Anaerobic Decomposition of Cattle Manure Blended with Food Waste for Biogas Production

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Anaerobic Decomposition of Cattle Manure Blended with Food Waste for Biogas Production

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***Abstract:** The concern on how food and livestock waste should be managed and recycled has greatly increased in the world. This research investigated the anaerobic decomposition (digestion) process for biogas production on dairy cattle manure (CM) and food waste (FW) using a bacteria as inoculum - Pseudomonas aeruginosa. CM and FW were co-digested with bacteria (P. aeruginosa) as the substrate. FW was allowed to decompose separately without inoculum for 30 days. Digesters (Bioreactor) were prepared in five places to monitor the maximum biogas production, generation rate of methane and number of days for the production of biogas. 1 to ratio 5ml and 10ml of FW were co-digested with P. aeruginosa (bacteria) in 2 proportion and also Cow manure with 1 to ratio 1 and 0.5ml in 2 proportions [1:5ml; 1:10ml and 1:1; 1:5ml]. Batch process operation was used under mesophilic condition (35ºC) for the digesters/bioreactor. Production of biogas was notices on the third and fourth day after commencement for the digesters with cattle manure, fourth to fifth day for the digester (bioreactor) with bacteria and third day for the digester with only FW. FW and CM generated highest cumulative biogas with volume of 88.5g/kg.*

***Keyword:** Decomposition, food waste, Pseudomonas aeruginosa, inoculum, methane, cattle manure, bioreactor.*

I. INTRODUCTION

The rapid increase in food, livestock and agricultural waste which endangers the life of both plants and every living thing has necessitated the need to study how they could be recycled. A lot of work has been done by researchers on various ways by which these pollutants can be of positive relevance to guarantee an healthier environment such as bioconversion of waste paper to glucose, waste citrus and sweet potato peel to biodiesel (Ojewumi et al., 2014, Ojewumi et al., 2018b, Ojewumi et al., 2019b).

Food waste has been anaerobic digested to biogas and some other useful products, which serves as an effective remedy for food waste treatment and valorisation (Zhang et al., 2014, Kim et al., 2006). Ojewumi et al., 2019b recorded that wastage of food in Nigeria has been reported to an estimate of about $750 billion every year. Li et al., 2016 also reported that good amount of kitchen (food waste) are produced every year especially in the urban area. This increase might likely become a big challenge to the environment if not properly managed (Ojewumi et al., 2017, Ojewumi et al., 2018a).

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Greenhouse is reduced during anaerobic digestion (AD) since carbon dioxide and methane are released in a closed reactor this avoids its increase (Limam et al., 2016). Disposal of Food (kitchen) wastes and other types of wastes, such as organic municipal wastes and animal manures has been a major challenge for a very long time (Kim et al., 2004, Nayono, 2010, Zhang et al., 2013, Yenigün and Demirel, 2013, Li et al., 2009, Tasnim et al., 2017). Zhang and Jahng, 2012, Owolabi et al., 2011 reported that the single stage fermentation treatment of food waste was introduced some years ago and it is yet to yield a positive result.

Pseudomonas aeruginosa, is a bacterium of *Pseudomononadaceae* family and order of *Pseudomonadales*. This bacterium with others have been used by different researchers in Bioremediation, fermentation and numerous health benefits have also been highlighted (Ojewumi et al., 2018c, d, e).

Aerobic fermentation occurs when air is involved in the reactor, while anaerobic takes place when air is required in the reactor (Ojewumi, 2016, Ojewumi, 2017, Ojewumi, 2018a,). Conversion of cow dung, food waste and so many other wastes to biogas has been studied by so many researchers (Himathongkham et al., 1999, Uzoma et al., 2011, Lehtomäki et al., 2007, Macias-Corral et al., 2008) and different microorganisms have also been used for the decomposition (Himathongkham et al., 1999, Lung et al., 2001, Wichmann et al., 2014).

II. MATERIALS AND METHOD

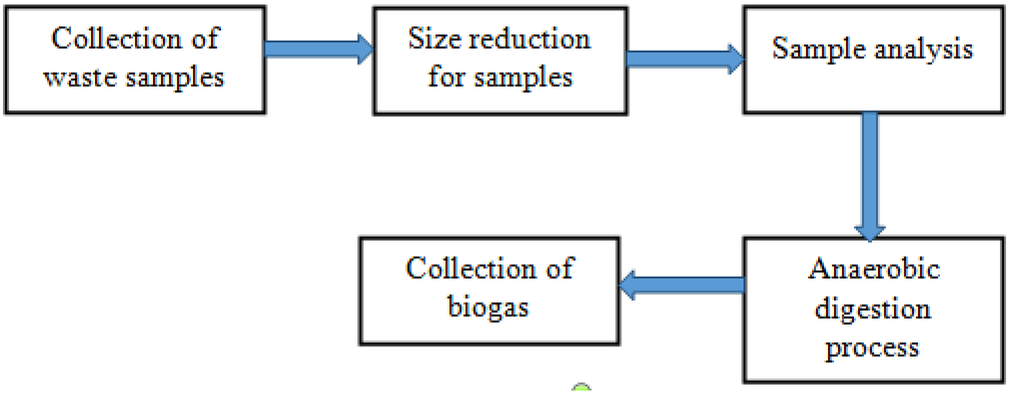

Figure 1. Biogas production flow diagram

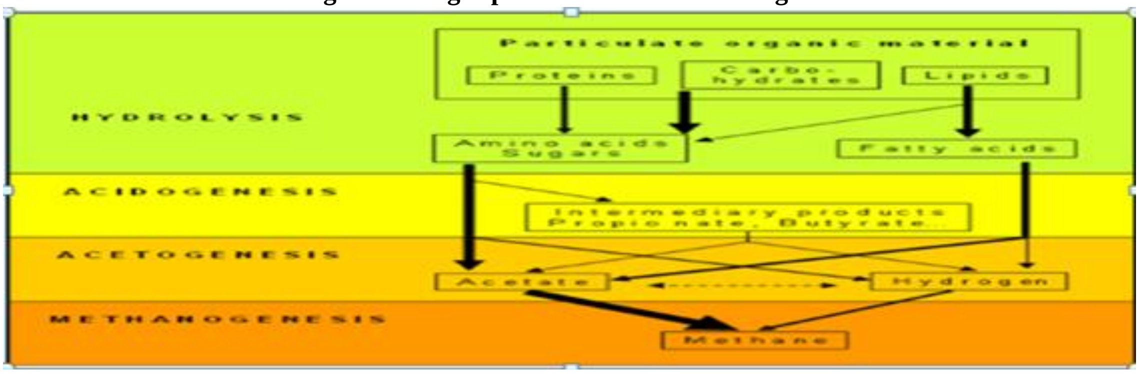

Figure 2. Biodegradation Process flow Chart (Vij, 2011)

2.1. Sources of raw materials

FW was collected from Covenant University Cafeteria. It was processed using method of (Ojewumi et al., 2019a). Cow manure was collected from an abattoir very close to the University.

2.2. Inoculum

Freshly prepared and cultured *P. aeruginosa* was obtained from the Microbiology laboratory of Covenant University, Ota using (Ojewumi et al., 2016a, b, Ojewumi, 2018b, Ojewumi et al., 2018c, Ayoola et al., 2012) method. The bacteria used in this study have hydrolysing, acidogenic, acetogenic and methanogenic properties. The bacteria were used shortly after culturing.

2.3. Bioreactor Set up and digestion process

Homogeneous mixture was obtained from 2kg of wastes and the method of (Ojewumi et al., 2019a) was used for the reactor setup.

2.4 Moisture content determination

Method of (Ojewumi, 2016, Ojewumi, 2017, Ojewumi et al., 2019a) was used for the moisture content determination.

2.6 Total solid

Method of (Ojewumi et al., 2019a) was also used for the determination of total solid.

2.8 Waste Loading

The digesters were each loaded with 2kg of FW sample with an organic waste loading of about 1g Volatile solid/Liquid (VS/L). Table 1 shows the ratio used for the mixture and bacteria loaded into the digester (inoculum). 15ml clinical syringe was used to measure bacteria into each reactor/digester. Digestion was carried out at room temperature for 30 days with intermittent mixing at every 30 seconds.

Table 1. Experimental ratio for the decomposition of FW and CM

Reactor	FW (kg)	*P. aeruginosa* (ml)	CM(kg)	Mixture Ratios
1	2	--	2	1:1
2	2	--	1	1:0.5
3	2	5	--	1:5
4	2	10	--	1:10
5	2	--	--	1

2.9 Stirring

The contents were stirred manually for 5 minutes and gently 2 times every day.

2.10 Collection & Testing of Gas

Gas generated was collected using method of (Ojewumi et al., 2019a)

2.11 Volume

Downward replacement of water was used for the determination of volume of biogas generated. Gas volume is measured at the upper part of the cylinder. A trough was mounted on water with a measuring cylinder to measure the level of the gas. Outlet of the bioreactor opening was connected to cylinder. The amount of water displaced by the gas was noted and recorded. The measuring cylinder allows the passage of the gas and the process continued until all the biogas was totally captured.

2.12 Composition of Gas

Syringe method was used for the collection of gas produced. 10ml of gas sample was piped through dilute NaOH, with intermittent shaking at 30 secs interval. Residual gas in the tube was recorded. Since CO_2 dissolves in the solution, the remaining gas is methane.

2.13 Withdrawing and weighting of Biogas

Biogas that flows into the tyre tube that was connected to the digester was noted and recorded daily using an electronic weighing machine. The flow was made possible as a result of the pressure inside the bioreactor.

III. 3. RESULTS AND DISCUSSION

Waste Analysis

Table 2. FW parameters before the digestion process

Parameter	Value
pH	6.84
Total Solid (%)	18
Moisture Content (%)	80.05
Dissolved Oxygen	5.8 ppm

Table 3. pH

Bioreactor No.	Bioreactor's content	Before digestion process	After the process
1	2 kg : 2 kg FW and CM	6.85	4.03
2	2 kg : 1 kg FW and CM	6.55	4.05
3	2 kg : 5 ml FW and Bacteria	6.25	3.85
4	2 kg : 10 ml FW and Bacteria	7.25	4.12
5	2 kg FW	5.55	3.99

3.2. Biogas Generation

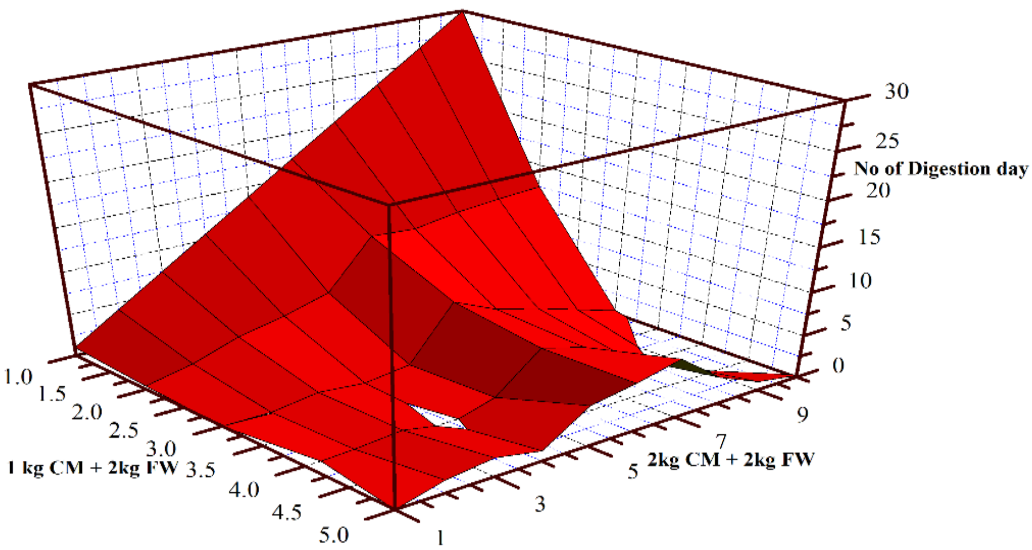

Figure 3. 3D plot of Biogas produced daily with CM (Digester 1 & 2)

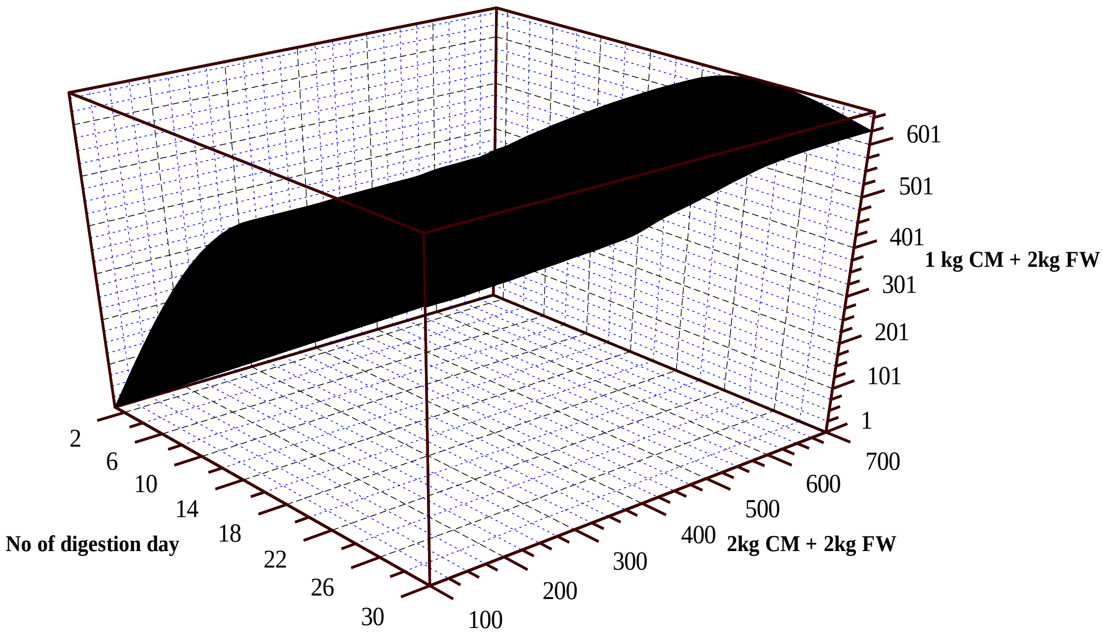

Figure 4. 3D plot of Biogas cumulative yield produced using different ratio of CM (Digester 1 & 2)

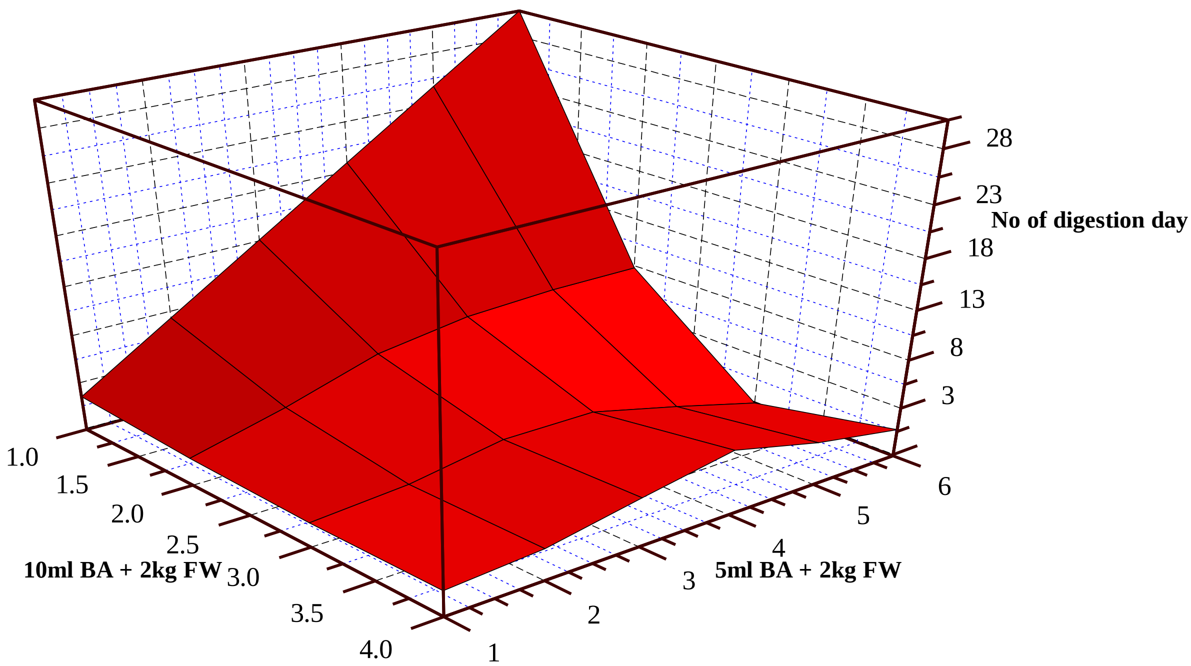

Figure 5. 3D plot of Biogas produced daily using different ratio of inoculum(Digester 3 & 4)

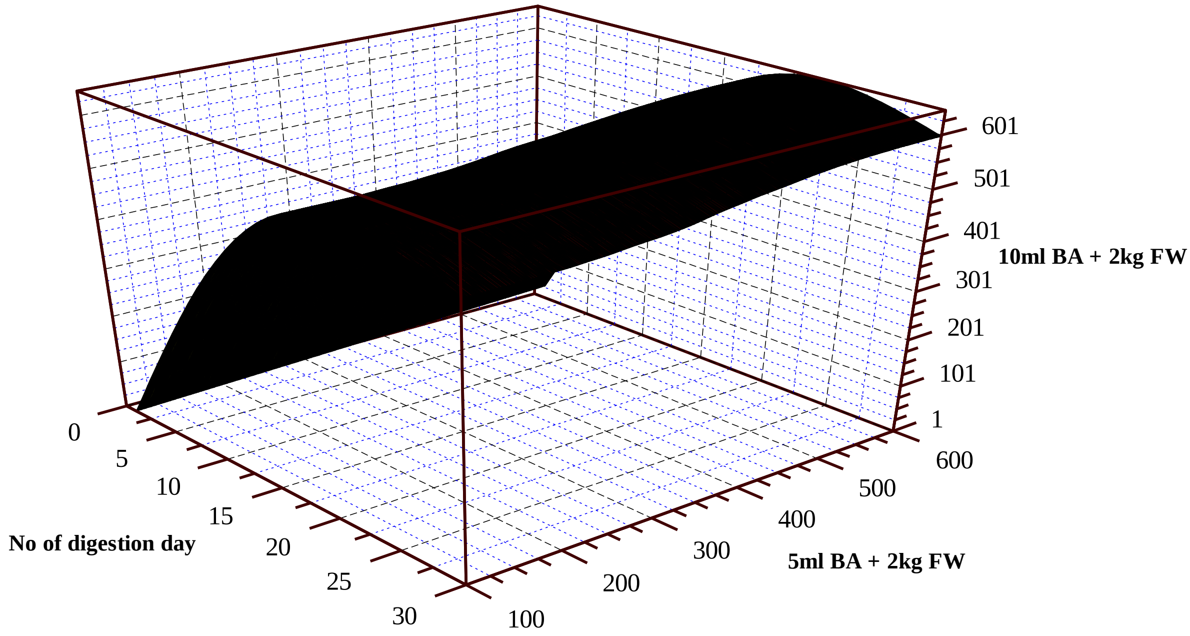

Figure 6. 3D plot of Biogas cumulative yield produced using different ratios inoculum (Digester 3 & 4)

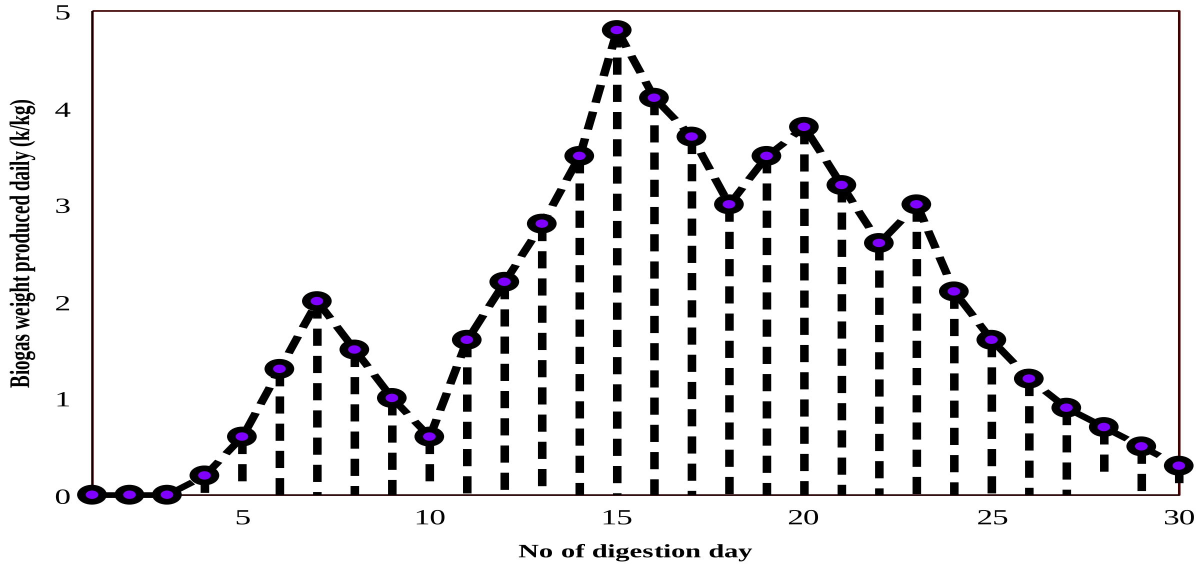

Figure 7. Weight of biogas produced daily with FW only (Digester 5)

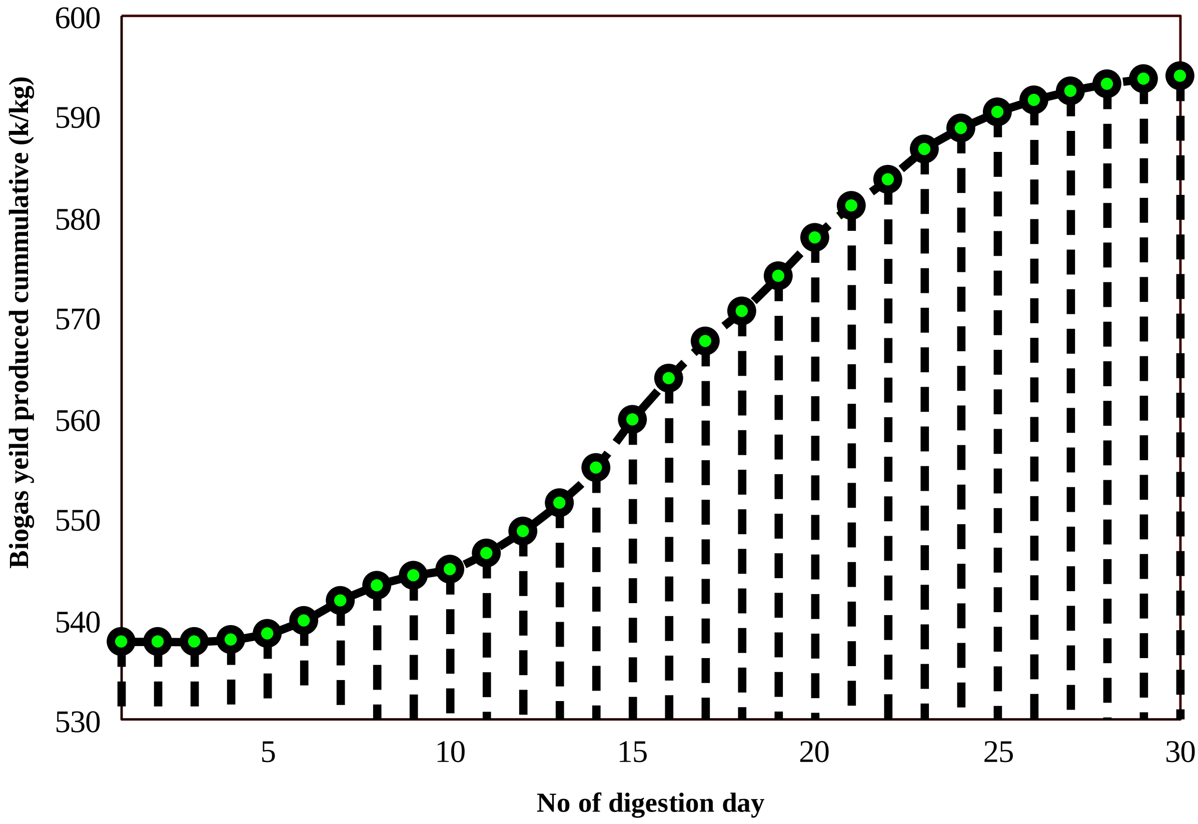

Figure 8. Biogas cumulative yield produced on food waste only (Digester 5)

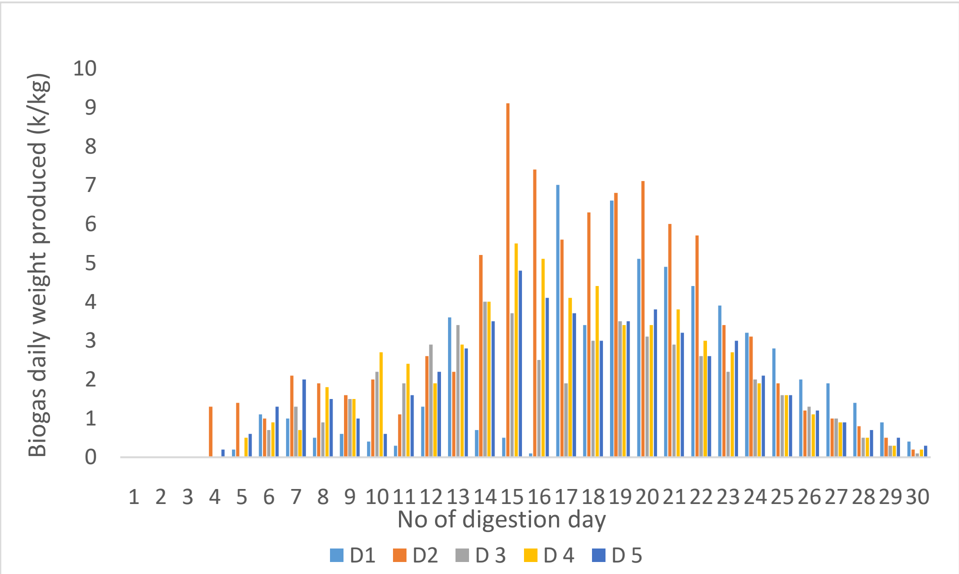

Figure 9: Biogas produced daily for the five digesters

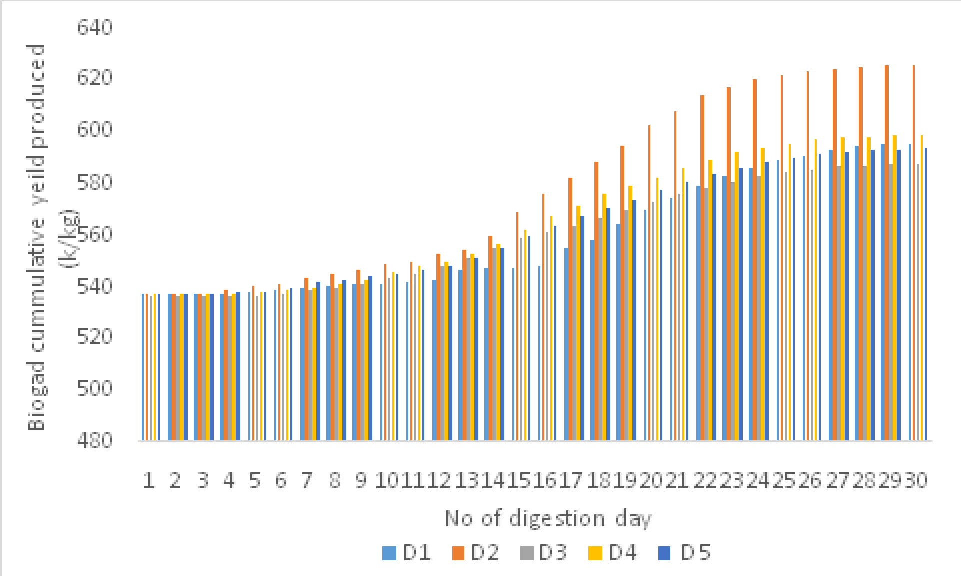

Figure 10. Biogas cumulative yield produced for all digesters

Key: D1 = Digester 1, D2 = Digester 2, D3 = Digester 3, D4 = Digester 4, D5 = Digester 5

3.1. Combination of FW with CM

Figures 3 and 4 above shows that 1 : 2kg CM and FW respectively (digester 2) produced more biogas than 2 : 2 kg CM and FW (digester 1). Digester 2 cumulative yield was about 88.5 g of biogas, while 2 kg CM + 2 kg FW produced about 58.6 g of biogas. Gas production was noticed on the fourth (4^{th}) and fifth (5^{th}) day for 2 : 2kg CM and FW (digester 1) and between the third (3^{rd}) and fourth (4^{th}) day for 1 kg CM mixed with 2 kg FW.

Highest biogas was produced by digester 1 with 2 kg CM + 2 kg FW with 7g/kg biogas after 17^{th} day. Decrease in the production of biogas was noticed starting from the 20^{th} day. The lowest biogas yield was recorded on the 16^{th} day (0.1 g/kg) with pH of 4.03, this justifies why low yield was observed as the bacteria used cannot grow in an acidic environment.

The bioreactor with 1: 2kg CM and FW recorded highest biogas yield on the 15^{th} day (2^{nd} reactor). Biogas decrease was steadily recorded on the 23^{rd} till the 30^{th} day. This probably happened as a result of the acidity in the bioreactor with pH of 4.05 which was acidic for methanogenesis to take place.

3.2. Waste inoculated with Bacteria

Figures 5 and 6 shows bioreactor 4 (digester 4) with 10 ml : 2 kg bacteria and food waste respectively. More biogas was produced more than bioreactor 3 with 5 ml : 2 kg bacteria and food waste respectively. Bioreactor/Digester 4 gave a cumulative yield of 61.3 g while bioreactor/digester 3 produced 52 g. For bioreactor 3 biogas production was recorded on the 5^{th} and 6^{th} day and 4^{th} and 5^{th} day for bioreactor 4.

4 g/kg of biogas was generated in the 3^{rd} bioreactor; on the 14^{th} day of digestion. From the 19^{th} day a steady decrease in biogas production was observed. The can be as a result of the unconducive pH of 3.85, *P. aeruginosa* used for the digestion cannot grow in an acidic environment. Low biogas yield was recorded on the 30^{th} day (0.2 g/kg). Since the bacteria used have reached it optimum operational condition, production is no longer possible; substrate has been fully used up during the digestion process.

The 4^{th} bioreactor recorded highest biogas yield on the 15^{th} day with 5.5 g/kg gas weight. 18^{th} day of digestion produced 4.4 g/kg biogas weight. There was a record of steady decrease in biogas production from the 23^{rd} day till 30^{th} day of digestion process. This can be as a result of acidic pH (4.12) obtained which makes methanogenesis impossible to take place. High production of biogas in digester 4 might also be due to the quantity of bacteria used which breaks down complex compounds to simpler form.

3.3. Food waste without inoculum

Biogas highest yield was recorded on the 15^{th} day in bioreactor 5 (digester with FW only), Figures 7 and 8 with biogas weight of 4.8 g/kg while 3.9 g/kg biogas produced on the 20^{th} day. Steady decrease of biogas production was observed on the 23^{rd} day of digestion till 30^{th} day. This is probably due to the acidic pH of 3.99 the waste during digestion which is also too acidic for methanogenesis to take place. Cumulative yield of 56.5 g/kg biogas was recorded in the 5^{th} bioreactor with no inoculum.

3.4. Comparison of all ratios

Bioreactor 2 gave the highest yield of biogas produced with 1 kg CM mixed with 2Kg FW, figure 9 and 10, while bioreactor 1 (2 : 2 CM with 2 kg FW) had the highest cumulative yield. From the result, it can be deduced that cow manure can produce biogas without adding inoculum or co-digesting it with food waste.

3.5. Gas Test

Methane content in the gas generated was roughly calculated using syringe method. Initial Methane volume in the syringe was used for the calculation. Bioreactor 1 shows the highest methane content. This may be due to the mixture of CM and FW as CM has a high C/N ratio while bioreactor 4 gave lowest methane content. This could be as a result of acidogenesis phase which is the rate limiting phase of the digestion phase, which can reduce the amount of methane generated.

The methane content produced is directly proportional to the quantity of CM used in bioreactor 1 and 2 while this content is inversely proportional to the quantity of inoculum used in bioreactor 3 and 4,. FW alone had 44% ratio of methane content produced (Deublein, 2008, Temitayo, 2017).

Table 4. Syringe method

S/N	Digester	CH_4:	Total volume of NaoH (ml)	Methane Content
1	2 kg Food Waste + 2 kg Cow manure	2.6: 7.4	10	52%
2	2 kg Food waste + 1 kg Cow manure	2.4: 7.6	10	48%
3	2 kg Food waste + 5 ml BA	2.1: 7.9	10	42%
4	2 kg Food Waste + 10 ml BA	2: 8	10	40%
5	2 kg Food Waste only	2.2: 7.8	10	44%

Flame Test

Light blue flame ignited from the collecting tube when lit as prove that the gas produced was biogas.

IV. CONCLUSIONS

The use of inoculum (*P. aeruginosa*) to degrade lipids of different types of waste into biogas shows that CM and FW can be used as feedstock/substrate for the generation of biogas. FW mixed with appropriate ratio of CM gave a good yield of total cumulative biogas production, which can be considered to be one of the most promising energy generations, provided anaerobic digestion treatment is adapted. The mixing together of FW and CM improved the generation of both biogas and methane, with total cumulative of about 88.5% biogas produced while the combination of 10ml *P. aeruginosa* with 2 kg FW (10ml + 2 kg FW) gave 61.2%. Since the raw materials used are readily available this can serve as a form of relieve to the world and a means of waste management.

Conflicts of Interest: No conflicts of interest.

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