Nigerian Research Journal of Chemical Sciences (ISSN: 2682-6054)
Volume 14, Issue 2, 2026

Anaerobic Co-Digestion of Broiler Litter and Cassava Peels for Biogas Production

*Alfa Y. M., Salihu A. B., Sulaiman L. A. and Danazumi N.
Chemical Sciences Department
The Federal Polytechnic, Bida, Niger State
*Corresponding Author: alfa.yahaya@fedpolybida.edu.ng

Accepted: *May 15, 2026*. **Published Online**: *May 18, 2026*

ABSTRACT

The study focused on the effects of co-digestion of cassava peels and broiler poultry litter on the biogas production. Litter samples of poultry bird and cassava peels were analyzed for their proximate and ultimate compositions using standard methods. Slurries prepared from the cassava peels and broiler poultry litter in the ratio 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 were fed into digesters labeled A, B, C, D, E, and F respectively. Biogas production in the labeled digesters were observed for a retention period of 49 days. Results showed that blends B, C, D, E, and F recorded similar compositions of proximate and ultimate analysis but differed from sample A (100% broiler litter). Carbon/ nitrogen ratios of cassava peels in samples A, B, C, D, E and F are 19.66, 11.43, 12.17, 13.16, 13.97, 13.33 and 12.86 respectively. Conclusively, sample D has the highest cumulative biogas production of 18,667.66 cm^3 with significant difference at 95% confidence level from all other samples. whereas sample B has the lowest (13,192.33 cm^3). The results revealed that addition of cassava peels to broiler litter increased the rate and volume of biogas produced.

Keywords: Anaerobic, broiler litter, co-digestion, proximate composition, ultimate composition

INTRODUCTION

The problem of inadequate energy supply and environmental pollution in Nigeria cannot be over-emphasized. If Nigeria is to achieve any meaningful growth and development, access to adequate energy and healthy environment demand for diversification of sources of energy supply, In Nigeria, the level of dependence on fossil fuels has created a great disparity in the sourcing, harnessing, exploration and exploitation of this natural endowment vis-à-vis other energy sources [1]. Biogas generation from anaerobic digestion of readily available wastes seems to be an attractive option. From the global perspective, the over-dependence on fossil fuels as a primary source of energy has resulted in climate change, many environmental destruction and related human health problems [2]. The joint challenge of global pollution and depletion of fossil fuels is driving intense search into alternative renewable energy sources, among which is the biogas [3]. Biogas is a colourless and flammable gas that contains 50-75% methane, 25-50% carbon IV oxide, 0-10% nitrogen, 0-1% hydrogen, 0-3% hydrogen sulphide and 0-2% oxygen [4]. The major component of biogas is methane because of its combustive properties. Biogas is formed through anaerobic digestion that involves degradation of organic matter in the absence of oxygen. Biogas is produced by biomethanation process which is the degradation of organic nutrients by microorganisms in the absence of oxygen. It is a multi-steps biological process in which organic carbon is converted mostly to carbon (iv) oxide and methane [4]. The process involves four stages. The first stage is hydrolysis which is the slowest among the four degradation steps. Bacteria's transform complex organic compounds into liquefied monomers and polymers. The second step is acidogenesis. That is where sugar and amino acids are converted into volatile fatty acid and alcohol. The third step is acetogenesis. That is where the substances formed in acidogenesis are converted into hydrogen, acetic acid and carbon dioxide. Finally, the fourth step is methanogenesis [5]. The methanogenic bacteria convert hydrogen and acetic acid into methane and carbon dioxide. During anaerobic digestion, parameters to be monitored are organic loading rate, pH, temperature, hydraulic retention time, carbon to nitrogen ratio, and particle size,

Biogas production from waste is not a new technology; historical evidence indicates that Anaerobic Digestion (AD) is one of the oldest technologies. The earliest record of biogas technology in Nigeria was in the 80s when a simple biogas plant that could produce 425 litres of biogas per day was built at Usmanu Danfodiyo University, Sokoto [6). About 21 pilot demonstration plants with a capacity range of between 10 m^3 and 20 m^3 have been cited in different parts of Nigeria (Achara, Nsukka LGA, Enugu State; Ifelodun farmer's cooperative at Ojokoro, Agege, Lagos; ANAPRI, Zaria, Kaduna State; Kano, Yobe, Kebbi States, etc) but none is presently functional [6]. However, efforts are being made by individuals, and organisations to reinstate biogas production in Nigeria.

Co-digestion of different materials may enhance the anaerobic digestion process due to better carbon and nitrogen balance. Digestion of more than one substrate in the same digester can establish positive synergism. Okonkwo, *et al*., carried out a comparative analysis of the rates of production of biogas from various organic wastes and weeds which enabled the determination of optimal ratio of poultry droppings to domestic wastes [7].

Biogas has proved to have significant potential as a renewable energy source for industrial as well as domestic applications and an efficient solution to the global energy crisis. Several research works on biogas production have been carried out using different substrates without laying much emphasis on the co-digestion of agricultural wastes and animal wastes especially poultry litters. This research is aimed at determining the proper mixing ratio for optimal biogas yield from broiler poultry litter and cassava peel.

MATERIALS AND METHODS

Sample Collection and Preparation

Litter samples of broiler poultry bird and cassava peels were collected from a major poultry farm and a major cassava processing site in Bida, Niger State, Nigeria. The sample of broiler litter was cleaned by hand picking stones and other impurities. Cassava peels sample was sun dried and ground using wooden mortar and pestle. The samples were stored in clean polythene bags properly labeled.

Proximate Analysis

Moisture content, and ash content were determined according to the method of AOAC, 2019 [8]. Volatile matter was determined using the method of Jigisha *et al.*, [9]. Percentage fixed carbon was determined by difference between 100% and the sum of the percentages of moisture, ash and volatile matter as described by Jigisha *et al.*, [9]

Ultimate Analysis

This was achieved by using a correlation for calculating elemental composition from proximate analysis of the samples as described by Jigisha *et al.,* [9]. Carbon/ Nitrogen ratio was estimated as described by Bagudo *et al*., [10].

Preparation of Slurry and Biogas Production

The slurry was prepared by mixing 1000 g of broilers litter in a bowl, with four liters of water, stirred thoroughly until a homogeneous mixture was obtained. The slurry was transferred into a 4 L plastic container (which served as the digester) with opening made on the cover and 0.8 cm PVC tube inserted. The opening and the covered were sealed using glue to make it air tight. This was labeled as digester A [10]. Similar method was adopted for the preparation of blended cassava and broiler poultry litter waste based the composition given in Table 1. Also a triplicate sets of digesters were prepared for all the composition (A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3, D_1, D_2, D_3, E_1, E_2, E_3, and F_1, F_2, F_3) and left to stand for a retention period of 49 days with daily shaken before readings were taken for biogas produced which was collected in 1000 cm^3 measuring cylinder by downward displacement of water as shown in Plate 1.

Table 1: Composition of blended cassava peels and broiler poultry litter

Digester	Composition
A	1000 g Broiler litter
B	900 g Broiler litter with 100 g cassava peel
C	800 g Broiler litter with 200 g cassava peel
D	700 g Broiler litter with 300 g cassava peel
E	600 g Broiler litter with 400 g cassava peel
F	500 g Broiler litter with 500 g cassava peel

Plate 1: Set up for biogas production from co-digestion of broiler litter and cassava peel

RESULTS AND DISCUSSION

Figure 1 shows the result of proximate compositions of the blended broiler litter and cassava peels. Ultimate composition of the blends aree shown in Figure 2 whereas Figure 3 shows the carbon-nitrogen ratios of the blends. Daily biogas production for the retention period and cumulative biogas production for each sample were shown in Figures 4 and 5 respectively.

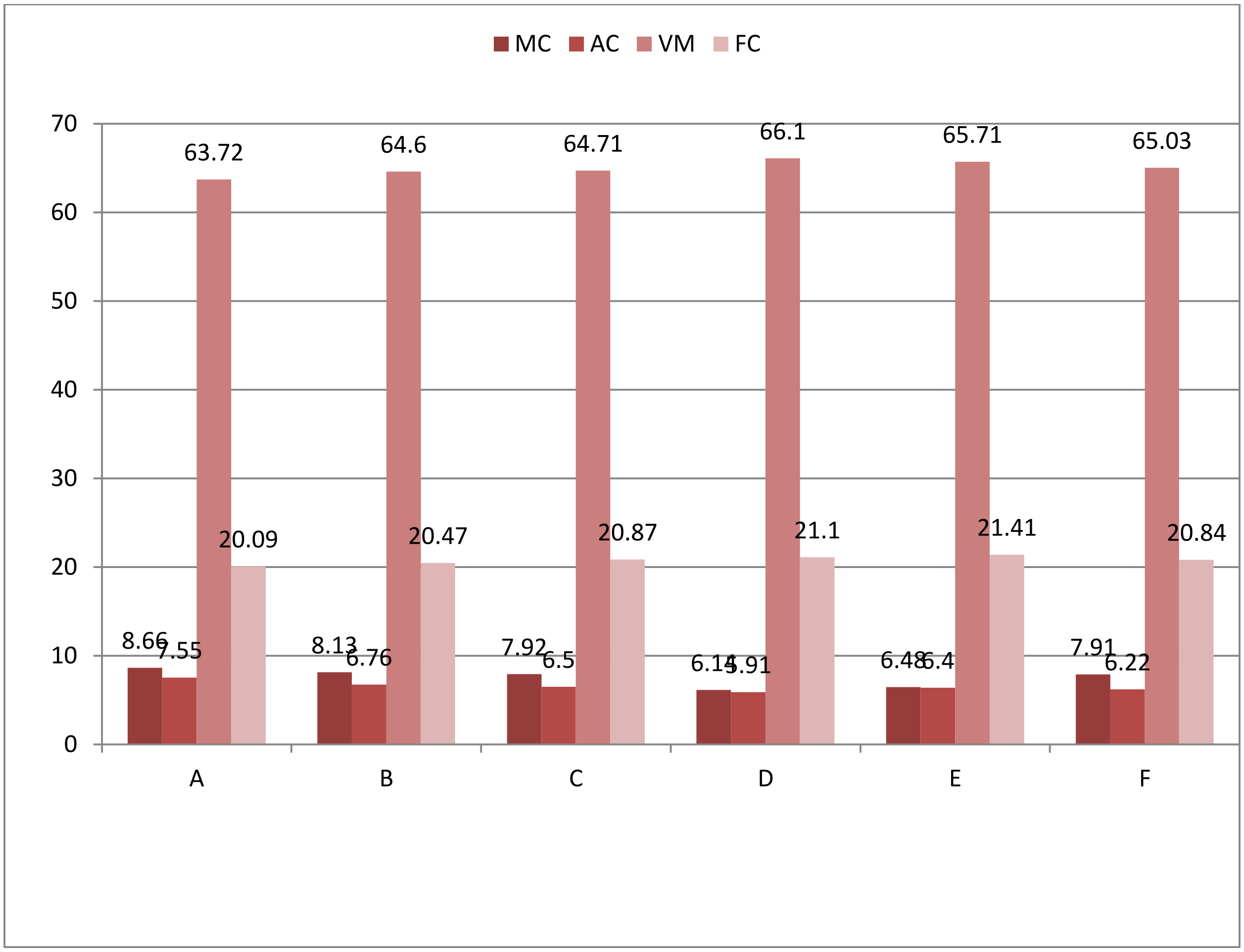

Figure 1: Proximate composition of cassava Peels blends with Broiler Litter

Key: A= 100% Broiler litter; B= 90% Broiler litter + 10% cassava peel; C= 80% Broiler litter+20% cassava peel; D= 70% Broiler litter + 30%cassava peel; E= 60% Broiler litter+40% cassava peel; F= 50% Broiler litter + 50% cassava peel.

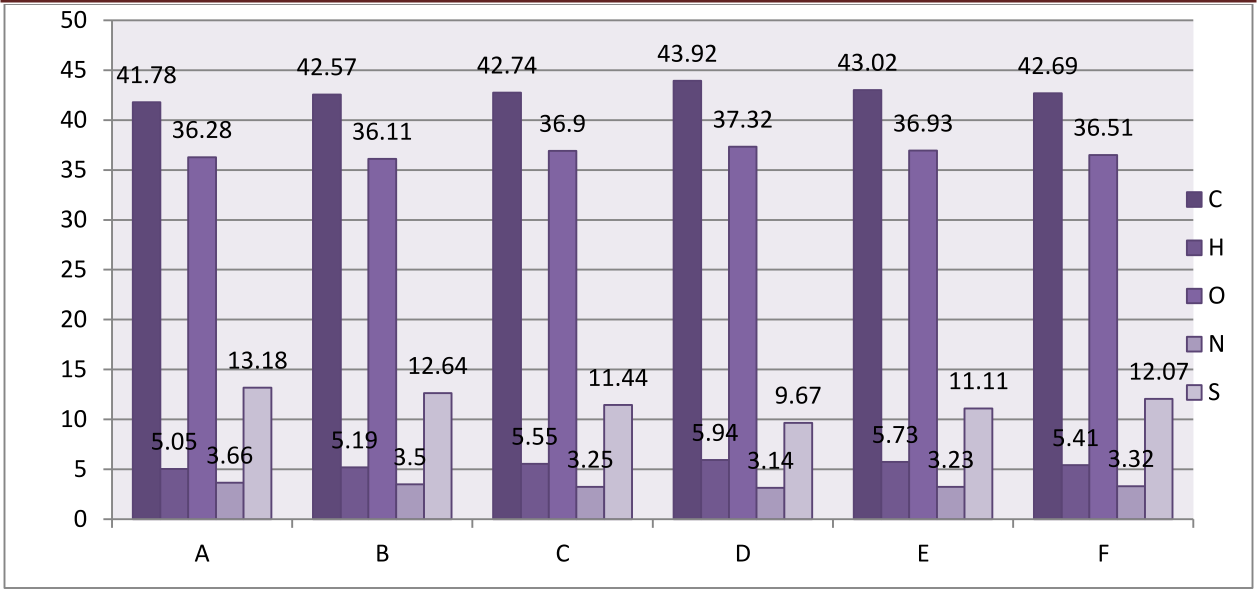

Figure 2: Elemental Compositions of Blends of Cassava Peels and Broiler Litter (Results are mean of three determinations ± SD)

Key: A= 100% Broiler litter; B= 90% Broiler litter + 10% cassava peel
C= 80% Broiler litter+20% cassava peel; D= 70% Broiler litter + 30% cassava peel
E= 60% Broiler litter+40% cassava peel; F= 50% Broiler litter + 50% cassava peel

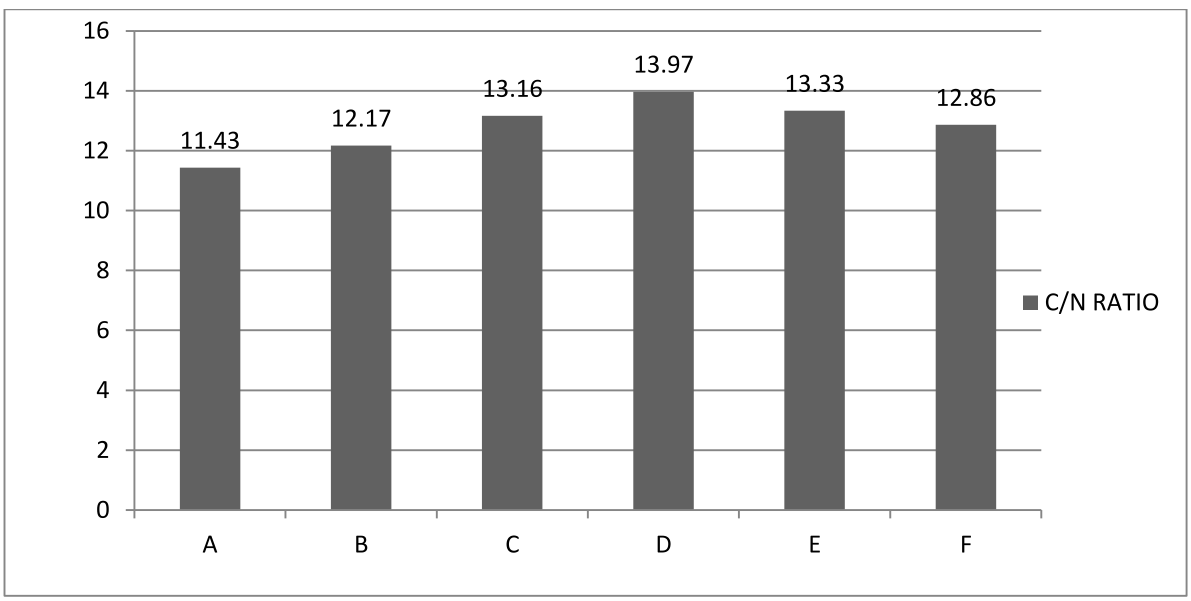

Figure 3: Carbon/Nitrogen ratio of blends of cassava peels and broiler litter
Key: A= 100% Broiler litter; B= 90% Broiler litter + 10% cassava peel
C= 80% Broiler litter+20% cassava peel; D= 70% Broiler litter + 30% cassava peel
E= 60% Broiler litter+40% cassava peel; F= 50% Broiler litter + 50% cassava peel

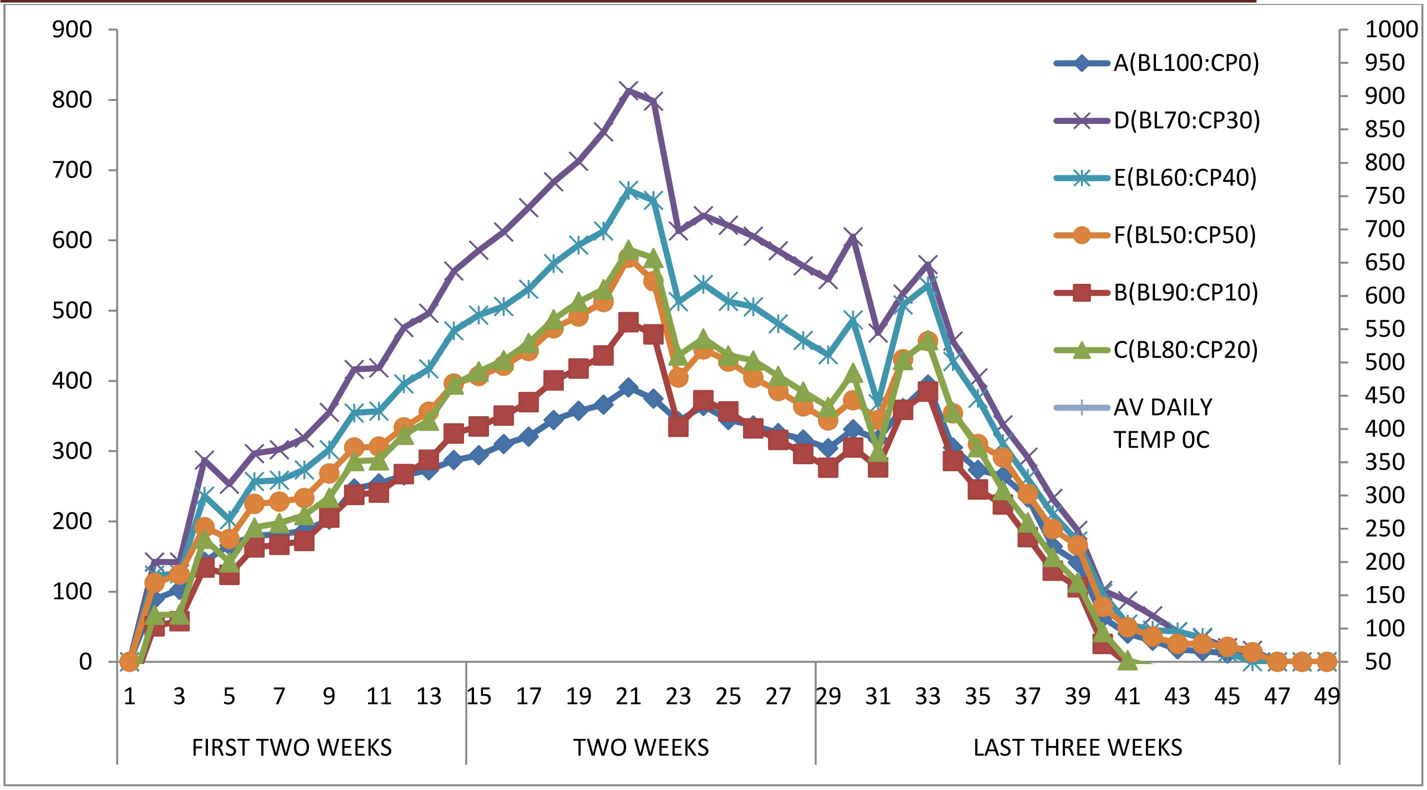

Figure 4: Daily biogas production for the retention time

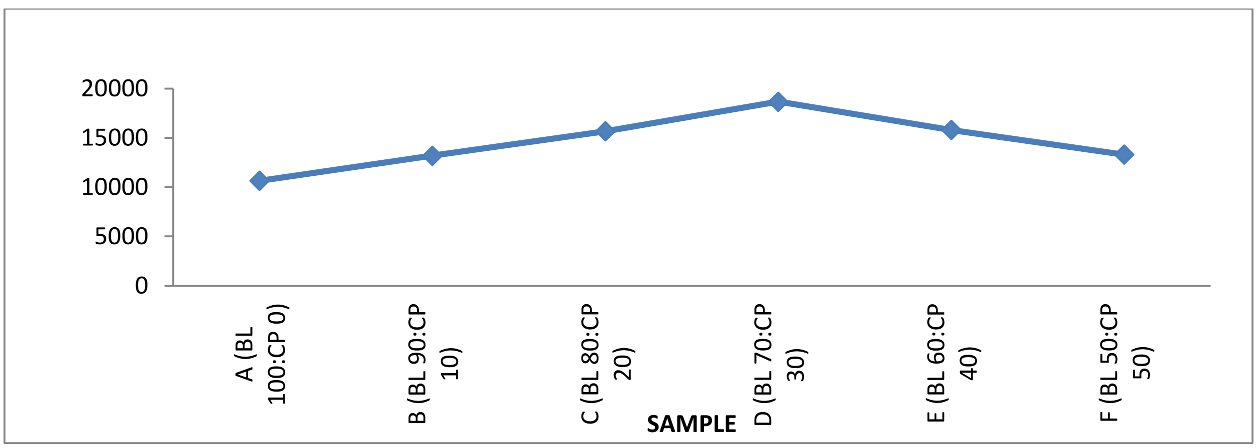

Figure 5: Cumulative biogas production for each sample

Proximate analysis is the quantitative analysis of the distribution of constituent products obtained when the sample is heated under designated conditions. It separates the constituents into four categories namely; moisture content, ash content, volatile matter and fixed carbon [11]. Proximate analysis of biomass provides information on combustion behaviours of biodegradable feedstocks [12].

The moisture content of feedstock is the quantity of water present in the sample expressed in weight percentage (Wt.%) of the sample. It is crucial to mention the basis on which moisture is determined because moisture plays a vital role in differentiating biomass fuel [13]. Figure 1 indicates the results of proximate composition of blended cassava peels and broiler poultry litter. The moisture contents of sample A is 8.66%, B 8.13%, C 7.92%, D 6.145, E 6.48 and F 7.91%. Sample D has the lowest moisture content and significantly different from the values obtained for other blends). Moisture content is one of the biomass properties to measure and can make the difference between a good and a bad fuel. High moisture content fuels burn less readily and provide less useful heat per unit mass. Excess moisture can lead to lower biogas yields due to dilution of organic matter and inhibition of microbial activity [14]. Determining the moisture content, could help in allowing for adjustments in feedstock composition or process conditions to optimize biogas production [15].

Ash content indicates the percentage of salts in the substrate which contain essential building blocks for microorganisms responsible for breaking down of feedstocks for biogas production but high salts will result in releasing excess salts which can inhibit concentration of the microorganisms' activities and hence low biogas production [15]. The results obtained for ash content of blended samples indicate that sample A has the highest ash content of 7.55%. and sample D having lowest 5.91%, and are all significantly different. The ash content is the amount of solid material remaining after the sample was incinerated and reflecting the mineral content of the sample [16]. A biomass with greater quantity of ash, can cause severe problems like Slagging, fouling and clogged ash removal problem associated with boilers.

Volatile matter is the portion of biomass that volatilized rapidly when it is burnt at high temperature under a particular condition. It promotes efficient anaerobic digestion, as microorganisms can readily access and metabolize the organic compounds present in the feedstock [15]. This leads to faster digestion rate and a shorter retention time thereby improving process efficiency and reducing the overall energy and operational costs associated with biogas production. From Figure 2 volatile matter for samples A, B, C, D, E, and F are 63.72%, 64.60%, 64.71%, 66.10%, 65.71% and 65.03% respectively, with sample D having the highest while A has the lowest. When compared statistically the difference of the mean of the value obtained for sample A and other blends is significant at 95% confidence level.

The portion of the fuel that will volatilize rapidly when it is burnt at a high temperature under a particular condition is called volatile matter. Fuels have high volatile matter produce volatile gasses by heating. The significant proportion of volatile matter in the selected biomass fuel can be a positive influence for an improved ignition of the dust-air cloud and flame stability [13]. It promotes efficient anaerobic digestion as microorganisms can readily access and metabolize the organic compounds present in the feedstock and hence lead to faster digestion [15]. The fixed carbon content for sample E is 21.41% closely followed by D 21.10% with no significant different but both are different from the rest blends respectively.

Fixed carbon content is the quantity of solid carbon residue that remains after the combustion of the sample with the removal of volatile matter. The value of fixed carbon content helps for evaluating the productivity of biomass fuel. At lower combustion temperature it improves the reactivity of fuel [15]. Comparing moisture contents obtained with fixed carbon values it could be deduced that there exists an inverse proportionality relationship between moisture contents and fixed carbon contents as the moisture content increases the fixed carbon content decreases. The value of fixed carbon obtained helps in evaluating productivity of biomass fuel.

Ultimate analysis provides information about other essential nutrients available in substrate. It gives a composition of chemical substances and elementary elements present in each biomass and determines its ability to produce a better fuel source [14]. The suitability and quality of biogas to be produced by any selected biomass could be informed by ultimate analysis; hence, these factors necessitated the elemental. CHNSO, and investigative contents shown in Table 4.3. Carbon 41.78%, 40.19% and 39.95% for broiler litter, cockerel litter and layer litter respectively with layer litter having the lowest carbon content and broiler litter having the highest. These values are closely related to (39.98–43.08%) for cow dung reported by Fajobi *et al* [14]. The values obtained for layer litter and cockerel litter show no significant difference while broiler litter value is significantly different from the two. The hydrogen contents of the three litter samples of broiler, cockerel and layer are 5.00%, 4.83% and 4.83% respectively with broiler litter significantly different from the values for cockerel and layer litters which both show no significant difference. The percentage oxygen contents for the three samples are 36.29%, 35.23% and 35.30% for broiler, layer and cockerel litters respectively. The result indicates that broiler litter has the highest oxygen content which is significantly different from layer litter and cockerel litter that show no significant difference. having the lowest. The nitrogen content for broiler litter is 3.78%, cockerel litter 4.89%

and layer litter 3.89%. The nitrogen contents for the three samples are significantly low compared to carbon, oxygen and hydrogen. The values obtained for the three samples are all significantly different. The Sulphur contents are 13.16%, 15.11% and 15.78% for broiler litter, cockerel litter and layer litter respectively. Layer litter has the highest sulphur content with broiler litter having the lowest. The values are all statistically different.

Ultimate analysis provides information about other essential nutrients available in substrate. It gives a composition of chemical substances and elementary elements present in each biomass and determine its ability to produce a better fuel source [12]. The suitability and quality of biogas to be produced by any selected biomass could be informed by ultimate analysis.

The ultimate compositions of blended samples are shown in Figure 2 and the carbon/nitrogen ratios are shown in Figure 3. The carbon content of sample D is highest (43.92%) significantly different from other blends. On the other hand, sample D has the lowest nitrogen content of 3.14.

Sample D has the highest carbon/nitrogen ratio of 13.97 while sample A has the lowest with 11.43. Previous studies have shown that anaerobic bacteria source their foods from carbon and nitrogen such that carbon is needed for energy, while a combination of carbon and nitrogen is used for building new cell structures [17]. The process of anaerobic digestion is inclined to be the proportion of carbon/nitrogen present because it is an indication of the nutrient level of the biomass [18]. Moreover, a very high Carbon/Nitrogen ratio tends to cause insufficient nitrogen for maintaining biomass cells and consequently brings about an ammonia nitrogen supply in the digester [18]. Additionally, a high Carbon/Nitrogen ratio is an indication of rapid consumption of nitrogen by methanogens, which results in lower gas production [19]. In contrast, a very low Carbon/Nitrogen ratio can lead to possible ammonium inhibition of microorganism activities in the digester, resulting in an optimum pH value to exceed 8.5, which is toxic to methanogenic bacteria [18, 19]. Therefore, to strike a balance between the two levels (high/low) of Carbon/Nitrogen ratios, a combination of biomass with considerably low and high ratios of Carbon/Nitrogen is proposed, such as organic waste blended with sewage or animal manure; thus, the biomass investigated in this study can form a good blend for biogas production. The advantages of this approach include not only having an optimum operational Carbon/Nitrogen ratio but also having a higher methane content yield when co-digested compared to sole digestion [20]. The values of carbon/nitrogen ratios reported in literature that work well in biogas process vary between 10-30 [21]. This formed the basis upon which the biomass could be considered an excellent anaerobic digestive for biogas production [17, 18].

Co-digestion of broiler litter and cassava peels at different proportions labeled as A (100% BL), B (90%BL:10%CP), C (80%BL:20%CP), D (70%BL:30%CP), E (60%BL:40%CP), and F (50%BL:50%CP) gave the following results. Figure 4 show the daily biogas production for the retention period of 49 days. The production commenced on the second day for all the digesters and progressed steadily throughout, up to day 21. From day 22, the production started declining slowly till day 33. The production curve started to drastically declining from day 34 up to day 49 when no visible production was noticed.

Figure 5 indicated the cumulative biogas production for each sample for the retention time of 49 days. It is clear from the figure that sample A recorded a total of 10,645cm^3, B 13,192.33cm^3, C 15,671cm^3 D 18,677.33cm^3 E 15,793dm^3 and F 13,302.67cm^3

From the results it is obvious that samples of broiler litter co-digested with cassava peels (B, C, D, E, and F) produced more biogas than sample A which is mainly broiler litter and the differences are significant when compared statistically at 95% confidence level with $\alpha = 0.05$. In most days samples C and E showed no significant difference, so also samples B and F. The volume of biogas produced from sample D is the highest of all and significantly different from the rest samples at 95% confidence level with $\alpha = 0.05$. In the whole there is significant positive effect on the volume of biogas produced as cassava peels were being added with the highest production of biogas from sample D having the mixing ratio of broiler litter and cassava peels as 70:30% respectively. This is followed by sample E (60:40%), sample C (80:20%) then sample F (50:50%) and sample B (90:10%). Sample A without cassava peels a recorded the lowest biogas production.

CONCLUSION

The study investigated the effect of biogas production using broiler litter co-digested with cassava peels. The results indicated that cassava peels plays a very significant role in improving the production rate of biogas from broiler litter. This could be as a result of high content of volatile matter, fixed carbon and carbon content as well as low nitrogen content which give rise to high carbon/nitrogen ratio exhibited by cassava peels when compared to broiler litter. All the samples with cassava peels produced more biogas than sample A without cassava peels and are significantly different at 95% confidence level. However, sample D produced the highest biogas of all the samples with significant difference from the rest sample at 95% confidence level with $\alpha = 0.05$. The inclusion of cassava peels to the broiler litter has progressive effects on the rate and amount of biogas production when compared to broiler litter alone. The highest production was recorded when 30% of cassava peels was blended with 70% of broiler litter. Sample D has the best medium and hence recorded the cumulative highest biogas yield.

This paper recommends a cassava peels-broiler poultry litter wastes mixing ratio of 3:7 by mass for slurries intended for biogas production from methane-generating systems. Kinetic study of the system is also recommended to enable selection of optimal conditions that favor high biogas yield.

REFERENCES

1. Achebe, C.H., Nwigbo, S. C., Chinwuko, E. C. & Odhomi, M. O., (2007). Biogas generation: a viable cleaner alternative energy source in south-eastern region of Nigeria, *Journal of Engineering and Applied Sciences*, 3(1&2), 31-34.
2. Budiyono, Widiasa, I.N., Johari, S. & Sunrso., (2010). Kinetics of Biogas Production Rate From Cattle Manure in Batch Mode, *International Journal of Chemical and Biological Engineering*, 3(1): 39-44
3. Gueguim-Kana, E. B., Oloke, J. K., Lateef, A. & Adesiyan, M. O. (2012). Modelling and Optimization of Biogas Production on Saw Dust and Other Co-Substrates using rtificial Neural Network and Genetic Algorim. *Renewable Energy*. 46: 276-281.
4. Angelidaki, I, Ellegaard, L., (2002). Anaerobic Digestion in Denmark:Past,Present and Future: in Anaerobic Digestion for Sustainability in Waste Treatment and Reuse. Proceedings of 7th Fao/Sren-Wokshop,19-22 may, Moscow, Russiapp.129-138
5. Li, Y., Stephen, Y. & Park, Jiying, Z., (2011). Solid–state anaerobic digestion for methane Production from Organic Waste, *Renewable and Sustainable Energy Review*, 15: 821- 828.
6. Dangoggo, S. M. & Fernando, C. E. C. (1986). A Simple Biogas Plant with Additional Gas Storage System. *Nigerian Journal of Solar Energy*, **5,** 138-141.
7. Okwonkwo, U. C., Onokpite, E. & Onokwai, A. O. (2016). Comparative Study of the Optimal Ratio of Biogas from Various Organic Wastes and Weeds for Digester/Restarted Digester. *Journal of King Saud University Engineering Sciences*. http://dx.doi.org/10.1016/j.jksues.2016.02.002. Assessed on 03/01/2026

8. AOAC (2019). Official Methods of Analysis of the Association of Official Analytical Chemists: Official Methods of Analysis of AOAC International. 21st Edition, AOAC, Washington DC.

9. Jigisha, P., Channiwala, S. A. & Ghosal, G. K. (2007). A Correlation for Calculating Elemental Composition for Proximate Analysis of Biomass Materials. *Fuel*. 86, 12 1710-1719.

10. Bagudo, B. U.,Garba, B., Dangoggo, S. M. and Hassan, L. G. (2008). Comparative Studies of Biogas Production from Locally Sourced Substrate Materials. *Nigerian Journal of Basic and Applied Sciences*, 16(2), b263-266.

11. ASTM-D 121-09a (2009). Standard Technoligy of Coal and Coke. Pennyslvania: Anmerica

12. Sivabalan, K., Hassan, S., Hamden, Y. & Pasupuleti, J (2021). A Review on Characteristic of Biomass and Classification of Bioenergy through Direct Combustion and Gasification as an Alternative Power Supply. *J. Phys: Conf. Ser*. 1831 012033

13. Energy from Biomass (1999). World Bank Technical Paper. Washington D.C. Available at http://www.wds.worldbank.org. Assessed on 12/02/2026

14. Fajobi, M.O., Lasode, O. A., Adeleke, A. A. Ikubanni, P. P. & Balogun O. (2022). Investigation of Physicochemical Characteristics of Selected Lignocellulose Biomass. *Science Reports*. 12, 2918.

15. Ramyarania L. (2016). Characterization of the Properties of some Biomass Species and Estimation of their Power Generation Potentials. A Thesis submitted to the Department of Metallurgical and Material Engineering, National Institute of Technology, Rourkela

16. Hafsah, M, A., Kaltum, U. M., Abdulhamid, M. R., Ali, A. A., Grace, F. A., Adeboye, M. M., Musa, I., Usman, A. B., Mohammed, H. A., Falmata, B. M. D & Daniel, I. D. (2023). Studies on the Potentials of Poultry Dropings for Biogas Production. *Arid Zone Journal of Basic and Applied Research* (AJBAR). **2**(2) 135-141.

17. Jain, S., Jain, S., Wolf, I. T., Lee, J. & Tong, Y. W (2015). A comprehensive review on operating parameters and different pretreatment methodologies for anaerobic digestion of municipal solid waste. *Renew. Sustain. Energy Rev.* **52**, 142–154.

18. Mao, C., Feng, Y., Wang, X. & Ren, G (2015). Review on research achievements of biogas from anaerobic digestion. *Renew. Sustain. Energy Rev.* 45, 540–555.

19. Olojede, M. A., Ogunkunle, O. & Ahmed, N. A. (2018). Quality of Optimized Biogas Yields from Codigestion of Cattle Dung with Fresh Mass of Sunflower Leaves, Pawpaw and Potato Peels. *Cojent. Eng*. 5. 1-21.

20. Kim, G., Lee, D. & Jeon, C. V. (2019). Fundamental characteristics and kinetic analysis of lignocellulosic woody and herbaceous biomass fuels. *Energies* **12**, 1008.

21. Anna, S. & Asa, J. (2010). Microbiological Hnandbook for Biogas Plants. *Swedish Waste Management U 2009:03.*