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Comparative analysis of the energy content of methane from cow dung manure and poultry manure

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Abstract
Owing to the fact that life depends entirely on reliable and adequate supply of energy, the energy supply in Nigeria is inadequate due to limited generation of power with no improvement in sight. Her power situation affects the manufacturing, service and residential sectors of the economy which in turn affects the country's economic growth. This study is a comparative analysis of the energy content of methane from cow dung and poultry manure using the biogas digester. Using 4g of dry samples of cow dung and poultry manure with 25ml of distilled water and 0.124g of yeast to function as a catalyst in order to facilitate the fermentation of the substrate, the biogas digester was set-up and the temperature was maintained at 40 – 56^{0}C while the gas was collected using the downward delivery method. Results shows that the average biogas production from cow dung and poultry manure were respectively (0.195dm^3/day) and (0.151dm^3/day). While, the percentage of methane in biogas were 18.60% cow dung and 21.36% poultry manure. Even though the poultry manure showed higher energy values in the first ten (10) days, the average energy content of methane obtained were cow dung manure (1.195kJ/day) and poultry manure (1.065kJ/day). However, energy content from animal waste especially cow dung can be harnessed; they can serve as alternative sources of energy that can support peak load and reduce over dependent on hydro to help boost the Nigerian economy.

Keywords: energy content, methane, cow dung manure, poultry manure, biogas

1. Introduction

Energy, as pointed out by Adejumobi *et al.* [1], is one of the critical infrastructural requirements for agricultural, industrial and socio–economic development of rural or remote environments, therefore, a basic and integral component of the overall development of any nation. As such, energy has become a major concern of every nation due to its great advantage in the socioeconomic development and economic growth of a country [2]. Several researches in the literature have established that energy has a long term effect or relationship with the gross domestic product (GDP) of a country [3, 4, 5, 6, 7, 8, 9]. Despite the importance of energy in the development of a country, Adejumobi *et al.* [1], posit that, currently more than 1.5 billion people are without access to electricity. In line with this, Igbinovia and Orukpe [10] estimated that, not more than 20% and in some countries as little as just 5%, of the population in Africa (excluding South Africa and Egypt) have direct access to electricity and in the rural areas the value falls to about 2%. Since lack of access to electricity and rural poverty are closely correlated, the low level of electricity access does not only pose great threat to the living standards of populace but also to the rapid socio – economic development of these sets of people.

Nigeria is still having serious problems with the energy sector attributed to over dependent on hydropower [11]. As such, Nigeria is among one of the countries that have very low electricity generation [12]. According to Wikipedia [13] Nigerian electricity generation is 28,000 GWh which is far low to support economic growth and development as compared to china (6, 495, 100 GWh) United State (4281, 800 GWh) and South Korea (571,700GWh). Even though Nigeria has the potential to exploit other forms of energy like solar, wind, gas and other renewable energy sources. No much concern has been made by government to harness these resources [14]. According to Adejumobi *et al.* [1], Power Holding Company of Nigeria (PHCN), has been unable to cope with the electricity demand that is growing at an average range of 7% annually. More so, about 65% of Nigerian rural populace does not have access to the available conventional power.

The quest for energy in days to day activities depends on some keys factors. Some of these factors include the population of the community, and the number of industries in that community [15]. These industries have to be provided with enough power to operate some of their machines that need higher power operation. In addition, due to the fact that the population is or keeps on increasing every day; provision for energy for this increment is needed. It is evident that the energy problem has had a serious danger in the development of humanity [15].

Actually there is no single solution to these problems as a result of fuel crisis in the oil sector. Nevertheless there has to be a search for an alternative source of energy which is renewable, apart from existing fuel or fossils fuel that are nonrenewable. This has brought to the existence of the non-conventional source of energy that is more reliable, friendly and also available [16]. Examples to these non-conventional energy sources are Biomass, wind energy, geothermal and hydropower [17].

This quest for other source of energy had brought the realization that our dependence on the fossils fuels for source of energy has blind folded us and hence has facilitated the limitation we had suffer in other source of energy so far. According to Iwayemi [18], the reason for considering other alternatives source of energy to the existing ones has several significant facets, most of which is the need to replace this sourced which are in short supplies. For instance, petrol which has been the major source of energy in Nigeria becoming depleted in supply, it is obvious that fossils fuel like petrol do not have infinite life time. According to Bello-Iman [19], Nigeria is heavily endowed with an abundant resources but electricity generation is relatively low with the current output less than 3000kW/h. A research by World Bank [20] pointed out that, only 48% of Nigeria's 174 million people have access to electricity and according to Emodi and Yusuf [21], the access to electricity is relatively low compared to other African countries.

There is therefore, the need to look for alternative sources. Iwayemi [18] explained this implication that any commodity that is dwindling in supply to the demand will eventually forces itself to high market prices to ensure the equity in demand and supply. Moreover, biomass play an important role in Nigeria in the form of fuel [19] and in the world today it is still mostly utilized for cooking and heating in both urban and rural area where the entire populace considered. Wood has been one of the oldest renewable sources of energy known in Nigeria and used by mankind to meet up with the domestic energy requirement.

Sambo [22] had pointed out some of the factors that results in the Nigerian poor energy situation where he mentioned inefficient power plants which are few in numbers to lack of renewables to support peak load. In view of the above, this paper tends to address the research questions: what form of renewable energy can be best suited to support the peak load of Nigerian national grid network? In order to solve the above research question, the paper carried out a comparative analysis of the energy content of methane from cow dung and poultry manure using the biogas digester. We believe that such energy if harnessed in the Nigerian grid network could reduce the over dependence on fossil fuels while producing energy at a low cost. In addition, it will reduce the environmental pollution and degradation of the ozone layer.

This paper is organized as follows: the next section presents the research methodology, followed by the experimental procedure. We then present the empirical analysis and findings. Finally, the interpretation of the findings and both theoretical and practical implications are described. The paper concludes by presenting the research limitations and proposing avenues for future research.

2. Materials and Method

The biogas digester was used for the study and we followed an experimental procedure in a laboratory set-up of the biogas digester and a downward delivery method was used to collect the biogas produced. The gasses so collected from samples of cow dung and poultry manure was analyzed for their energy content including cumulative volume of methane in biogas, biogas composition analysis and energy content of methane.

2.1 Experimental Procedures

Samples of cow dung and poultry dung were collected with shovel and were carefully placed in a plastic container sealed with an air tight cover to prevent contamination from dust, flies and other contaminants. The samples were dried in the research laboratory in a desiccator for three days, after which they were removed and grinded into powdered form using the pestle and mortar. The samples were further sieved to obtain fine powder. The biogas digester was then set up, which consist of two round bottom flask, six retort stand, a rubber tube, two measuring cylinders and a water bath. 4g of each samples were weighed and put into the round bottom flask, and 25ml of distilled water was added, after which 0.124g of yeast was also added to function as a catalyst in order to facilitate fermentation of the substrate so easily. After that, the samples were mounted on the retort stands into the water bath and the rubber tubes were connected to the measuring cylinder where the gas was being collected using downward delivery method. The temperature of the gas was being regulated at about 40 to 56^{0}C. The experimental set-up of the study is as shown in Figure I.

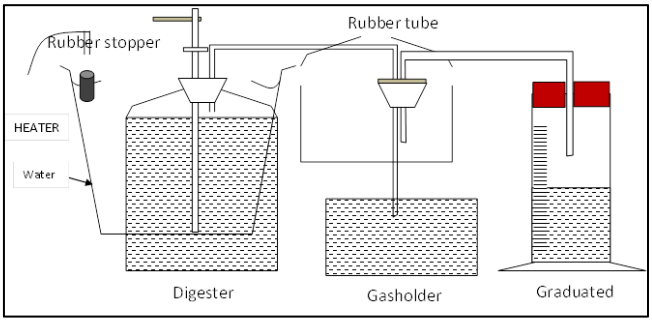

Fig 1: Experimental Setup

3. Theory and calculations

3.1 Theory

3.1.1 Cumulative Volume of Methane in Biogas

For both poultry and cow dung manure the volume of methane CH_4 is calculated from the volume of biogas given in Equation I as:

$$V_{biogas} = V_{CH4} + V_{CO2} + V_{H2S} \quad \text{(I)}$$

Where $V_{biogas} = Volume\ of\ biogas$

$V_{CH4} = Volume\ of\ methane$

$V_{CO2} = Volume\ of\ carbon\ dioxide$

$V_{H2S} = Volume\ of\ hydrogen\ sulphide$

Hence, volume of methane (CH_4) can be given as:

$$V_{CH4} = V_{biogas} - (V_{CO2} + V_{H2S}) \quad \text{(II)}$$

3.1.2 Biogas Composition Analysis

Calculate of the percentage of the components for both poultry manure and cow dung is carried out from Equations III, IV and V respectively as:

Percentage of carbon dioxide

$$CO_2\% = \frac{V_{CO2}}{V_{biogas}} \times 100 \quad \text{(III)}$$

Percentage of impurities

$$H_2S\% = \frac{V_{H2S}}{V_{biogas}} \times 100 \quad \text{(IV)}$$

Percentage of methane

$$CH_4\% = \frac{V_{CH4}}{V_{biogas}} \times 100 \quad \text{(V)}$$

3.1.3 Energy Content of Methane

The energy content of methane is now calculated from Equation VI as:

Energy E = Heat of combustion of $CH_4 \times density\ of\ CH_4 \times$ volume of CH_4 $= 50J/g \times 660 \frac{g}{m^3} \times volume\ (m^3) = xxx(kJ)$ (VI)

3.2 Calculations
3.2.1 Percentage components

The percentage of the components for the various constituents is calculated using Equations III, IV and V.

For the poultry manure, the percentage of the components is calculated as follows:

$$CO_2\% = \frac{V_{CO2}}{V_{biogas}}\ x\ 100$$

$$= \frac{61.86}{151.14}\ x\ 100$$

$$= 40.93\%$$

$$H_2S\% = \frac{V_{H2S}}{V_{biogas}}\ x\ 100$$

$$= \frac{57.00}{151.14}\ x\ 100$$

$$= 37.71\%$$

$$CH_4\% = \frac{V_{CH4}}{V_{biogas}}\ x\ 100$$

$$= \frac{32.29}{151.14}\ x\ 100$$

$$= 21.36\%$$

For the cow dung manure, the percentage of the compositions is calculated as follows:

$$CO_2\% = \frac{V_{CO2}}{V_{biogas}}\ x\ 100$$

$$= \frac{78.50}{194.71}\ x\ 100$$

$$= 40.32\%$$

$$H_2S\% = \frac{V_{H2S}}{V_{biogas}}\ x\ 100$$

$$= \frac{80.00}{194.71}\ x\ 100$$

$$= 41.09\%$$

$$CH_4\% = \frac{V_{CH4}}{V_{biogas}}\ x\ 100$$

$$= \frac{36.21}{194.71}\ x\ 100$$

$$= 18.60\%$$

4. Results
4.1 Cumulative volume of biogas production

Table I shows the cumulative biogas production from both samples. The biogas produced here contains all the components including CO_2, CH_4, and the impurities (e.g. H_2S). From Table I, it is observed that the daily biogas production for both caw dung and poultry manures are observed to increases with the number of days. The daily biogas production from cow dung are observed to be higher than those obtained from the poultry manure even though there were some days where the poultry manure gave higher values like day two, seven and eight as shown in Figure II. However, the average biogas obtained from cow dung ($0.195dm^3$/day) is higher than the average biogas obtained from poultry manure ($0.151dm^3$/day).

4_g of Poultry manure + 0.12g of yeast + 25ml of distilled water and 4_g of Cow dung + 0.124_g of yeast +25m of distilled water.

Table 1: Cumulative volume of biogas production from cow dong and poultry manure.

Days	Poultry manure (ml)	Cow dung (ml)
1	0.00	0.00
2	36.00	31.00
3	46.00	59.00
4	56.00	70.00
5	79.00	88.00
6	103.00	106.00
7	141.00	123.00
8	168.00	151.00
9	197.00	217.00
10	218.00	285.00
11	241.00	334.00
12	255.00	396.00
13	274.00	415.00
14	302.00	451.00
Average	151.14	194.71

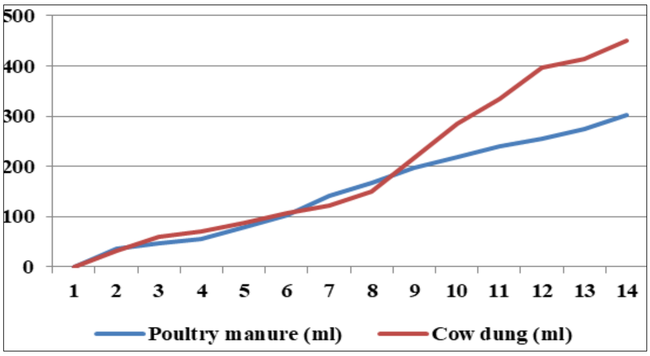

Fig 2: Cumulative volume of biogas production from cow dong and poultry manure

4.2 Cumulative volume of CO_2 contain in biogas

Table II Show the cumulative volume of the amounts of the CO_2 content in the biogas. It is a known fact that carbon dioxide is insoluble in the solution of sodium hydroxide NaOH, therefore is being released into the cylinders. From Table II, it is observed that the daily CO_2 content in biogas for both caw dung and poultry manures are observed to increases with the number of days. The daily CO_2 content from cow dung are observed to be higher than those obtained from the poultry manure even though there were some days where the poultry manure gave higher CO_2 values like day two and seven. However, the average CO_2 content obtained from cow dung ($0.0785dm^3$/day) is higher than the average CO_2 content from poultry manure ($0.0619dm^3$/day).

4g of Poultry manure + 0.124g of yeast + 25ml of distilled water + 1M NaOH(aq) and 4g of Cow dung + 0.124g of yeast +25ml of distilled water + 1M NaOH(aq)

Table 2: Cumulative volume of CO_2 content biogas

Days	Poultry manure (ml)	Cow dung (ml)
1	0.00	0.00
2	17.00	14.00
3	18.00	18.00
4	20.00	21.00
5	29.00	32.00
6	37.00	45.00
7	56.00	53.00
8	70.00	74.00
9	83.00	95.00
10	94.00	116.00
11	105.00	120.00
12	107.00	158.00
13	110.00	171.00
14	120.00	182.00
Average	61.86	78.50

4.3 Cumulative volume of impurities (H_2S) in biogas

Table III shows the cumulative amount of the volume of impurities such as the H_2S in the biogas. From Table III, it is observed that the daily H_2S content in biogas for both caw dung and poultry manures are observed to increases with the number of days. The daily H_2S content from cow dung are observed to be higher than those obtained from the poultry manure even though there were some days where the poultry manure gave higher H_2S values like day seven and eight. However, the average impurities H_2S content in cow dung manure (0.080dm^3/day) is higher than the average impurity H_2S in poultry manure (0.057dm^3/day).

4g of Poultry manure + 0.124g of yeast + 25ml of distilled water + 1M Pb $(CH_3COOH)_2$ and 4g of Cow dung + 0.124g of yeast +25ml of distilled water +1M Pb $(CH_3COOH)_2$.

Table 3: Cumulative volume of impurities (H_2S) in biogas

Days	Poultry manure (ml)	Cow dung (ml)
1	0.00	0.00
2	5.00	13.00
3	12.00	31.00
4	18.00	36.00
5	27.00	40.00
6	38.00	41.00
7	51.00	49.00
8	63.00	54.00
9	74.00	93.00
10	81.00	128.00
11	90.00	141.00
12	101.00	157.00
13	111.00	161.00
14	127.00	176.00
Average	57.00	80.00

4.4 Cumulative volume of CH_4 in biogas

The volume of methane for each day is obtained from Equation II and the values are represented in Table IV. From Table IV, it is observed that the daily volume of methane CH_4 content in biogas for both caw dung and poultry manures are observed to increases with the number of days. The daily volume of methane CH_4 content from poultry manure are observed to be higher than those obtained from the cow dung manure from day two (2) to day ten (10) after which that of cow dung becomes higher than the poultry manure as shown in Figure III. However, the average volume of methane CH_4 content in cow dung manure (0.0362dm^3/day) is higher than the average volume of methane CH_4 content in poultry manure (0.0323dm^3/day).

Table 4: Cumulative volume of CH_4 in biogas

Days	Poultry manure (ml)	Cow dung (ml)
1	0.00	0.00
2	14.00	4.00
3	16.00	10.00
4	18.00	13.00
5	23.00	16.00
6	28.00	20.00
7	34.00	21.00
8	35.00	23.00
9	40.00	29.00
10	43.00	41.00

11	46.00	73.00
12	47.00	81.00
13	53.00	83.00
14	55.00	93.00
Average	32.29	36.21

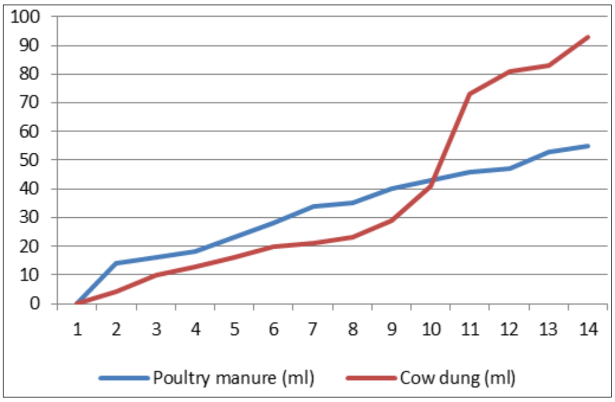

Fig 3: Cumulative volume of CH4 in biogas

4.5 Percentage composition of overall biogas production

Table V shows the summary of the percentage composition of the overall biogas production which is illustrated in Figure IV. From Figure IV it is clear that the percentage of methane obtained from cow dung biogas (18.6 percent) is less than that of the poultry biogas (21.36 percent) even though the volume of methane from cow dung manure biogas is greater than that of the poultry manure biogas. The percentage of CO_2 obtained from the poultry manure biogas and cow dung manure biogas appears to be almost the same even though that of the poultry manure is just slightly higher (40.93 percent against 40.32 percent). The percentage of impurity present in the cow dung manure (41.09 percent) is greater than that in the biogas from poultry manure (37.71 percent).

Table 5: Percentage composition table for overall biogas production

Categories	Poultry manure	Cow dung
Percentage of CH_4	21.36%	18.60%
Percentage of CO_2	40.93%	40.32%
Percentage of impurities	37.71%	41.09%

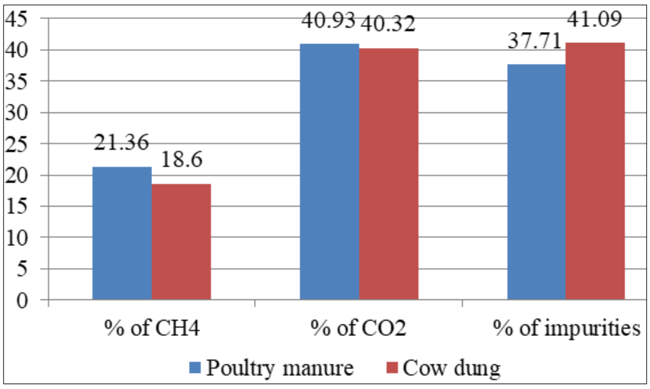

Fig 4: Percentage composition of the Biogas production of cow dung and poultry manure

4.6 Energy content of methane

The methane gas was obtained after separation from CO_2 and other impurities present in the biogas, and the energy content is calculated by multiplying the heat of combustion of the methane with the product of the density and volume of the methane at atmospheric pressure. The energy content of methane is obtained using Equation VI.

From Table VI, it is observed that the daily energy content of methane CH_4 obtained in biogas for both caw dung and poultry manures are observed to increases with the number of days. The daily energy content of methane CH_4 obtained from poultry manure are observed to be higher than those obtained from the cow dung manure from day two (2) to day ten (10) after which that of cow dung becomes higher than the poultry manure and increases rapidly as shown in Figure V. However, the average energy content of methane CH_4 obtained from cow dung manure (1.195kJ/day) is higher than the average energy content of methane CH_4 obtained from poultry manure (1.065kJ/day).

Table 6: Daily energy content of methane

Days	Poultry manure (kJ)	Cow dung (kJ)
1	0.00	0.00
2	0.462	0.132
3	0.528	0.330
4	0.594	0.429
5	0.759	0.528
6	0.924	0.660
7	1.122	0.693
8	1.155	0.759
9	1.320	0.957
10	1.419	1.353
11	1.518	2.409
12	1.551	2.673
13	1.749	2.739
14	1.815	3.069
Average	1.065	1.195

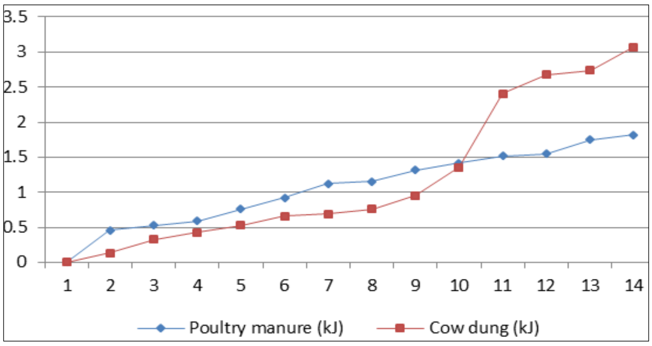

Fig 5: Daily energy values

5. Discussions

5.1 Theoretical implications

The average biogas production from cow dung ($0.195dm^3$/day) is higher than the average biogas production from poultry manure ($0.151dm^3$/day). This finding is in line win Henry *et al.* [23], who found that cow dung substrate is a better effective feedstock for biogas production. However, it is not in line with the findings of Alfa *et al.* [24], Ojolo *et al.* [25] and Alfa [26] who found the average biogas production of poultry droppings to be higher than cow dung before and after scrubbing.

Even though, the average volume of methane CH_4 content in

cow dung manure (0.0362dm^3/day) was observed to be higher than the average volume of methane CH_4 content in poultry manure (0.0323dm^3/day), the percentage of methane CH_4 in poultry biogas was higher than that of the cow dung biogas (21.36 percent against 18.60 percent), which is not in line with the findings of Alfa [26]. This was due to the fact that there was more impurities in cow dung biogas than the poultry biogas (41.09 against 37.71 percent). The high volume of methane produced by cow dung biogas have a small percentage of methane indicates that the quality of methane produced by poultry biogas is better than that of the cow dung biogas even though the volume may be smaller. This finding not in line with the findings of Alfa *et al.* [24], and Alfa [26] who found cow dung to have a better cooking rate than poultry dropping biogas for both scrubbed and un scrubbed gas.
However, the average energy content of methane CH_4 obtained from cow dung manure (1.195kJ/day) is higher than the average energy content of methane CH_4 obtained from poultry manure (1.065kJ/day) even though the poultry manure showed higher energy values in the first ten (10) days.

5.2 Managerial implications

Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. It has been estimated that Nigeria produces about 227,500 tons of fresh animal waste daily. Since 1 kg of fresh animal waste produce about 0.03 m^3 biogas, then Nigeria can potentially produce about 6.8 million m^3 of biogas every day from animal waste only [27]. A recent study that assessed Nigeria's biogas potentials (minimum value) from solid waste and livestock excrements revealed that in 1999, 10 Nigeria's biogas potential represents a total of 1.382 x 10^9 m^3 of biogas/year or an annual equivalent of 4.81 million barrels of crude oil [25]. In addition, 20 kg of municipal solid waste (MSW) per capita has been estimated to be generated in the country annually [27]. By the 2006 census figure of about 140.4 million inhabitants, the total generated MSW will be at least 2.81 million tons every year. With increasing urbanization and industrialization, the annual MSW and animal waste generated will continue to increase. Biogas production may therefore be a profitable means of reducing or even eliminating the menace and nuisance of urban wastes and animal wastes in many cities in Nigeria.

6. Conclusions

The determination and comparison of the energy contents of methane obtained from biogas of cow dung manure and that of poultry manure has been carried out using the biodigester. Biogas is a renewable energy source because its production and use cycle is continuous, and it generates no net carbon dioxide. It is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amount of hydrogen sulphide (H_2S), moisture and siloxanes. The gasses methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen and the energy released is used as fuel, used for heating purpose, like cooking or in gas engine to convert the energy in the gas into electricity and heat. Biogas can also be compressed, the same way as natural gas is compressed to CNG, and used to power motor vehicle. From our result, the average biogas production from cow dung was higher than the average biogas production from poultry manure in line with Henry *et al.* [23]. While, the percentage of methane in poultry biogas was higher than that of the cow dung biogas due to higher percentage of impurities in cow dung biogas. In terms of the energy content, the average energy content of methane obtained from cow dung manure is higher than that of poultry manure even though the poultry manure showed higher energy values in the first ten (10) days. The biological reactions occurring during the digestion of organic matter in a biogas unit reduce the content of waste material by 30 – 60 percent and produce stabilized product (slurry) which can be used as a fertilizer or soil conditioner. However, aggressive odour could be removed, a greater number of pathogens could be reduced, and organic nitrogen could be converted to ammonia, thereby reducing environmental hazards. The by-product has various uses; it can be used as fertilizer, in fish production and in manufacturing of animal feeds. It does not retain the smell of dung nor does it attract flies. For biogas owners who do not have enough land to cultivate, slurry can be drained of excess water, dried singly or composted with other organic wastes and transported for use in a far off place. Farmers using bioslurry on their farm have benefits of improved soil. Also, slurry as feed for pigs, cattle and sheep has been shown on experimental basis to increase production. Therefore, government, private sectors and also individuals can harness this opportunity of producing methane so as to be used as fuel substitute of nonrenewable source of energy.

7. Limitations and recommendations

Some limitations are worth mentioning here. First, the sample size was actually small, which may not fully represent the actual case. However, more samples could allow the researcher to arrive at a more conclusive result. Second, this study used simple digester slurry from single substrate 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. Sasse *et al.* [28], has established that methane content of biogas depends to a significant extent on the nature of the feed material and succulent grass was the highest value about 70%. Previous biogas researches in Nigeria using succulent plants have been limited to water lettuce, water hyacinth, cassava leaves and *Eupatorium odoratum* [29, 30; 31, 32, 33]. Acoording to Akhila [34], there is no record of any research on the potential of *Cymbopogon citratus* (Lemon grass) which is more widely distributed in Nigeria than the other plants previously tested mostly found in the riverine regions of the country.

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9. References

1. Adejumobi IA, Adebisi OI, Oyejide SA. Developing small hydropower potentials for rural electrification. International Journal of Research and Reviews in Applied Sciences. 2013; 17(1):105-110.
2. Emodi VN, Yusuf SD, Boo KJ. The necessity of the development of standards for renewable energy technologies in Nigeria. Smart Grid and Renewable Energy. 2014; 5(11):259-274.
3. Ashnani MHM, Johari A, Hashim H, Hasani E. A source

of renewable energy in Malaysia, why biodiesel? Renew Sustain Energy Rev. 2014; 35:244-57. http://dx.doi.org/10.1016/j.rser.2014.04.001.

4. Shaari MS, Hussain NE, Ismail MS. Relationship between energy consumption and economic growth: empirical evidence for Malaysia. Business Systems Review. 2013; 2(1):17-28.
5. Faisal F, Tursoy T, Ercantan O. The relationship between energy consumption and economic growth: Evidence from non-Granger causality test. Procedia Computer Science. 2017; 120:671-675.
6. Kasperowicz R. Electricity Consumption and Economic Growth: Evidence from Poland. Journal of International Studies. 2014; 7(1):46-57. DOI: 10.14254/2071-8330.2014/7-1/4.
7. Vafaeirad M, Mohammadiha M, Goodarzy Y. ENERGY Consumption and GDP in Selected Asian Countries: A Cointegrated Panel Analysis. Journal of Asian Scientific Research. 2015; 5(4):177-184.
8. Campo J, Sarmiento V. The relationship between energy consumption and GDP: evidence from a panel of 10 Latin American countries. Latin American Journal of Economics. 2013; 50(2):233-255. doi 10.7764/LAJE.50.2.233.
9. Aqeel A, Butt MS. The relationship between energy consumption and economic growth in Pakistan. Asia-Pacific Development Journal. 2001; 8(2):101-110.
10. Igbinovia SO, Orukpe PE. Rural Electrification: The Propelling force for Rural Development of Edo State, Nigeria. Journal of Energy in Southern Africa. 2007; 18(3):18-26.
11. Oji JO, Idusuyi N, Aliyu TO, Petinrin MO, Odejobi OA, Adetunji AR. Utilization of solar energy for power generation in Nigeria. International Journal of Energy Engineering 2012; 2(2):54-59. DOI: 10.5923/j.ijee.20120202.07.
12. Tajidin NE, Ahmad SH, Rosenani AB, Azimah H, Munirah M. Chemical composition and citral content in lemongrass (cymbopogon citratus) essential oil at three maturity stages. African Journal of Biotechnology. 2012; 11(11):2685-2693.
13. Wikipedia. Electricity generation by country, http://en.m.wikipedia.org/wiki/List_of_countries_by_electricity_production, 2017. [accessed 30 August 2018].
14. Yusoff S. Renewable energy from palm oil innovation on effective utilization of waste. Journal of Clean Production. 2006; 14(1):87-93.
15. Adaramola MS, Oyewole OM. Wind Speed Distribution and Characteristics in Nigeria. ARPN Journal of Engineering and Applied Sciences. 2011; 6(2):82-86.
16. Karki A. From Kitchen Waste to Biogas: An Empirical Experience. Biogas and Natural Resources Management, 2002, 75.
17. Ocwiela SL. Life Cycle Thinking Assessment Applied to Three Biogas Projects in Central Uganda. A MSc. dissertation submitted to school postgraduate studies. Michigan Technological University (unpublished), 2010.
18. Iwayemi A. Nigeria's Dual Energy Problems: Policy Issues and Challenges. International Association for Energy Economics. 2008; 53:17-21.
19. Bello Iman IB. The power and energy conundrum in Nigeria: which way forward. Yar'Adua's Seven-Point Agenda an Assessment, 2009, 20-49.
20. World Bank Databank. Access to electricity, www.worldbank.com, 2013. [accessed 11 September 2018].
21. Emodi NV, Yusuf SD. Improving electricity access in Nigeria: obstacles and the way forward. International Journal of Energy Economics and Policy. 2015; 5(1):335-251.
22. Sambo AS. Strategic developments in renewable energy in Nigeria. International Association for Energy Economics. 2009; 16(3):15-19.
23. Henry VI, Ani OI, Iloabachie ICC, Chime AC. A comparative study of characterized cow dung and poultry droppings as a substrates in biogas digester. International Journal of Advanced Engineering and Technology. 2018; 2(2):22-26.
24. Alfa IM, Dahunsi SO, Iorhemen OT, Okafor CC, Ajayi SA. Comparative evaluation of biogas production from poultry droppings, cow dung and lemon grass. Bioresource Technology. 2014; 157:270-277. doi: 10.1016/j.biortech.2014.01.108.
25. Ojolo SJ, Oke SA, Animasahun K, Adesuyi BK. Utilization of poultry, cow and kitchen wastes for biogas production: a comparative analysis. Iranian Journal of Environmental Health Science & Engineering. 2007; 4(4):223-228.
26. Alfa MI. Comparative study of biogas production from cow dung, chicken droppings and cymbopogon citratus as alternative energy sources in Nigeria. A MSc. Thesis submitted to the department of water resources and environmental engineering Ahmadu Bello University, Zaria, Nigeria (unpublished), 2013.
27. Mshandete AM, Parawira W. Biogas Technology Research in Selected Sub-Saharan Africa. African Journal of Biotechnology. 2009; 8(2):116-125, http://www.academicjournals.org/AJB.
28. Sasse L. Biogas Plants; a Publication of the Deutsches Zentrum für En twick lungs technologien - GATE in: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, 1988. http://www.gateinternational.org/documents/publications/webdocs/pdfs/g34bie.
29. Akinbami JFK, Akinwumi IO, Salami AT. Implications of environmental degradation in Nigeria. In Natural Resource Forum. 1996; 20(4):319-331.
30. Akinbami JFK, Ilori MO, Oyebisi IO, Akinwuni IO, Adeoti O. Biogas energy use in Nigeria: current status, future prospects and policy implications. Renewable and Sustainable Energy Reviews. 2001; 5(1):97-112.
31. Okagbue RN. Fermentation research in Nigeria.

MIRCEN Journal. 1988; 4:169-182.

32. Ubalua AO. Cassava wastes: treatment options and value addition alternatives. African Journal of Biotechnology. 2008; 6:2065-2073.
33. Odeyemi O. Biogas from Eupatorium odorantum, an Alternative Cheap Energy Source for Nigeria. Global Impacts of Applied Microbiology, 6th International Conference. 1981; 246-252.
34. Akhila A. Essential Oil-bearing Grasses: The genus Cynibopogon. Medical and aromatic plants-industrial profile. Taylor and Francis Goup, LLC, 2010.