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BIOGAS PRODUCTION FROM READILY AVAILABLE ORGANIC WASTES (COW DUNG, RAM DUNG AND CORN PEELS) AS A WASTE MANAGEMENT STRATEGY

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ABSTRACT Biogas production from readily available organic waste materials was evaluated in this study using individual and combined organic waste materials using anaerobic digestion. The study was for 28 days and biogas production was monitored by measuring the pressure. Results obtained showed that biogas production from cow dung and ram dung began on day 5 with gas volumes, 1.5 psi and 1.3 psi respectively and temperature of 29˚C. Corn peels began on day 4 with gas volume 0.5 psi, while integrated began on day 6 with gas volume 0.6 psi.and temperature of 28˚C The result also indicated that temperature was a major contributing factor of the fluctuations noticed in the daily biogas yield for the period of 28 days with peak biogas production occurring on day 20 in all the wastes which had the highest temperature of 35˚C. The integrated (co-digestion) showed the highest cumulative biogas yield of 142.9 psi equivalent to 82573.68m, followed by corn peels with biogas yield volume of 134.3 psi, cow dung of 129.8 psi and ram dung which produced the lowest volume of biogas at 92.1 psi equivalent to 47111.8m. Biogas production from the organic substrates is all positively correlated with one another, even though with varying degrees. It is therefore recommended that for an effective optimal production of biogas for use as a sustainable energy source which eliminates organic waste pollution from both rural and urban communities, co-digestion should be performed to improve the performance of the anaerobic digester. Proper sensitization of the public on the production potentials of biogas should be done in order to help drastically reduce or eliminate the adverse effects of these organic wastes on our environment. It will also help to encourage the use of renewable energy, which is a cleaner and more sustainable form of energy than fossil fuels.

Keywords**:** Anaerobic digestion, Biogas, Environment, Fossil fuels, Organic wastes, Pollution

INTRODUCTION

Globally, there has been a massive interest in sustainability and reduction of environmental wastes. As far back as the 1800's, several studies have implicated the importance of recycling environmental wastes to reduce pollution and its accompanying adverse effects on the ecosystem all around the world. Studies have shown that as at 2018, more than 30% of the world's environmental waste can be recycled for various uses (EPA, 2021). In addition, the use of fossil fuels and dirty energy sources has been a growing concern around the world. From the early discovery of crude oil and its variants, the world has relied on energy sources that are unsustainable and pose adverse effects on the environment. Due to increased population growth, there has been a continuous increase in energy demands which has posed a serious problem worldwide. Aibuedefe and Aisien (2020) stated that this problem is more pronounced in both underdeveloped and developing countries of the world, where the social-economic situations are very low. Aside, increased energy demand, population growth has led to high rate of waste generation making wasting management a global priority. Sustainable waste management not only focuses on removal of wastes from the environment but also how to make such wastes to be useful (Njoku and Ezego, 2021).

The United Nations Sustainable Development Goal (SDG) number 7 is targeted at provision of affordable, reliable and modern energy services for everyone. It also aims at increasing substantially the share of energy mixed at regional and global level with renewable energy sources (Calzadilla and Mauger, 2018; Ajao *et al.*, 2021). The need for renewable energy sources has been recognized as being efficient, economical and environmentally friendly globally (Chukwuma *et al.*, 2021). There is an urgent need for energy to carry out daily activities such as, lighting, heating and running of machineries; the need of energy for purposes, according to (Onwukeme *et al.*, 2017), has already been a problem to man since primitive man first discovered fire. Lack of infrastructures for energy generation, transmission, distribution, unavailability of nonrenewable energy sources such as fossil fuels, low technology for energy conversion from renewable energy sources, lack of funds for the purchase of fossil fuels, infrastructural and technological developments in energy sectors have been implicated in the near energy crisis in most underdeveloped and developing countries (Aisien, *et. al.*, 2010; Kwasi-Effah *et. al.*, 2015). Also, the increasing global awareness and concern about the environmental impacts of fossil fuels, have lent enormous weight to a switch to renewable energy sources (Akinbami *et al*, 2001). With this background in mind, one of the newer sources of energy that could provide a more sustainable energy source is biogas as biogas production from organic waste is one way to meet energy requirement and achieve waste disposal management (Okoro *et al* 2020).

Biogas is a non-toxic, colourless combustible gas produced by the decomposition of organic matter (Biodun *et al* 2021). It is from organic materials like human wastes, biomass, cow dung, green waste and agricultural residues such as cassava, sugar cane, etc (Deressa *et al* 2015). Biogas production is cheap, renewable and viable solution to providing energy to rural communities. It offers smallholders and farmers a long-term, cheap and sustainable energy source that is independent of national grid (Muvhiiwa *et al* 2017). The technology involved in biogas production is fairly simple and can be implemented cheaply and efficiently by means of small-scale digesters that are easy to use and maintain (Muvhiiwa *et al* 2017). Biogas can be upgraded to biomethane, suitably used as a vehicle fuel or injected into national gas grid (Paolini *et al* 2018). Biogas can enhance energy security due to its high energetic potential. Biogas has been used in several sectors and for numerous purposes such as; fuel in electricity generation, combined heat and power plants, waste management in agriculture, cooking fuel as a sustainable energy source, clean renewable fuel for transport vehicles, biogas fuel cell and injection into a natural gas pipeline (Makadi *et al.,* 2012; Muvhiiwa *et al.,* 2017).

Production of biogas from waste reduces waste load in the environment (Tiepelt, 2015). Biogas production from organic waste also reduces the depletion woody biomass contributing to increased carbon sequestration. It is one of the biological methods of waste management and also a waste to wealth strategy. Proper understanding of the processes of biogas production will also assist to reduce the cost of domestic gas, reduce production of greenhouse gases and thus assist in reducing global warming. The main objective of biogas industry is the reduction of fossil fuel consumption and ultimate goal of mitigating global warming (Paolini *et al* 2018). Biogas production from organic waste is helpful in waste management and assists in ameliorating energy crises. Biogas technology offers environmental advantages; it depletes greenhouse gas (GHG) emission, improves energy protection and it is a viable sources of renewable energy (Biodun *et al* 2021).

Many underdeveloped and developing countries of the world such as Nigeria, have also joined the global trend on the utilization of renewable energy, although, many people are yet to fully stand a ground on this. It has been stated that Nigeria is endowed with an abundance of organic waste resources which includes; crops, forage grasses and shrubs, animal waste arising from forestry, agriculture, municipal and industrial activities, as well as, aquatic biomass (Olanrewaju *et al.*, 2019). Crops such as sorghum, maize, sugarcane were the most promising feedstocks for biofuel production (Nnaji *et al.*, 2010). In Nigeria, identified feedstock substrates for an economically feasible biogas production include water lettuce, water hyacinth, animal dung, corn and cassava leaves, urban refuse, agricultural residues and sewage (Akinbam, 2001). According to Ezeugwu, (2015), it has been estimated that Nigeria produces about 227,500 tons of fresh animal waste daily. This suggests Nigeria can potentially produce about 6.8 million m^3 of biogas every day from animal waste only since 1kg of fresh animal waste produces about 0.03 m^3 biogas. This in terms of energy is equivalent to about 3.9 million liters of petroleum (Ozor *et al.*, 2014). Biogas use has the capability of providing a special impetus in both rural and urban areas. However, biogas plants can be built by using materials which are locally available in most developing countries like Nigeria (Esan, 2008).

MATERIALS AND METHODS

Source of Materials

The organic animal wastes - cow and ram dung were collected from a cattle ranch in Ajah, Lagos Nigeria. They were both fresh samples, less than 24hrs old. The organic plant waste - fresh corn peels were obtained from a refuse dump near a corn seller, along Lekki road, Lagos Nigeria, while the containers used in the local construction of the anaerobic digester was obtained from a refuse dump in Lekki market, Lagos Nigeria.

Construction of Anaerobic Digester

The anaerobic digester model used in this study was constructed using waste dispenser bottles. Four 18.9 liters capacity waste dispenser bottles were used to construct a local anaerobic digester following description of (Ona *et al.*, 2019) and the description of Makadi *et al.,* (2012). The digester construction model used for this study was the "floating drum" design as described by Rajendran *et al.*, (2012). The digesters each consisted of a water inlet pipe used in feeding the digester, a water outlet tap where the slurry is taken out and a gas outlet pipe for collecting the biogas produced (Makadi *et al.*, 2012). A pressure-gauge was fixed at the top of the setup to measure the amount of biogas produced per day.

Preparation of Organic Waste Materials

The preparation process of the organic wastes feedstock used in this study was according to (Ona *et al*, 2019). Six kilogram (kg) of each of the feedstocks were weighed and mixed with equal proportions of water. The corn peel was cut into smaller sizes and mashed using mortar and pestle to reduce its particle size before it was mixed with equal proportions of water. Each waste was properly mixed with water using wooden spatula. The mixtures were poured into separate labelled digester containers.

Each digester was filled to 1/3 of its capacity with corresponding feedstock. During this process, the water outlet tap was locked to avoid leakage of the digester components. The fourth digester, which was for co-digestion of all three organic waste substrates, comprised 2kg of each substrate, making a total of 6kg and equal volume of water before pouring it into its labelled digester. The digester inlet pipe was then sealed to avoid the escape of gases and exchange of air from the surroundings in all four set-ups and then left for 28 days for anaerobic digestion to take place. A summary of parameters for the anaerobic digestion is shown in Table 1.

Table 1: Summary of materials for anaerobic digestion of waste samples

Items	Cow Dung	Ram Dung	Corn Silage	Integrated waste
Mass of Waste used (Kg)	6.0	6.0	6.0	6.0
Mass of Water used (Kg)	6.0	6.0	6.0	6.0
Total Mass of Slurry (Kg)	12.0	12.0	12.0	12.0
Duration of Digestion (Days)	28.	28	28	28
Volume of Digester (L)	18.9	18.9	18.9	18.9

Determination of Volume of Biogas

The digester set-up was observed every day for 28 days retention time. Daily readings of biogas produced were taken. This was done by recording the reading on the pressure gauge fixed at the top of the digester. 1psi =573.8268meter of air

Statistical Analyses

Data obtained from the volume of biogas produced from each of the organic waste substrates was subjected to inferential statistics (correlation) and Analysis of Variance (ANOVA) at 95% confidence interval using Microsoft Excel 2013, GraphPad Prism 9.0 and Past software. Hierarchical cluster analysis was also performed using Dendrogram.

RESULTS

Biogas Production from Cow Dung Waste

The biogas production by cow dung started on the 5^{th} day of the study with 1.5psi of biogas produced (Table 2). The highest volume of biogas (8.0psi) was produced on days 20 and 22. There was a general increase in the volume of biogas produced daily until day 22 when the volume of biogas produced started reducing. The highest increment of the biogas produced occurred on day 20 where there was 1.5psi increment and the least increment occurred on 26 with -2.0 increment. The cumulative biogas produced on day 28 was 129.3psi. Biogas production by cow dung had a positive correlation with biogas production by ram dung and corn peel (r = 0.98) and combined wastes (r = 0.96)

Table 2: The Biogas Production (psi) from Cow Dung

Day	Temperature (˚C)	Daily Biogas Production (psi)	Increment	Cumulative Daily Biogas Production (psi)
1	30	0.0	0.0	0.0
2	31	0.0	0.0	0.0
3	29	0.0	0.0	0.0
4	29	0.0	0.0	0.0
5	29	1.5	1.5	1.5
6	28	2.0	0.5	3.5
7	29	3.0	1.0	6.0
8	30	3.5	0.5	9.5
9	29	3.9	0.4	12.4
10	31	4.0	0.1	16.4
11	32	4.5	0.5	20.9
12	31	4.9	0.4	25.8
13	30	5.0	0.1	30.8
14	30	4.5	-0.5	35.8
15	32	5.5	1.0	40.6
16	31	6.0	0.5	46.8
17	31	6.0	0.0	52.8
18	28	6.5	0.5	59.3
19	28	6.5	0.0	65.8
20	35	8.0	1.5	73.8
21	26	7.5	-0.5	81.3
22	33	8.0	0.5	89.3
23	32	7.5	-0.5	96.8
24	30	7.5	0.0	104.3
25	30	7.5	0.0	111.8
26	29	5.5	-2.0	117.3
27	30	6.0	0.5	123.3
28	30	6.0	0.0	129.3

Biogas Production from Ram Dung Waste

Biogas production by ram dung is shown in Table 3. Ram dung started biogas production on the 5th day of the study with 1.3psi of biogas. The highest volume of biogas (6.0 psi) was produced on the 20th and 22nd days of the study. The daily production of biogas increased on different days during the study with the highest increment occurring on day 20 (1.5psi) and least increment (-1.0psi) occurring on day 21. The total cumulative biogas production was 92.1psi on day 28. Biogas production by ram dung had positive correlation with cow dung (r =0.98), corn peels (r = 0.97) and combined wastes (r = 0.92)

Table 3: The Biogas Production (psi) from Ram Dung

Day	Temperature (˚C)	Daily Biogas Production (psi)	Increment	Cumulative Daily Biogas Production (psi)
1	30	0.0	0.0	0.0
2	31	0.0	0.0	0.0
3	29	0.0	0.0	0.0
4	29	0.0	0.0	0.0
5	29	1.3	1.3	1.3
6	28	1.5	0.2	2.8
7	29	1.5	0.0	4.3
8	30	1.9	0.4	6.2
9	29	3.0	1.1	9.2
10	31	2.0	-1.0	11.2
11	32	2.5	0.5	13.7
12	31	2.9	0.4	16.6
13	30	3.5	0.6	20.1
14	30	3.5	0.0	23.6
15	32	4.0	0.5	27.6
16	31	4.0	0.0	31.6
17	31	4.5	0.5	36.1
18	28	4.5	0.0	40.6
19	28	4.5	0.0	45.1
20	35	6.0	1.5	51.1
21	26	5.0	-1.0	56.1
22	33	6.0	1.0	62.1
23	32	5.5	-0.5	67.6
24	30	5.0	-0.5	72.6
25	30	5.0	0.0	77.6

26	29	4.5	-0.5	82.1
27	30	5.0	0.5	87.1
28	30	5.0	0.0	92.1

Biogas Production from Corn Peel Waste

The daily production of biogas by the corn peel waste started on day 4 with 0.5psi of biogas produced (Table 4). The same volume of biogas was produced on day 5 and subsequently the volume of biogas produced varied in the different days. The highest volume of biogas (9.0 psi) was produced on 20 after which daily biogas production reduced until it got to 6.0 psi on days 26, 27 and 28. The highest daily increment in biogas production occurred on day 20 in which biogas production increased from 7.0 psi on day 19 to 9.0 psi while the least increment occurred on day 21 with -1.5 psi increment. The total cumulative biogas produced by corn peel waste was 135.3 psi on day 28. Production of biogas by corn peel waste had a positive correlation (r = 0.97) with ram dung and combined wastes and with cow dung (r = 0.98)

Table 4: The Pressure of Biogas (psi) produced from Cow Dung

Day	Temperature (˚C)	Daily Biogas Production (psi)	Increment	Cumulative Daily Biogas Production (psi)
1	30	0.0	0.0	0.0
2	31	0.0	0.0	0.0
3	29	0.0	0.0	0.0
4	29	0.5	0.5	0.5
5	29	0.5	0.0	1.0
6	28	1.5	1.0	2.5
7	29	2.0	0.5	4.5
8	30	2.9	0.9	7.4
9	29	3.5	0.6	10.9
10	31	4.0	0.5	14.9
11	32	4.5	0.5	19.4
12	31	5.0	0.5	24.4
13	30	5.5	0.5	29.9
14	30	5.9	0.4	35.8
15	32	6.0	0.1	41.8
16	31	6.5	0.5	48.3
17	31	7.5	1.0	56.8
18	28	7.0	-0.5	63.8

19	28	7.0	0.0	70.8
20	35	9.0	2.0	79.8
21	26	7.5	-1.5	87.3
22	33	8.0	0.5	95.3
23	32	7.5	-0.5	102.8
24	30	7.5	0.0	110.3
25	30	7.0	-0.5	117.3
26	29	6.0	-1.0	123.3
27	30	6.0	0.0	129.3
28	30	6.0	0.0	135.3

Biogas Production from Co-digestion of Organic Wastes

Production of biogas by the mixture of the different organic wastes started on day 6 with 0.5psi biogas (Table 5). Daily biogas production was highest on day 20 where 8.5psi volume of biogas was produced. The daily increment in the biogas production was highest on day 7 with 3.0psi increment and was least on day 21 and day 26 with -1.0 psi increment. The cumulative volume of biogas produced by the mixture of the organic wastes was 143.90psi on day 28. Temperature of the digester fluctuated with the period of the study and was slightly positively correlated with biogas production by the mixture of the organic wastes (r = 0.28).

Table 5: The Pressure of Biogas (psi) produced from Combined Organic Wastes

Day	Temperature(˚C)	Daily Biogas Production (psi)	Increment	Cumulative Daily Biogas Production (psi)
1	30	0	0.0	0.0
2	31	0	0.0	0.0
3	29	0	0.0	0.0
4	29	0	0.0	0.0
5	29	0	0.0	0.0
6	28	0.5	0.5	0.5
7	29	3.5	3.0	4.0
8	30	4.5	1.0	8.5
9	29	4.5	0.0	13.0
10	31	5.0	0.5	18.0
11	32	5.5	0.5	23.5

12	31	6.0	0.5	29.5
13	30	6.5	0.5	36.0
14	30	6.0	-0.5	42.0
15	32	6.9	0.9	48.9
16	31	7.0	0.1	55.9
17	31	7.5	0.5	63.4
18	28	8.0	0.5	71.4
19	28	8.0	0.0	79.4
20	35	8.5	0.5	87.9
21	26	7.5	-1.0	96.4
22	33	8.0	0.5	104.4
23	32	7.5	-0.5	111.9
24	30	7.5	0.0	119.4
25	30	7.0	-0.5	126.4
26	29	6.0	-1.0	132.4
27	30	6.0	0.0	138.4
28	30	5.5	-0.5	143.9

Relationship between Temperature and Biogas Produced by the Different Substrates.

Temperature fluctuation had 26% influence on biogas production by the animal dungs and the integrated (combined) wastes and 30% influence on biogas production by corn peel (Figure 1). Biogas production by the combined wastes had 96% positive relationship with biogas production by cow dung, 92% relationship with biogas production by ram dung and 97% relationship with biogas production by corn peel.

The ANOVA result shows that the gas produced on day 1 is statistically significant from that produced on day 20 at p = < 0.0001.

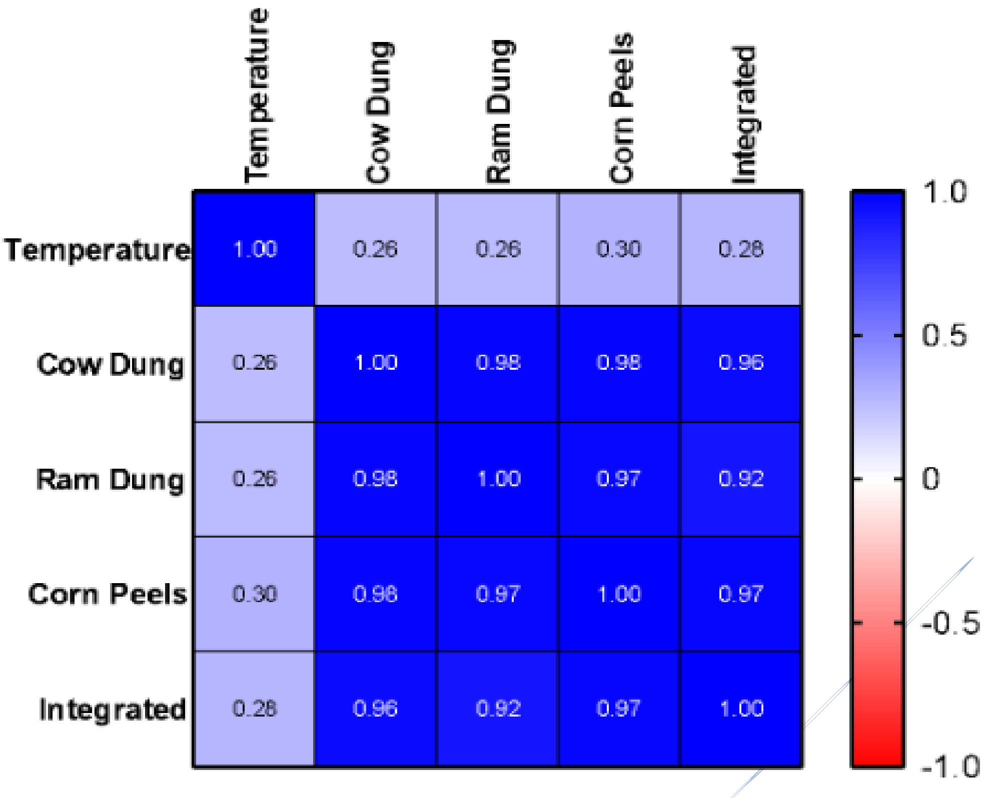
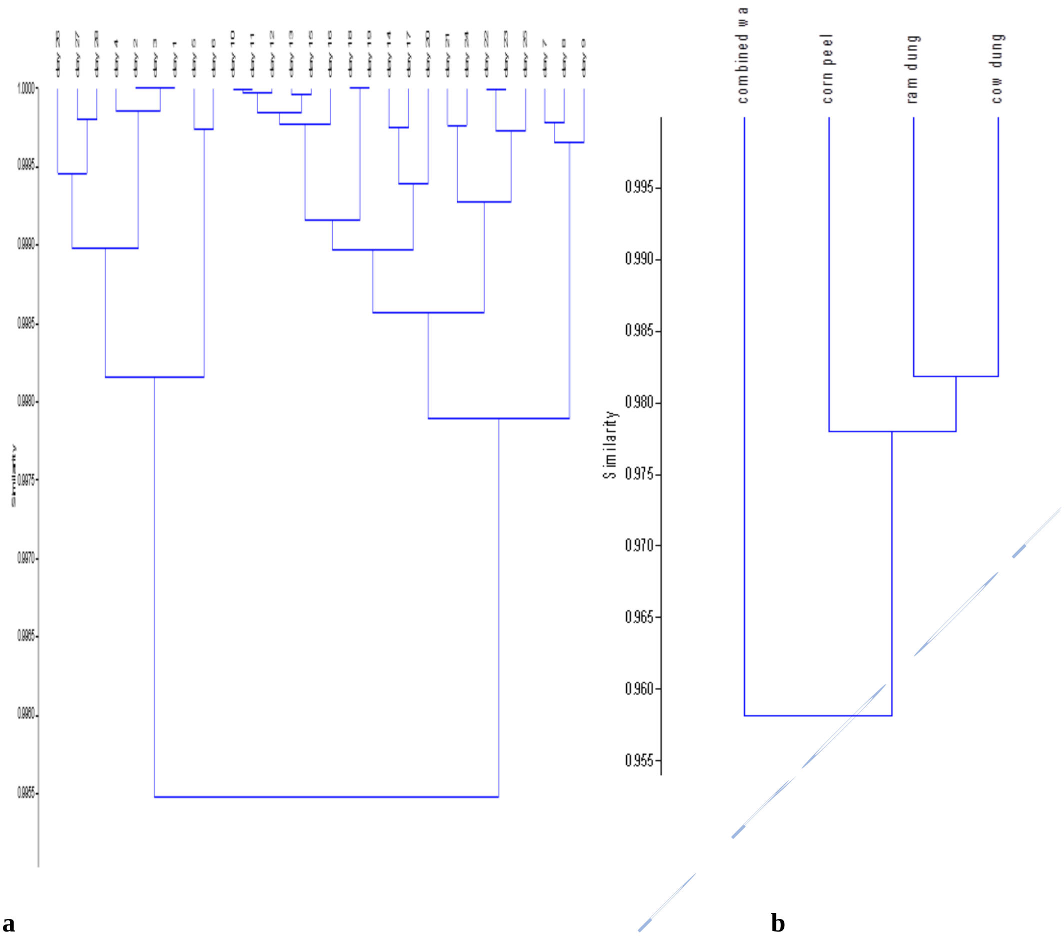


Figure 1: Correlation (HEATMAP) of temperature and biogas from cow dung, ram dung, corn peels and integrated wastes.

Cluster Analysis

The similarity among the biogas levels produced in the different days and that among the bases from the different substrates are shown figure 2. The biogas produced in the different days form two major clusters (Figure 2a), the first group was made up of day 26, day 27, day 28, day 4, day 3, day 2, day 1, day 5 and day 6. The second group of the cluster analysis contains all the other days. The amounts of gases produced on day 2, day 3 and day 1 were similar, although they share similarities with day 4, but day 4 conditions has a slight deviation from them. Day 10 and day 11 are on the same similarity level, day 18 and 19 are on the same level, day 22 and day 23 are on the same level.

The biogas produced from the combined wastes had 95.7% .level of similarity with the biogas produced by the other (Figure 2b). The biogas produced by ram dung and cow dung have the closest level of similarity (98.25%)



a b

Figure 2: Dendrogram showing the results of cluster analysis of the biogas produced on different days. (a = similarity of biogas produced at different days; b = biogas produced by the different substrates)

DISCUSSION AND CONCLUSION

DISCUSSION

Waste has become an increasingly serious issue in the twenty-first century as a result of rising global population, urbanization, and industrialisation (Feo *et al.,* 2019). As people's incomes rise, so does the amount of rubbish they generate (Malinauskaite *et al.,* 2017), and worldwide solid waste creation is anticipated to triple by 2100 (Hoornweg, 2013). This issue is especially evident in emerging and undeveloped nations, where social and economic conditions are relatively poor (Aibuedefe and Aisien, 2020). However, in the case of organic wastes, these so-called wastes may be repurposed or recycled into other valuable goods such as a clean and sustainable energy source or soil nutrients. Globally, the demand for renewable energy sources has been acknowledged as efficient, cheap, and ecologically benign (Owusu and Asumadu, 2016). As a result, its adoption is critical.

The results of this study indicates that biogas can be generated from all the organic waste samples used for this study (cow dung, ram dung and corn peels). All samples had their highest volume of biogas generated on day 20 of anaerobic digestion at the highest mesophilic temperature of 35˚C. This result conforms with the works of Chae *et al.,* (2008); and Choorit and Wisarnwan, (2007) which show that optimum biogas production occurs 35˚C. However, the volumes of biogas produced at this mesophilic temperature in all digesters were different which show the differences in the potentials of the different organic waste to produce biogas.

According to Murphy *et al.,* (2011), different organic substrates generate different volumes of biogas irrespective of the digestion temperature. This is due to the variation in composition of the wastes. This explains the reason the organic wastes had different volumes of biogas generated at day 20 where they had peaked and temperature condition is most favourable. According to Makadi *et al.,* (2012), plant waste substrates are rich in carbon while animal waste substrates (dungs) are rich in nitrogen. A combination of this carbon and nitrogen organic waste sources increases the production of biogas in any co-digestion design (Avicenna, 2015; Harryanto *et al.,* 2017). This could be the reason the co-digestion had the highest cumulative biogas yield. The digester with corn peel waste has the second highest cumulative biogas yield and such could be due to the high carbon content of corn and as was stated by Harryanto *et al.*, (2017), methanogenic bacteria need carbon in order to function optimally. Cow dung and ram dung both produced lower volumes of biogas. However, ram dung produced much lesser volume than cow dung and it produced the least volume of biogas compared to other substrates. This result is in contrary to the work by (Adamu, 2014), where ram dung produced the highest volume of biogas in comparison with other organic substrates. The substrate composition of the wastes could also be the reason the integrated (co-digestion) digester showed a noticeable biogas yield on day 6, unlike cow and ram dung which started the yield early enough on day 4, while corn peels started its biogas yield on day 5.

The total amount of biogas generated from the organic wastes substrates equates to 499.1 psi from a total of 24 kilogram of organic waste materials. This means that for a developing country like Nigeria, with a lot of wastes clogging around the streets and polluting the environment, this can be beneficial. According to Ngumah *et al.,* (2013), Nigeria generates about 542.5 million tons of organic wastes per annum, which in turn has the potential of yielding about 25.53 billion m^3 of biogas (about 169 541.66 MWh) and 88.19 million tons of biofertilizer per annum. Both have a combined estimated value of about N 4.54 trillion ($ 29.29 billion). Slurry (digestate) produced as a byproduct of anaerobic digestion of organic wastes has been shown to significantly enhance soil quality and boost crop yield (Makadi *et al*, 2012). This slurry contains all of the nutrients required for agricultural crops to operate properly, such as mineral nitrogen in the ammonium form. As a result, agricultural yield and food production for the population will increase.

Temperature control is an important consideration when designing digest (Uzodinma *et al* 2007) and according to Wang *et al* (2019), moderate temperatures above 25˚C are more conducive to high biogas production efficiency. Also, temperature conditions of 30-40˚C have been generally adopted for anaerobic digestion of agricultural organic waste and good performance for biogas production (Cai *et al* 2004; Cho *et al* 2013). In this study, the temperature generally fluctuated between 28˚C and 35˚C

The high level of correlation among the biogas produced by different organic wastes show that the organic wastes used for this study produced biogas in similar manner. The result of cluster analysis shows that days closer to each other on the cluster plot produced similar effects during biogas production. Correlation analysis of the samples show a positive correlation across all samples. Corn peels higher positive correlation with cow dung (r = 0.98), than with ram dung (r = 0.97) and integrated (co-digested) (r = 0.97) show that the high biogas yield in the co-digested substrates was due to the synergistic effect of both cow dung and corn peels present in the integrated digester (co-digestion). Cluster analysis for day 2, day 3 and day 1 with the Euclidean distance on the Dendrogram show they have a closer similarity than any other days and produced similar effects during biogas production. This is the same case with day 10 and day 11, day 18 and day 19, day 22 and day 23.

CONCLUSION

This study shows that the generation of biogas from organic wastes is an efficient method of dealing with organic wastes that contaminate the environment. Cow dung, ram dung and corn peels all have good biogas production potential. All waste samples showed the highest biogas yield at the optimal mesophilic temperature of 35^0C, however, the amount of biogas yield at this temperature varied across the samples. This was attributed to the difference in substrate composition of the organic wastes used. Co-digestion of substrates with high cumulative volume of biogas indicates that co-digestion is a suitable way of optimizing biogas production from anaerobic organic waste samples. High cumulative total volume of biogas generated from all the wastes suggests that the selected organic waste materials are potential raw materials for a renewable, cleaner and safe energy. To help dramatically minimize or eliminate the negative impacts of these organic wastes on our environment, proper public sensitization on the production potentials of biogas from organic wastes should be done.

RECOMMENDATION

From the results obtained in the research, it is thereby recommended that;

i. Biogas production from organic wastes has proven to be a good means of eliminating the health and environmental effects that arises from them and also keeping our ecosystem clean. It is also a viable source of clean and renewable energy source that can help in providing man with insatiable energy needs. Although, many people are not aware of what they can do with these wastes which are generated and discarded on a daily basis where they cause serious health and environmental issues. It is therefore recommended that sensitization of the public on this growing technology would go a long way.

ii. Due to the high yielding effect of co-digestion of organic plants and animal wastes, it is recommended that co-digestion should be applied as a strategy to optimize biogas generation.

iii. Asides temperature and type of organic substrate, other factors such, operational pH, organic loading rate and hydraulic retention duration all have an impact on the volume of biogas generated through anaerobic digestion. However, these were not considered in this study. It is therefore recommended that subsequent studies should look into these parameters.

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