung, and potash.
This research aims to establish optimal mixing conditions and temperatures for the digestion and decomposition of waste substrate, and to quantify biogas production across a range of temperatures.

1.1 Statement of Problem

Given that the anaerobes responsible for waste breakdown are temperature sensitive in their activities, the success of the digestion process might be affected by the temperature of municipal solid waste (food wastes). The ideal performance of an anaerobic digestion system is most affected by the reactor's operating temperatures. Different types of microbes thrive in one of three temperature ranges. Psychrophilic organisms thrive at temperatures between 10 and 20 degrees Celsius (or less than 30 degrees Celsius), mesophilic organisms thrive at temperatures between 30 and 40 degrees Celsius (or slightly more than 50 degrees Celsius), and thermophilic organisms thrive at temperatures between 50 and 60 degrees Celsius (or more than 60 degrees Celsius) [8]. At temperatures between the mesophilic and thermophilic, anaerobic bacteria thrive [2]. Both very high and very low temperatures are lethal to anaerobes, which slows down the entire process of anaerobic digestion [9].

1.2 Aim

The aim of this study is to determine the effect of temperature on the biogas generated from the substrate.

1.3 Objectives

1. To evaluate the influence of temperature on the amount of biogas generated by sample.

2. Determine the relationship between temperature and the amount of biogas generated by the substrate.

1.4 Research Questions

1. What quantity of biogas will be generated by selected substrate with increase in temperature?
2. Will there be variations in the quantity of biogas generated by the substrate with increase in temperature?
3. Does temperature have any influence on the amount of biogas generated by substrate?

1.5 Research Hypotheses

The following null hypothesis was tested at the 0.05 level of significance:
Ho: There is no relationship between temperature and the amount of gas generated by substrates.
H_1: There is a relationship between temperature and the amount of gas generated by substrates.

2. METHODOLOGY

2.1 Study Area

This research was conducted at Uturu, a metropolitan center in Nigeria's Abia State. Abia state is one of Nigeria's 36 states. Abia encompasses around 6,320 square kilometers and is bordered to the north and northeast by the states of Enugu and Ebonyi. Rivers State is to the south, Cross River State is to the east, and Akwa Ibom State is to the south-east. It is located in southern Nigeria. Crude oil and natural gas production, as well as agricultural products including as yams, maize, taro, oil palm, and cassava, constitute the backbone of Abia State's economy. Manufacturing is a significant secondary sector, notably in Aba. Abia is quickly urbanizing and industrializing, which contributes to its high Human Development Index position (tied for ninth highest). The state contains several local government areas, including uturu, where the research was conducted. Uturu is located in northern Abia State, Nigeria, between the latitudes of 05.33°N and 06.03°N. As a result of its transition from rural to urban status, it is now undergoing tremendous growth. It is well-known for being the location of several schools and the Marist Brothers' hamlet. Uturu is home to several institutions and colleges. Abia State University, Marist Brothers' Juniorate, Uturu, and Gregory University are among them.

2.2 Research Design

The experimental research design was used for this study. The experimental design for the anaerobic digestion of cow dung, potash and food waste was made up of nine reactors labeled B1 through B9. The reactors were set up at various waste concentrations made up of 140g, 175g, 210g, 245g, 280g, 315g, 350g, 385g and 420g to give 4,5,6,7,8,9,10,11 and 12% as described by [9]. Biogas measurement was carried out by water displacement technique to quantify the amount of biogas produced every day for the period of 90 days. The amount of water displaced was proportional to the volume of gas produced. The volume of gas generated was directly proportional to the quantity of water lost.

2.3 Sampling Technique

Purposive sampling technique was employed for the study and a total of 2000g of food wastes,1000g cow dung and 500g of potash was used for this study. This gave a ratio of 3:2:1 of food wastes, cow dung and potash.

2.4 Variables

2.4.1 The Experimental Method

Fresh food waste (2000g), fresh cattle dung (1000g) and potash (500g) were used for the study. The food waste was pound in a mortar while the cattle dung and potash were ground in a mill. Food waste, cow manure, and potash were all crushed up and combined to produce a consistent paste. Nine digesters and gas collection system labelled B1 to B9 were designed using buckner flasks. 140g of the homogenous mixture was put into digester B1 and 250ml of distilled water was added to make up a 4% concentration. Other concentrations (5, 6, 7, 8, 9, 10, 11 and 12%) of the homogenous mix were constituted and loaded into different digesters. Potash was added to determine its effect on the biogas production since potash contain potassium which acts as a catalyst. The cattle dung in the slurry served as the source of inoculum containing the methane producing bacteria which were fed with the food waste to allow the microbes to degrade the waste. The digesters were manually agitated daily in order to ensure intimate contact between the microorganisms and the substrate for effective biogas production. Each setup was allowed for a period of 90 days. Biogas measurement was carried out by water displacement technique to quantify the amount of biogas produced every day for the period of 90 days. The amount of water displaced was proportional to the volume of gas produced [9].

3. RESULTS AND DISCUSSION

3.1 Production of biogas in the different digesters.

The result of the production of biogas in the different digesters for the period of 90 days is shown in Figure 1. It was observed that there was no evidence of biogas production in the different biodigesters for the first 21 days for all the different concentrations used. This could be because the inoculum is either in the lag phase or the methanogens are undergoing a metamorphic growth process. The result also showed that the production of biogas was affected by the concentration of the substrate. The higher the concentration of the substrate, the more production of the biogas as observed in Figure 1. Digester B1 (4% of the substrate) had the least production of biogas (1341.2m^3) while digester B9 (12% of the substrate) produced the highest quantity of biogas (2428.5m^3) for the 90 days duration.

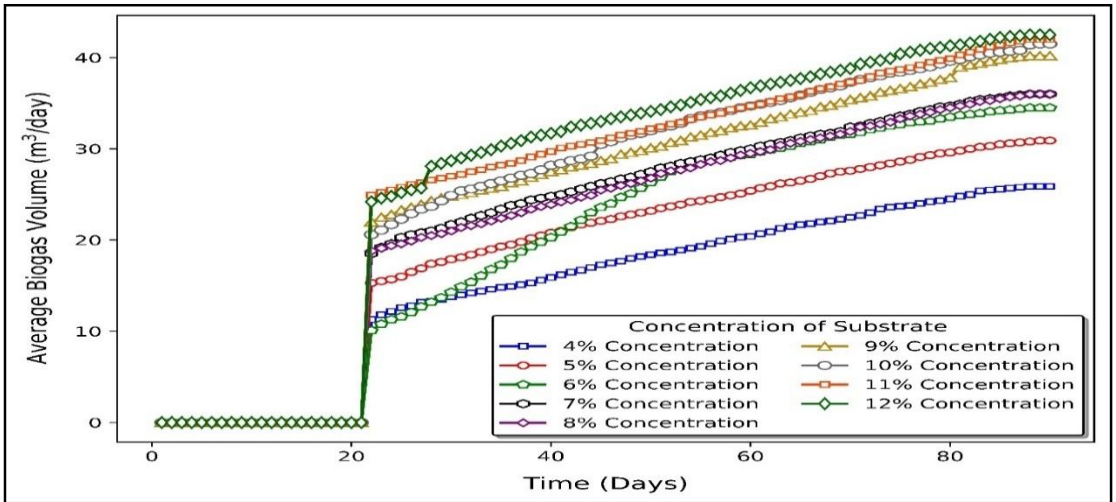

Figure 1: Production of biogas in the nine digesters over a period of 90 days

Analysis of Covariance (ANCOVA) was used to analyze the biogas production yield at different time of production. The result from the ANCOVA as presented in Tables 1 and 2 showed that the variables (different substrate concentrations) had a significant contribution in predicting the volume of biogas produced as F value (9,611) = 2684.28 and p-value < 0.0001. The Type III sum of square analysis as presented in Table 2 showed that both the different digesters and duration significantly contributed to the biogas production.

Table 1: ANOVA of Production of Biogas

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	9	32119.3521	3568.8169	2684.2777	< 0.0001
Error	611	812.3404	1.3295		
Corrected Total	620	32931.6925			

Table 2: Sum of Squares analysis for type III

Source	DF	Sum of squares	Mean squares	F	Pr > F
Days	1	17792.9196	17792.9196	13382.9050	< 0.0001
Digesters	8	14326.4325	1790.8041	1346.9493	< 0.0001

3.2 Effect of Temperature on the Volume of Biogas Produced

The result of the effect of temperature on the volume of biogas produced in the 9 digesters is shown in Figure 2. It has been noted that the digesters heat up as the number of days of production grows. While most digesters maintained a steady temperature for the first 60 days, a temperature reduction was seen after 60 days, as depicted by the break in the curve in Figure 2. For digester B1, B2, B3, B4 and B5, their temperatures increased from 10.1 to 38.5; 11.3 to 38.35; 15.3 to 41.1; 18.5 to 45.0; 18.5 to 44.5^{o}C while the volume of the biogas produced increased from 11.3 to 25.9; 15.3 to 30.9; 10.1 to 34.5; 18.5 to 36.0 and 18.8 to 36m^3/day for the period of 90days. For digesters B6, B7, B8 and B9, their temperatures increased from 20.6 to 48.4; 22.0 to 43.8; 24.2 to 44.4; 24.9 to 44.5^{o}C while the volume of the biogas produced increased from 22.1 to 40.2; 20.6 to 41.5; 24.9 to 42.0 and 24.2 to 42.5m^3/day respectively for the period of 90days. This was evident in the sizes of the circle markers shown in the Figure 2. At lower temperatures the size of the circle marker was small but at a higher temperature, the size of the circle markers was bigger.

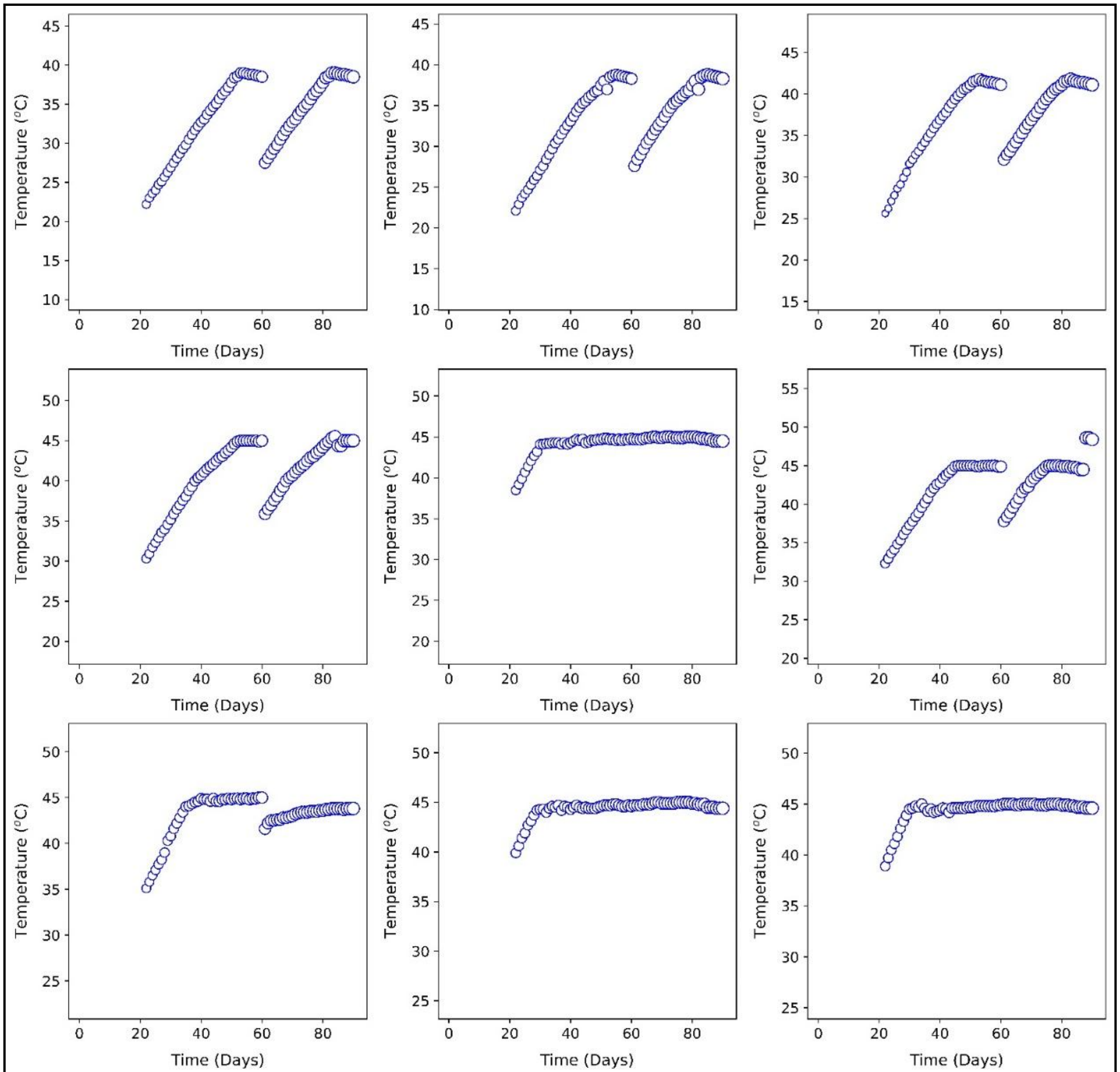

Figure 2: Effect of temperature on the volume of biogas production

Tukey multiple pairwise comparison tests were used to investigate the average temperature in the different digesters and the result is presented in Figure 3. From the result, it can be seen that digesters B5, B8 and B9 had relatively similar average temperatures of 40.67, 41.46 and 41.34°C respectively with the highest average temperature of 41.46°C. The result from the Analysis of variance (ANOVA) and multiple comparisons of the temperature is presented in Tables 3 and 4. From Table 3, it showed there was a significant difference in the average temperature in the different digesters ($P<0.05$). From Table 4, average temperature ranges from 29.30 ± 3.00 °C of digester B1 (4 % concentration of sample) to

41.46 ± 4.33 °C of digester B8 (11 % concentration of sample). Similar result was reported by [9] for co-digestion of food waste and cow dung under mesophilic temperature of 37°C. Also, [1] reported a mesophilic temperature of 37 ± 1 °C for co-digestion of food waste and cow dung. However, [6] reported a temperature range of 25.2 – 27.8°C for co-digestion of cow dung and food waste.

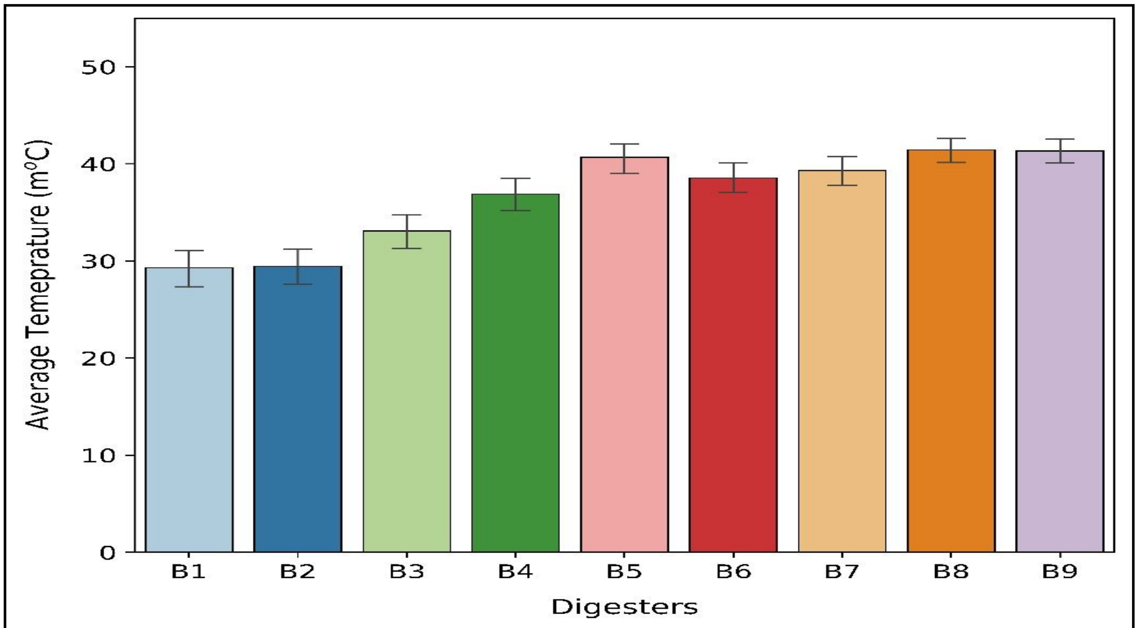

Figure 3: Average Temperature in different Digesters

Table 3: ANOVA for the significant difference of temperature in Digesters

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	8	17155.9526	2144.4941	36.2869	< 0.0001
Error	801	47337.6848	59.0982		
Corrected Total	809	64493.6374			

Table 4: Tukey Multiple Comparison Test

Category	LS means	Groups			
B8	41.4611	A			
B9	41.3422	A			
B5	40.6778	A			
B7	39.3333	A	B		
B6	38.5511	A	B		
B4	36.8956		B		
B3	33.0889			C	
B2	29.4611				D
B1	29.3011				D

3.2 Relationship between Temperature and Amount of Biogas Generated

The relationship between temperature and the amount of biogas generated by each digester was correlated. Two hypotheses were established. Null hypothesis **(H_o)**: which shows that there is no relationship between temperature and the amount of gas generated by substrates. Alternative hypothesis **(H_1)**: which shows that there is a relationship between temperature and the amount of gas generated by substrates. The result of the correlational analysis is presented in Table 5.

According to Table 5, there was a strong correlation between temperature and substrate concentrations (from B1 (4%) to B9 (12%)), indicating that temperature had a major impact on biogas production. For digester B5G (8% concentration), there was a significant but weak association between temperature and the substrate ($p = 0.05$, $r = 0.269$). There were significant relationships between temperature and the substrates at $p = 0.01$ only for $r = 0.760$ (B2G), $r = 0.740$(B3G), $r = 0.721$(B6G), and $r = 0.650$(B8G). For $r = 0.064$(B4G) correlation, however, was not statistically significant at the $p = 0.01$. As a result, we accept the alternative hypothesis (H_1), which states that there is a statistically significant correlation between temperature and the amount of biogas generated by substrates in the biogas technology experiment, and reject the null hypothesis (H_0) for these gases. The results show that co-digesting food scraps, cattle manure, and potash has a temperature-dependent effect on the amount of biogas produced.

Table 5: Relationship between Temperature and the amount of Biogas generated.

	B1T	B2T	B3T	B4T	B5T	B6T	B7T	B8T	B9T	B1G	B2G	B3G	B4G	B5G	B6G	B7G	B8G	B9G
B1T	1																	
B2T	0.290**	1																
B3T	0.290**	0.976**	1															
B4T	-0.011	0.036	-0.01	1														
B5T	0.091	0.357**	0.359**	0.004	1													
B6T	0.287**	0.977**	0.984**	0.007	0.329**	1												
B7T	-0.011	0.008	0.00	-0.011	0.00	-0.017	1											
B8T	0.246*	0.865**	0.872**	0.027	0.346**	0.859**	0.012	1										
B9T	0.064	0.314**	0.271**	.955**	0.104	0.289**	- 0.012	0.279**	1									
B1G	0.330**	0.757**	0.730**	0.06	0.271**	0.729**	0.131	0.649**	0.262*	1								
B2G	0.339**	0.760**	0.737**	0.058	0.271**	0.736**	0.133	0.657**	0.262*	0.998**	1							
B3G	0.336**	0.764**	0.740**	0.062	0.273**	0.740**	0.115	0.661**	0.267*	0.998**	0.999**	1						
B4G	0.331**	0.760**	0.734**	0.064	0.275**	0.733**	0.128	0.652**	0.267*	0.999**	0.998**	0.999**	1					
B5G	0.333**	0.765**	0.738**	0.068	0.268*	0.737**	0.125	0.663**	0.272**	0.999**	0.998**	0.999**	0.999**	1				
B6G	0.321**	0.751**	0.722**	0.066	0.260*	0.721**	0.118	0.655**	0.268*	0.988**	0.984**	0.982**	0.984**	0.988**	1			
B7G	0.336**	0.766**	0.743**	0.064	0.268*	0.741**	0.128	0.666**	0.269*	0.998**	0.999**	0.999**	0.998**	0.999**	0.985**	1		
B8G	0.321**	0.756**	0.724**	0.075	0.265*	0.723**	0.122	0.650**	0.275**	0.994**	0.988**	0.990**	0.994**	0.995**	0.984**	0.990**	1	
B9G	0.325**	0.761**	0.731**	0.069	0.264*	0.730**	0.121	0.661**	0.273**	0.996**	0.993**	0.992**	0.994**	0.997**	0.996**	0.994**	.994**	1

4. CONCLUSION AND RECOMMENDATION

Temperature influences the generation of biogas in digesters used to co-digest food waste, cow dung and potash. The effect of temperature on the biogas volume indicated that as the days of production increased, the temperature in the digesters increases and the volume of the biogas produced also increased. The result of the average temperature revealed that digesters B5, B8 and B9 had relatively similar average temperatures (40.67, 41.46 and 41.34^{o}C respectively). Average temperature ranges from 29.30 ± 3.00^{o}C of digester B1 (4 % concentration of sample) to 41.46 ± 4.33^{o}C of digester B8 (11 % concentration of sample).

This result was further clarified from the Analysis of variance and multiple comparisons of the temperature which revealed that digesters B5, B8 and B9 had no significant difference among them. The correlation of temperature and volume of biogas generated by each digester revealed that temperature significantly influenced the quantity of biogas generated at P= 0.01 and r = 0.760 (B2G), r = 0.740(B3G), r = 0.721(B6G) and r = 0.650(B8G) showing relationship were significant and had a high relationship between temperature and the substrates.
Following the findings of this research, the following recommendations were made:

- A comparative study of the use of spent digester slurry from different substrates digested singly and synergistically should be carried out so as to establish the optimum use of compost produced from the slurry.

Applying the waste as fertilizer requires extreme care. Only plants that are cooked before consumption (such as vegetables) should be treated with this chemical. The residue must be sprayed to the plant's roots, not sprinkled on the crop's surface. Additionally, it is recommended to wash your hands completely after use and to avoid getting it in your mouth or on any cuts.

6. CONSENT

The consent of the respondents was sought before embarking on data collection. The written document is preserved by the authors.

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