Original Research Article

INFLUENCE OF POTASH ON BIOGAS PRODUCTION FROM COW DUNG AND FOOD WASTE

ABSTRACT

This study investigated the production of biogas from food waste co-digested with potash and cow dung as inoculant. The aim of this study was to determine the amount of biogas generated from the waste substrate. Experimental research design was used and it was carried out at Uturu, Abia State, Nigeria. 4% to 12% concentrations of the substrate were mixed and fed into anaerobic digesters labeled B1 to B9 for 90days. Result of ultimate analysis showed oxygen (41.33%,14.06%), nitrogen (3.23%,1.48%), carbon (36.50%,29.67%) and P^H value(6.25, 8.47) for food waste and cow dung respectively. The quantity of biogas generated in the different digesters (B1-B9) was 1341.2, 1668, 1784.5, 1945.2, 1941.7, 2159.2, 2328.1 and 2428.5m^3/day respectively. Analysis of Covariance (ANCOVA) used to model the biogas production volume showed that there was significant contributions in predicting the volume of biogas produced with F (9,611) = 2684.28 and p-value <0.0001. The effect of potash on biogas production revealed that there was an increase in the quantity of gas generated by the substrates with increase in quantity of potash added. Digester B1 with the lowest quantity of potash, generated 1341.2m^3/day of biogas while Digester B9 with the highest quantity of potash, generated 2428.5m^3/day of biogas in 90days. The flame test showed that the biogas burned with a blue flame. The findings revealed that biogas can be generated from co-digestion of food waste, potash and cow dung. Thus, potash could have helped to boost the biogas production. More studies should be done on how local organic materials can be useful for the production of more biogas.

Keywords: Substrate, Biogas, food waste, cow dung, potash, Proximate Analysis, Ultimate Analysis

1 INTRODUCTION

Biogas, a byproduct of anaerobic digestion of the organic component of biomass such as industrial effluents, sewage sludge, or animal waste, is a renewable energy resource that may be used as an alternative to conventional energy sources. Methane (CH_4) is the most vital part of biogas since it contains the greatest energy per mole. Thus, biogas's high CH_4 concentration is essential [1]. Methane (CH_4) and carbon dioxide (CO_2) make up the bulk of biogas, with the remaining components including hydrogen (1%), nitrogen (10%), which can come from air saturation in the influent. Biogas also contains vapor water (5-10%) which may be higher at thermophilic temperatures and derived from medium evaporation. It also contains hydrogen sulfide (1-3%), which is created by the reduction of sulfate contained in some waste-streams, and ammonia (NH_3) [2].

Since most of the solid waste produced cannot be efficiently recycled, treated or disposed, many of them are dumped in landfills without being sorted. This is neither cost-effective nor environmentally friendly, and it also creates issues with land acquisition [3]. The improper management of these solid wastes has both long-term and short-term repercussions on the ecosystem since most of the disposal methods like incineration, is expensive due to the high cost of the fuel required and the environmental damage caused by the release of flue gases.

Organic waste can be turned into usable energy using biogas technology. Biogas can be produced in bio-digesters by breaking down the feedstock and it has many uses and benefits, including being good for the environment, renewable, clean, affordable, and of high quality. The use of anaerobic digestion for the production of biogas and thereby treating biodegradable waste and reducing the volume of waste to be disposed can reduce environmental pollution [4].

The municipal garbage consists largely of discarded food. The majority of food waste comes from commercial kitchens and food processing facilities. Additionally, households produce a substantial quantity of food waste in the form of uneaten meals, fruit peels, and unharvested produce [5]. Substrates with a poorer biodegradability and higher nitrogen content can be co-digested with food waste to increase biogas production [6]. Co-digestion is a process when at least two substrates are treated at the same time [7 , 8]. There have been a number of reports of increased biogas output from the co-digestion of food waste and other trash for biogas generation [4, 9]. Researchers [10] looked into the impact of paper waste on the biogas yield from the co-digestion of cow manure and water hyacinth, and found that it increased the biogas yield. Additionally, [11] showed that biogas generation was increased by the anaerobic co-digestion of kitchen garbage and calf manure. In addition, [5] studied the effects of digestion and co-digestion of food waste and cow dung on the quantity and quality of biogas generated, finding that the co-digestion procedure enhanced biogas quantity and quality, although the proportion of methane in the biogas was relatively low. Therefore, increasing the amount of biogas generated would need stimulating the digestion and co-digestion process.

Potash is an alkali metal that is extracted from subsurface deposits that originally formed when ancient sea bottoms evaporated. Minerals like potassium chloride, sodium chloride, and other salts and clays can be found in abundance in potash ores. It comes as powder, granules, and lumps and has a high salt concentration. Plant, animal, and human life depend on potassium [12]. It's useful as an additive to animal feed since it encourages robust development and boosts milk production without negatively impacting animal health. When there is a potassium deficit in the soil, potassium-containing fertilizers are used to increase crop yields and enhance plant quality [13]. Potassium enhances plant defenses against stress and disease and deters weeds and insects. Potassium prevents leaf drop, fortifies the plant's rhizosphere and stems, and facilitates the transport of nutrients. It stimulates enzymes in plants, which improves their ability to utilize water. Plants are better able to endure adversity when there is more potassium in the soil. In addition to these two uses, potash may be a manufacturing catalyst [14] and a fire extinguisher. It functions well as an oxidizing agent. The purpose of this research was to examine how adding potash to a batch reactor for co-digesting cow manure and kitchen trash affects the amount of biogas produced. Since potash may function as a catalyst in reaction, it was added to increase biogas generation.

1.1 Statement of Problem

Since less of the garbage produced is efficiently recycled, treated, or disposed of, much of it is just dumped in landfills without being sorted. This is neither cost-effective nor environmentally sound, and it also creates issues with land acquisition [15]. The incorrect management of this solid waste has both long-term and short-term repercussions on the ecosystem, making the issue of garbage creation and disposal all the more pressing. The most efficient method of disposal, incineration, is also the most expensive due to the high cost of the fuel required and the environmental damage caused by the release of flue gases. Therefore, a functional framework for solid waste management needs to be created by treating the issues from social, economic, technological, political, and administrative perspectives.

1.2 Aim

The aim of this study is to determine the amount of biogas (methane) that can be generated from the waste substrate.

1.3 Objectives

1. Determine the physiochemical composition of the waste and cow dung samples.
2. Determine the ultimate analysis of the waste and cow dung samples
3. Determination of the Volume of biogas Produced

1.4 **Significance of Study**

The power generated is a renewable resource that may be utilized for various purposes, including heating and powering appliances. Traditional biomass, such as firewood or charcoal, is a major contributor to indoor air pollution, which has particularly negative effects on the health of women and children. Nearly 4 million deaths annually are attributed to smoking-related illnesses, according to [16]. Conditions include pneumonia, asthma, COPD, lung cancer, tuberculosis [17], and stroke all affect the respiratory system.

2. METHODOLOGY

2.1 Study Area

Uturu is a settlement in the northern portion of Abia State, Nigeria, lying between latitudes 05.33°N and 06.03°N of the equator. Abia state is one of the 36 states of Nigeria. The state covers 6,320 km^2 and is situated between the states of Enugu and Ebonyi to the north and northeast. The food waste used for the study was collected from a restaurant in Uturu while the cow dung was collected from a cattle ranch in Okigwe. The map of study area is shown in Map 1.

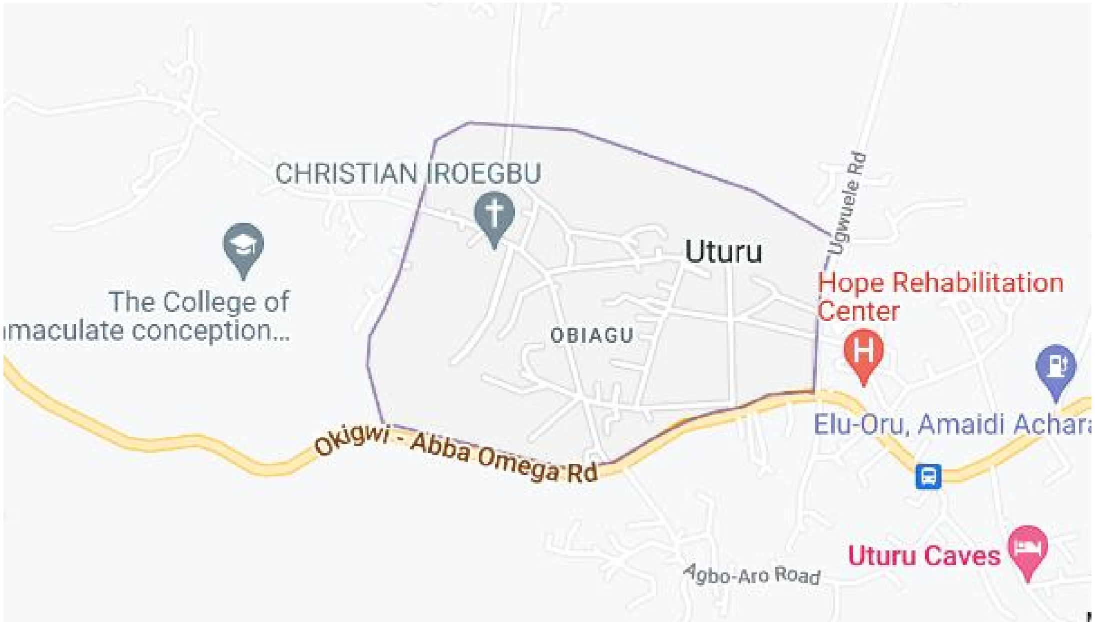

Fig 1. Map of Study Area

2.2 Research Design

The experimental design for the anaerobic digestion of cow dung and food scraps comprised 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%. 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.

2.3 Sampling Technique

A total of 2000g of food wastes and 1000g cow dung was used. The purposive sampling technique was employed for the study to determine the population and sample size of the food waste and cow dung used.

2.4 Variables

<u>2.4.1 The Experimental Method</u>

2000g of fresh food waste, 1000g of fresh cow dung and 500g of potash was used for this experiment. The food waste was pound in a mortar while the cow dung and potash were ground in a mill. A homogenous mixture of the ground food waste, cow dung and potash were form. Nine digesters and gas collection system labeled 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. The different percentage of concentrations gave different quantities of potash (20, 25, 30, 35, 40, 45, 50, 55 and 60g) in each digester. Potash was added to determine its effect on the biogas production since potash contains potassium which acts catalyst. The cow 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 bacteria to grow and perform biological activity. 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.

2.4.2 Proximate and Ultimate Analysis of feedstock

50 grams each of food scraps and cow dung were air dried for 7 days and then oven dry at 105 degrees Celsius for 48 hours. They were then ground to powder and used for proximate and ultimate analyses. An electronic weighing scale (SF-400, 10000g x 353oz x 0.1oz) was used for the measurements.

2.4.2.1 Determination of Proximate Analysis

The proximate analysis would determine the biogas production potential of the feedstock. This includes moisture content, ash content, fiber content, volatile matter, fixed carbon and carbohydrate content of the food scraps and cow dung. The standard techniques method of [18] was used. All analyses were run in triplicate and the average result was used.

Moisture content was determined by heating 2g of each sample to a constant weight in a crucible placed in an oven maintained at 105^{o}C. The percentage moisture content was calculated using Equation 1:

$$\% \text{ Moisture content} = \frac{W2-W3}{W2-W1} x\ 100 \quad (1)$$

Where;

W_1= weight of empty crucible, W_2= weight of crucible + sample before drying, W_3= weight of crucible + sample after drying.

The ash content was determined by the incineration of 2g of each sample placed in a muffle furnace maintained at 550^{o}C for 5-8 hours. The percentage ash content was calculated using Equation 2:

$$\% \text{ Ash content} = \frac{W3-W1}{W2-W1} x\ 100 \quad (2)$$

Where;

W_1= weight of crucible, W_2= weight of crucible + sample before ashing, W_3= weight of crucible + ash.

The fiber content was obtained by digesting 2g of each sample with H_2SO_4 and NaOH and then incinerating the residue in a muffle furnace maintained at 550^{o}C for 5-8 hours. The percentage was calculated using Equation 3:

$$\% \text{ Fiber content} = (\frac{W2-W1)-(W4-W3)\ X\ 100}{weight\ of\ sample} \quad (3)$$

Where;

(W_2-W_1) = weight of residue, (W_4-W_3) = weight of ash, W_1= weight of filter paper, W_2= weight of filter paper+ residue, W_3= weight of crucible, W_4= weight of crucible + ash

Carbohydrate content was calculated by subtracting the combined percentages of water, ash, fiber, fat, and protein from 100. So, the breakdown of carbohydrates is shown in Equation 4:

$$\% \text{ Carbohydrate} = 100 - (\sum \text{moisture + ash + fiber + fat + protein}) \quad (4)$$

The Volatile matter was determined by subtracting the weight of the dish with the sample before heating from the weight of dish with sample after heating and divided by sample weight.
The fixed carbon was determined by subtracting the percentages of moisture content, ash content and volatile matter from a sample. It can be calculated using Equation 5:

$$100 - (\%\text{Moisture content} + \%\ \text{Ash content} + \%\ \text{volatile matter}) \quad (5)$$

2.4.2.2 Determination of Ultimate Analysis

In the ultimate analysis, the percentages of carbon, hydrogen, nitrogen, oxygen, sulphur and phosphorus in the waste samples are calculated. The standard techniques method of [18] was used. All analyses were run in triplicate and the average result was used. The ultimate analysis of dried ground food waste and cow dung was as follows:
The Sulphur content was calculated using the oxygen bomb method. Each waste sample was collected in a platinum sample cup (ranging in size from 2.5 ml to 5.0 ml) and then deposited into a 300 liter bomb. The sample cup bomb assembly included a platinum wire for the firing cup and 5ml of distilled water for supersaturating the oxygen fueling the explosion with water vapor. To prevent the sample from being blown out of the cup, the bomb was sealed snugly and compressed oxygen was passed slowly. The bomb was subtly lowered into the water, and a spark from an electrical current set off the sample. The explosive was removed and pressure was released at a constant pace after 10 minutes. The bomb's cover was carefully removed and cleaned. A beaker of water was used to thoroughly rinse the bomb and the cup. After adding 5ml of bromine water to convert sulfites to sulfates, 5ml of 50%HCl was poured in. Steaming the contents down to a volume of 75-100ml allowed for easy handling. The sulphate was precipitated by gravimetric method and calculated from Equation 6:

$$\%\ \text{Sulphur} = \frac{weight\ of\ BaSO4\ x\ 0.1373\ x\ 100}{weight\ of\ sample} \quad (6)$$

The nitrogen present in each waste samples was determined using Kjeldahl technique and concentrated H_2SO_4 was used as a catalyst. 1.0 g of each powdered waste sample was heated in a Kjeldahl's flask until a clear solution formed. This solution was then subjected to an excess of KOH. Standard acid solution of known volume was used to absorb the released NH_3. The amount of acid that had not been consumed was calculated using a NaOH standard solution for back titration. Using the volumes of acid and ammonia released, the proportion of nitrogen in the waste sample was calculated using Equation 7:

$$\%\ \text{Nitrogen (N\%)} = \frac{vol.of\ acid\ used\ \ x\ normality\ x\ 1.4}{weight\ of\ sample} \quad (7)$$

Phosphorus content was determined using a volumetric phosphomolybdate method. The phosphorus concentration was measured by ashing 5g of each powdered waste sample at 700–750 degrees Celsius. The ash was collected in a platinum crucible and then mixed with 10 ml of concentrated HNO_3 and 5 ml of concentrated hydrochloric acid. The contents were dried off by evaporation. After adding 5 ml of concentrated HNO_3, the crucible was cooled, and the contents were evaporated until dry. Next, the residue was fused with 3-5 grams of $NaCO_3$ by heating it over a red-hot Meker burner until no more fumes were released. Hot distilled water was used to leach the melted or fused substance, and then it was filtered. The leftover residue was re-combined with Na_2CO_3, leached with hot water, and filtered. Both filtrates were combined into one. The equation of reaction is shown in Equation 8 while subsequent titration is shown in Equation 9:

$H_3PO_4 + 12(NH_4)_2MoO_4 + 21HNO_3 \rightarrow (NH_4) PO_4 . 12MoO_3 + 21NH_4NO_3 + 12H_2O$ (8)

$2(NH_4)_3 PO_4 . 12MoO_3 + 46NaOH + H_2O2 (NH_4)_2HPO_4 \rightarrow (NH_4)_2 MoO_4 + 23Na_2MoO_4 + 23H_2O$ (9)

The oxygen content was determined using the composition of the waste samples as expressed in the form of percentages of ash, carbon, sulphur, nitrogen and hydrogen. The sum of all these constituents was taken as equal to 100%. As indicated in Equation 10, oxygen was estimated by deducting the total of the other ingredients (ash, carbon, sulphur, nitrogen, and hydrogen) from 100. This was done since there is no reliable way to precisely measure oxygen.

$$\% \text{ Oxygen} = 100 - (\sum \text{ash} + \text{carbon} + \text{sulphur} + \text{nitrogen} + \text{hydrogen}) \quad (10)$$

For carbon and hydrogen content, 0.2 g. of each waste sample was burnt in a combustion apparatus in a current of air. As a result, carbon and hydrogen present in the sample were converted into CO_2 and H_2O respectively and were absorbed respectively in potassium hydroxide (KOH) and $CaCl_2$ tubes of known weights. The increase in weights of these tubes gave the amounts of CO_2 and H_2O formed as a result of combustion and can be calculated from Equation 11 and 12 respectively:

$$\% \text{ Carbon } (C\%) = \frac{\text{increase in weight of KOH tube} \times 12 \times 100}{\text{weight of sample} \times 44} \quad (11)$$

$$\% \text{ Hydrogen } (H\%) = \frac{\text{increase in weight of CaCl2 tube} \times 2 \times 100}{\text{weight of sample} \times 100} \quad (12)$$

2.4.3 Determination of the Volume of Gas Produced.

Water downward displacement technique was used to measure the volume of biogas produced by each digester. This method is based on a volumetric test, which considered the displacement of a liquid into gas to measure the quantity of biogas produced. In this method, the amount of water displaced was proportional to the volume of biogas produced. The volume of biogas produced were measured and recorded daily for a period of 90 days.

3. RESULTS AND DISCUSSION

3.1 Proximate and Ultimate Analysis

The results of the proximate and ultimate analysis of the food waste and cow dung are presented in Tables 1 and 2. It was observed that food waste has a moisture content of 12.43%, carbohydrate content of 72.38%, volatile matter of 12.07%, fixed carbon of 73.3%, ash content of 2.24% and fiber content of 0.35%. The cow dung has a fiber content of 28.22%, carbohydrate content of 30.71%, volatile matter of 4.78%, fixed carbon of 72.08%, ash content of 15.25% and moisture content of 7.98%.

Table 1: Results of the Proximate Analysis of the Samples

Parameters (%)	Source	Mean Value	Source	Mean Value
Moisture content	Food waste	12.43	Cow dung	7.98
Ash content	Food waste	2.24	Cow dung	15.25
Fibre	Food waste	0.35	Cow dung	28.22
CHO	Food waste	72.38	Cow dung	30.71
Volatile Matter	Food waste	12.07	Cow dung	4.78
Fixed Carbon	Food waste	73.3	Cow dung	72.08

The ultimate analysis showed that the food waste has oxygen content of 41.33%, volatile content of 12.07%, phosphorus content of 0.47%, nitrogen content of 3.23%, Sulphur content of 2.78%, carbon content of 36.50% and pH of 6.25. Also, ultimate analysis of cow dung gave oxygen as 14.06%, carbon as 29.67%, nitrogen as 1.48%, Sulphur as 13.69% and pH as 8.47.

Table 2: Results of the Ultimate Analysis of the Samples

Parameters (%)	Source	Mean Value	Source	Mean Value
Oxygen	Food waste	41.33	Cow dung	14.06
Phosphorus	Food waste	0.47	Cow dung	1.04
Nitrogen	Food waste	3.23	Cow dung	1.48
Sulphur	Food waste	2.78	Cow dung	13.69
Carbon	Food waste	36.5	Cow dung	29.67
PH	Food waste	6.25	Cow dung	8.47

Furthermore, the result of the atomic ratios of carbon and nitrogen (C/N), oxygen and carbon (O/C) and total solids which were determined from Equation 11 to 13 are presented in Table 3. It was observed that the percentage of total solid in food waste was 87.58% while the weight of total solids in the food waste was 248.4kg. Also, the percentage of total solid of cow dung was 92.03% while the weight of total solid was 79.7kg. The C/N ratio of food waste was 11.3 while C/N ratio of cow dung was 20.2. Also, the O/C ratio of food waste was 1.13 while O/C ratio of cow dung was 0.47.

Table 3: Results of total solids, C/N and O/C ratio of the Samples

S/N	Parameters	Food Waste	Cow Dung
1	Total solid (%)	87.58	92.03
2	Total solid (Kg)	248.4	79.7
3	C/N ratio	11.3	20.2
4	O/C ratio	1.13	0.47

3.2 Production of Biogas in the different digesters.

The result of the production of biogas in the nine digesters for duration of 90 days is shown in Figure 2. It was observed that there was no evidence of gas 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 2. Digester B1 (4% of the substrate) had the least production of biogas with average production of 14.90m^3/day while digester B9 (12% of the substrate) produced the highest quantity of biogas with average production of 26.98m^3/day.

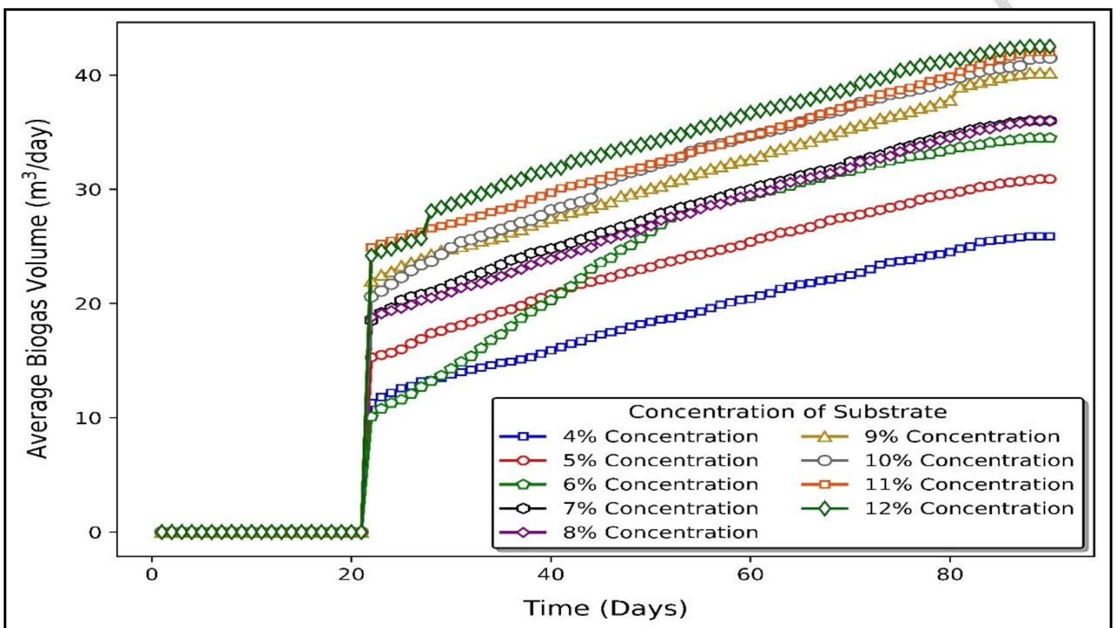

Figure 2: Production of biogas in the nine digesters over a period of 90 days

Analysis of Covariance (ANCOVA) was used to model the biogas production volume at different time of production. The result from the ANCOVA as presented in Tables 4 and 5 showed that the predictor/explanatory variables 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 5 showed that both the different digesters and duration significantly contributed to the biogas production.

Table 4: 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 5: Type III Sum of Squares analysis

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

The result from the ANCOVA suggests that the different digesters tend to significantly produce different volumes of biogas at different time. Also the duration (days) of production significantly affects the volume of biogas produced which was evident in Figure 3. Tukey multiple pairwise comparison tests were used to investigate which digesters significantly produce more biogas than the other and the result is shown in Figure 3. This showed that digester 9 which had a 12% substrate concentration significantly produced more biogas than any other digesters. There was no significant difference in the production of biogas between digesters 4 and 5. The result from the Tukey multiple comparison tests provides sufficient evidence that the percentage concentration of the substrate tends to significantly affect the production volume of the biogas.

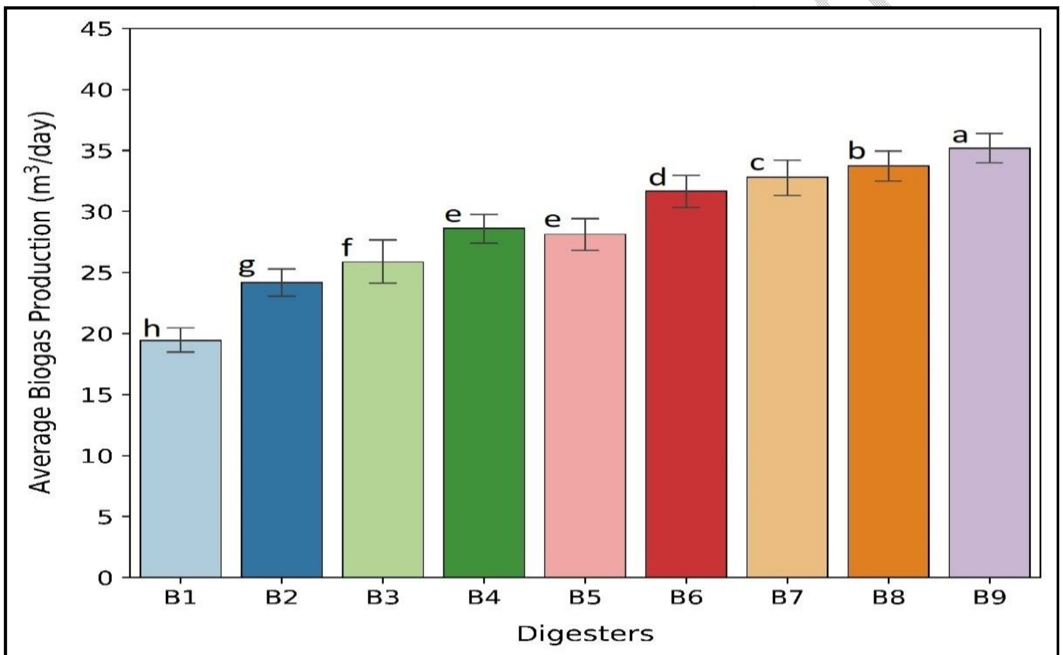

Figure 3: Average Production volume of biogas in the different digesters

3.3. Effect of Potash on the Production of Biogas.

The result of the biogas production as shown in Figure 3 revealed that there was an increase in the quantity of gas generated by the substrates with increase in concentration/ quantity of potash added. The result showed that digester B1 with 20g of potash had the lowest biogas production of 1341.2m^3 while digester B9 with 60g of potash had the highest gas production of 2428.5m^3 for the 90 days period. This shows that potash may have boosted the production of the biogas since potash acts as catalyst in reactions [12].

3.4 Flammability of the Biogas produced

The flammability test was used to show if the biogas produced from the experiment can lit up after the retention time. The result showed that the biogas produced burned with a blue flame as shown in Figure 4. The potash added may have helped to boost the flammability of the biogas due to the oxidizing nature of potash.

Figure 4: Biogas generated was flammable.

4. CONCLUSION AND RECOMMENDATION

Biogas production from food waste, cow dung and potash were established to be feasible at room temperature. A maximum biogas of 2438.5m^3 was generated in 90 days from biodigester B9 (12% concentration) which was closely followed by biodigester B8 (11% concentration) with 2328.1m^3 and this decreased till biodigester B1 (4% concentration) which had 1341.2m^3 as the least amount of biogas produced. It was found from the study that food waste, potash and cow manure, which is abundant locally, can be co-digested anaerobically to generate biogas. These materials which accumulate as garbage and cause problems for the environment can be put to good use to produce biogas. From the findings of this research, the following recommendations were made:

- To determine the best use of the compost that may be made from discarded digester slurry, it would be useful to conduct a research comparing the usage of slurry from substrates digested separately and in combination.

- In rural locations, where the substrates are readily accessible, a specifically constructed clay pot with sufficient control to avoid gas leakage might be utilized as a digester.

- Ecological calamities like deforestation and desertification can be halted and climate change may be mitigated if we devote more resources to finding renewable energy sources like biogas.

7. REFERENCES

1. Ngan, N.V.C., Gummert, M., Hung, N., Chivenge, P., & Douthwaite, B. Anaerobic digestion of rice straw for biogas production. Sustainable Rice Straw Management. Cham: Springer International Publishing; 2020 PP. 65-92.

2. Chatterjee, P., Ghangrekar, M.M., & Rao, S. Low efficiency of sewage treatment plants due to unskilled operations in India. *Environmental Chemistry Letters*. 2016: 14:407-416.
3. Tajidin, N.E., S.H. Ahmad, A.B. Rosenani, H. Azimah & M. Munirah. Chemical Composition and Citral Content in Lemongrass (Cymbopogoncitratus) Essential Oil at Three Maturity Stages. *African Journal of Biotechnology*. 2012: 11(11): 2685-2693.

4. Labatut R.A., Angenent L., & Scott N. Biochemical methane potential and biodegradability of complex organic substrates. *Bioresource Technology*, 2010: 102(3): 2255-2264.

5. Ojo, M. Biogas Quality and Quantity for Digestion and Co-Digestion of Food Waste and Cow Dung. *Journal of Applied Sciences and Environmental Management*. 2021. 25(7): 1289-1293.

6. Owamah, H.I & Izinyon, O.C. Optimal combination of food waste and maize husk for enhancement of biogas production. *Environmental Technology and Innovation.* 2015: 4: 311-318.

7. Ojo, M., Babatola J.O., Akinola, A.O., Lafe, O., & Adelodun, A.A. Co-digestion of Water Hyacinth and Poultry Manure for Improved Biogas yield. ABUAD *Journal of Engineering Resources and Development*, 2019: 2(1): 42-48.

8. Ojo, M.& Babatola J.O. Association between Biogas Quality and Digester Temperature for Selected Animal Dung-Aided Water Hyacinth Digestion Mixes. *Journal of Applied Sciences and Environmental Management.* 2020: 24(6):955-959.

9. Li, Y., Sasaki, H., Yamashita, K., Seki, K., & Kamigochi, I. High-rate methane fermentation of lipid-rich food wastes by high-solids co-digestion process. *Water Science Technology,* 2002: 53: 249-258.

10. Momoh, Y. & Nwaogazie, I. L. The effect of waste paper on the kinetics of biogas yield from the co-digestion of cow dung and water hyacinth. *Biomass and Energy* 35(3): 2011: 1345-1351.

11. Li, R., Chen, L., Li, X., Lar, J.S., He, Y., & Zhu, B. Anaerobic co-digestion of kitchen waste with cattle manure for biogas production. *Energy fuel*, 2009: 23: 2225-2228.

12. Okoye N. Potash and its benefits. 2022.

13. Okpala, B.Benefits of Kaun Potash. Https//globalfoodbook.com. 2015: Accessed 29th January, 2023.

14. Dinesh, G.; Ejaz, A; Kamal, K.P. and Basudeb, S. Efficient utilization of potash alum as a green catalyst for production of furfural, 5-hydroxymethylfurfural and levulinic acid from mono-sugars. Royal Society of chemistry Advances. 2017: Vol. 7, 41973.

15. Tajidin, N.E., S.H. Ahmad, A.B. Rosenani, H. Azimah & M. Munirah. Chemical Composition and Citral Content in Lemongrass (Cymbopogoncitratus) Essential Oil at Three Maturity Stages. *African Journal of Biotechnology*. 2012: 11(11): 2685-2693.

16. World Health Organization (WHO). "Household Air Pollution and Health."Available at http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health 2018.

17. Sumpter, Colin, & Daniel, Chandramohan. "Systemic Review and Meta-Analysis of the Associations between Indoor Air Pollution and Tuberculosis." School of Hygiene and Tropical Medicine, London. Journal of Agriculture, Food systems, and Community Development. 2013: 7(3): 1-3.

18. APHA. Standard methods for determining proximate analysis.2005