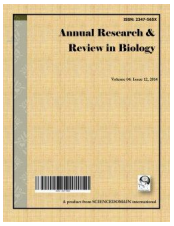

Annual Research & Review in Biology

13(4): 1-9, 2017; Article no.ARRB.29459
ISSN: 2347-565X, NLM ID: 101632869

Biogas Generation from Co-digestion of Four Substrates; Water Hyacinth, Cassava Peels, Poultry Droppings and Cow Dung

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Authors' contributions

The work was carried in collaboration between all authors. Author AEBE designed the study, wrote the protocol and interpreted the data. Author EJ anchored the field study, gathered the initial data and performed preliminary data analysis. Authors AB and DRT managed the literature searches and produced the initial draft. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/29459
Editor(s):
(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Ify L. Nwaogazie, University of Port Harcourt, Nigeria.
(2) Olugbemide Akinola David, Auchi Polytechnic, Auchi, Edo State, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/19453

Original Research Article

Received 12th September 2016
Accepted 6th October 2016
Published 10th June 2017

ABSTRACT

Generation of biogas by a combination of four substrates of water hyacinth (*Eichhornia crassipes*), cassava (*Manihot esculentum*) peels, poultry droppings and cow dung was investigated using anaerobic digester and gasometric chamber to determine the level of production. Total viable bacterial counts in the combination were 7.86 $X10^7$, 5.45 $X10^5$ $cfuml^{-1}$ before and after digestion respectively while fungal counts were 2.45 $x10^2$, 3.35 $X10^4$ $cfuml^{-1}$ before and after digestion respectively. The combination of the four substrates, yielded biogas of 815 mls, 875 ml and 1340 mls from respective weights of 1 kg, 2 kg and 3 kg within 15 days without starter culture while with starter culture biogas yield within 15 days was 840 mls 1170 mls and 1690 mls from the 1 kg, 2 kg and 3 kg weights respectively. Total biogas yield obtained without starter culture was 4355 mls, 5325 mls and 6700 mls from the 1 kg, 2 kg and 3 kg weights respectively and 4865 mls,

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5935 mls and 7822 mls within 45 days with starter culture. Results, show that biogas volume vary significantly, [F(2, 16) = 14.93, P < 0.001] with and [F(2, 16) = 19.42, P < 0.001] without starter culture at the 1% level of significance due to weights. There was also significant difference [F(2,16) =16.45, P<0.001] with starter culture and [F(2,16)=25.05, P<0.001] without starter culture. Positive correlation was observed in biogas production with and without starter culture. There was evidence of synergy in the consortium of waste for biogas generation.

Keywords: Biogas; water hyacinth; cassava peels; poultry droppings; cowdungs.

1. INTRODUCTION

Two important challenges of the millennium and the twenty first century have been identified to include; the development and use of renewable energy to decrease dependence on fossil fuel and management of the waste generated by human activities as a result of agricultural activities, industrial growth and population explosion which are associated with waste generation [1,2,3,4,5,6]. It has also been asserted, that achieving the Millennium Development Goals (MDGs) in Africa also requires a significant expansion of access to modern and alternative renewable energy such as biogas which is of growing interest for the sustainable management of our waste and a major breakthrough in the search for a renewable energy for the reduction in over-dependence on non-renewable fossil fuel [7,8]. Biogas which is the product of organic matters decomposition under oxygen-free condition with microbial participation especially Methanogens stands out as a significant source of the much desired renewable energy. Biogas formation can occur naturally in swamps, marine sediments, and water logged soils, rice fields, deep bodies of water, sanitary landfills and even in the digestive system of ruminants; and termites. It can also be recovered from lagoons used for waste treatment. Biogas is also called; swamp gas, sewer gas, marsh gas, gobar gas and digester gas 'will O the wisp gas, natural gas, landfill gas and sewage gas. Biogas is a mixture of gasses consisting of methane 50 – 70%, carbon dioxide 30 – 40%, Hydrogen 5 – 10%, Nitrogen 1 – 2%, water vapour 0 – 3%, and traces of Hydrogen sulphide. It is colourless, relatively odourless and flammable; it is also stable and non-toxic. It burns with a blue flame and has a calorific value of 4500 – 6000 kcal/m^3 when its methane content ranges from 60 – 70% [3,8]. Generally, four different stages have been recognized in the production of biogas with several other intermediate products. These include; hydrolysis, acidogenesis, acetogenesis and methanogenesis. The efficiency, effectiveness and stability of anaerobic digestion and consequently biogas generation can vary significantly based on various operational factors such as; type of waste streams, digester design , temperature, moisture content, retention time, pH, agitation or mixing, bacterial species and organic loading rate. Presence of toxicants can also influence biogas production. Positive implications of biogas include; the reduction in environmental pollution, odour [9,10], and in the destruction of most pathogenic organisms, worms, ova, etc. Biogas can also serve as a clean alternative to fuel energy source to oil, electricity and wood. The negative implications of biogas technology include; concentration of toxic compounds such as pesticides and heavy metals in plants and ground water contamination [11] This research is aimed at determining the potentials of biogas energy generation from water hyacinth which is a nuisance in aquatic environment (blockage of waterways) and cassava peels, poultry droppings and cow dung which constitute nuisance in our environment (foul odour due to uncontrolled fermentation). These waste sources abound in Cross River State and other parts of Nigeria, thus raw material sourcing may not be a problem [12].

2. METHODS

2.1 Sample Collection

Use of four substrates combination- Water hyacinth + Cassava peels+ Poultry dropping + Cow-dung-WH+CP+PD+CD.

The four substrates; water hyacinth +cassava peels + poultry droppings + cow dung were mixed in the ratio of 0.25:0.25:0.25:0.25 kg; 0.5:0.5:0.5:0.5 kg and 0.75:0.75;0.75:0.75 kg weights to yield total weights of 1 kg, 2 kg and 3 kg respectively. Respective weights were mixed with water at the ratio of 1:3 and placed in the digesters. Duplicate of each weight was prepared, one without starter culture and the other with 1kg weight of starter culture from an old digester slurry mixed with charcoal. The

digesters were tightly corked with rubber stopper to create anaerobic condition and connected to a gasometrical chamber. Biogas was monitored and measured daily over a period of 45 days using the gasometrical chamber [13].

2.2 Preparation of Starter Culture

The method of [14], were used. The support activated carbon (charcoal) was washed 5 times with acetate buffer pH (4-5) and finally re-suspended in the buffer overnight. Twenty kilogram weights were placed in storage containers and kept at 10°C in a refrigerator. Twenty kilogram weight of the slurry (residue w/v) of an old but active cow dung digester was mixed with 20 kg weight of the pre -treated activated carbon and incubated at room temperature in anaerobic condition for 40 days. The adsorbed cells were used as crude starter culture for all digesting combinations.

The advantage of using the activated carbon as support for the immobilisation was that it was relatively cheap and affordable, readily available, mild and posses no problem of cell and enzyme inactivation.

2.3 Innovation in Digester Design with Gasometrical Chamber

Biogas yield was measured daily using the gasometrical chamber which was an innovation, specially designed for this research by [15]. The chamber consisted of a gasometrical assembly which comprised of a graduated burette which was connected to the locally designed anaerobic digester through a rubber tube. The burette was also connected to a funnel with paraffin oil through a synthetic rubber tube (which could be transparent). The burette was linked to the tube from the anaerobic digester by a glass connector with two taps; the inlet and the outlet taps. The outlet tap was sealed with a flexible plastic tube with a strong clip (to avoid leakage). The total biogas yields were determined by opening the outlet tap of the anaerobic digester and the inlet tap to the graduated burette. The biogas generated was released through the tube which then displaced the paraffin oil in the graduated burette downward. The volume of gas yield was determined by the volume of paraffin oil displaced, i.e gas yield was directly proportional to paraffin oil displaced (Figs. 1, 2 and 3).

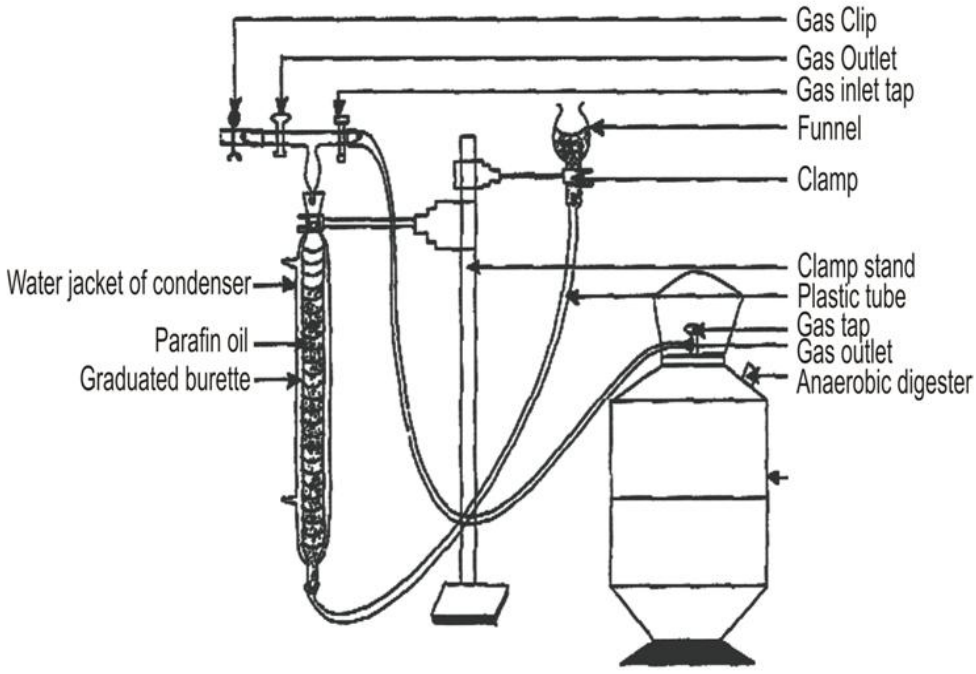

Fig. 1. Anaerobic digester and gasometric chamber assembly

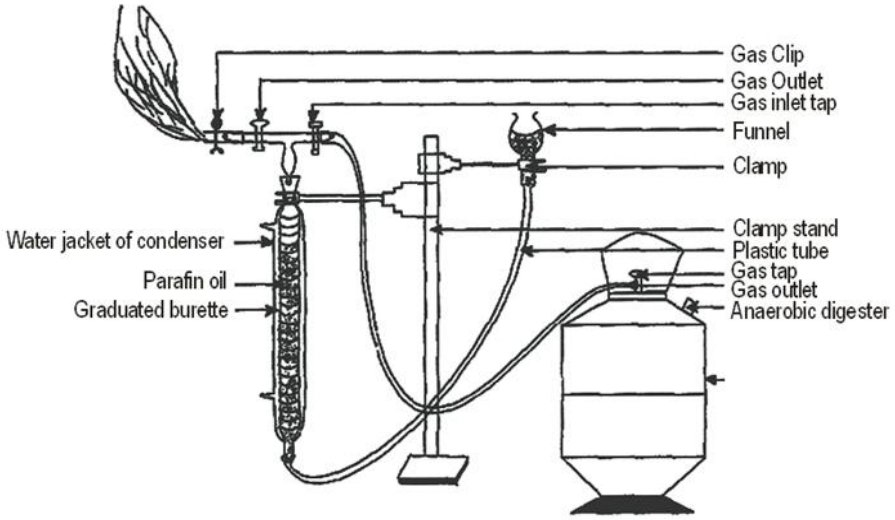

Fig. 2. Anaerobic digester and gasometric chamber assembly showing flammable gas

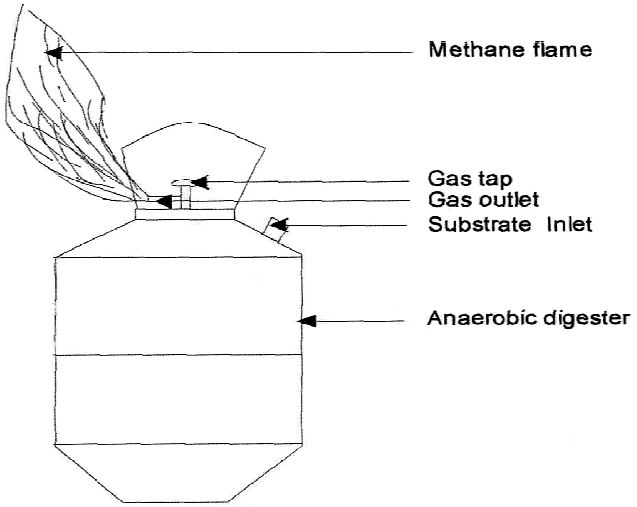

Fig. 3. Burning methane gas from anaerobic digester without gasometrical chamber

3. RESULTS

3.1 Potential of Biogas Yield from WH+CP+PD+CD

In the combining the four substrates WH + CP + PD + CD, optimum biogas yield of 815 mls, 875 ml and 1340 mls was obtained from respective weights of 1 kg, 2 kg and 3 kg within 15th day without starter culture while with starter culture optimum biogas within 15 days was 840 mls 1170 mls and 1690 mls from the 1 kg, 2 kg and 3 kg weights respectively (Fig. 4). Total biogas yield obtained without starter culture was 4355 mls, 5325 mls and 6700 mls from the 1 kg, 2 kg and 3kg weights respectively and 4865 mls, 5935 mls and 7822 mls within 45 days with starter culture as shown in (Table 1). Fig. 5 shows percentage yield of 25.43% in the 1kg weight, 32.92% in 2 kg and 41.65% in the 3kg weights without starter culture while Fig. 5 shows percentage biogas of 24.760%, 32.24% and 43.00% the 1 kg, 2 kg and 3 kg weights from the combination of the four substrates with starter culture.

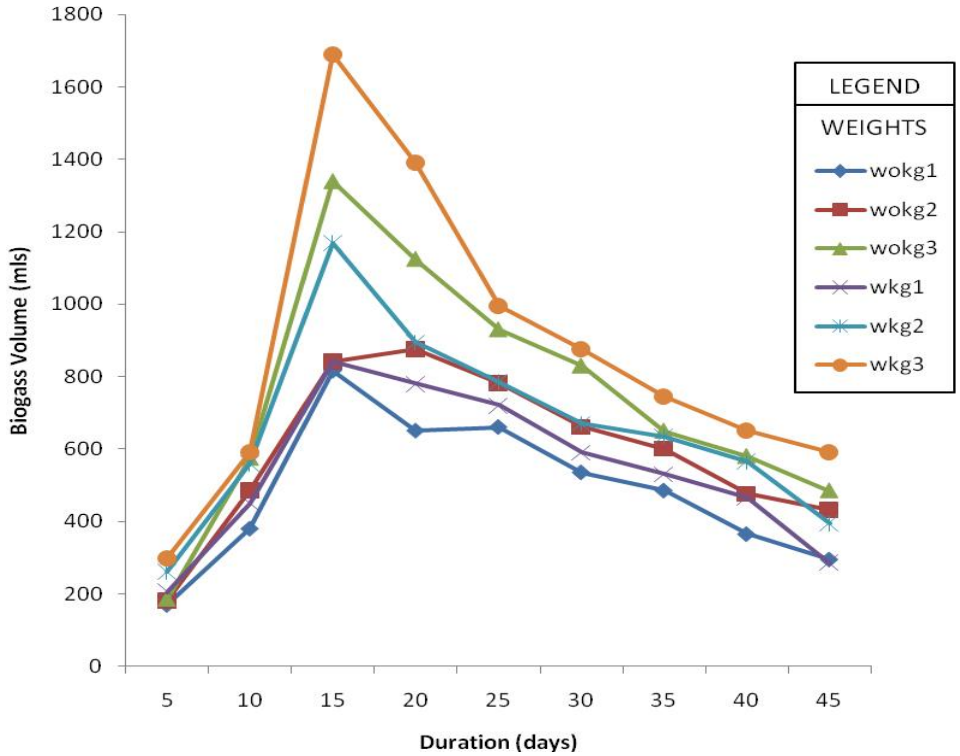

Fig. 4. Optimum biogas yield from WH+CP+PD+CD, with and without starter culture

Table 1. Total biogas yield from combination of water hyacinth, cassava peels, poultry droppings and cow dung- WH+CP+PD+CD with without starter culture (ml)

Digestion time (days)	Volume of biogas (mls/5 days)					
	Substrate weight without starter culture			Substrate weight with starter culture		
	1 kg	2 kg	3 kg	1 kg	2 kg	3 kg
5	170	180	185	205	260	297
10	380	485	575	450	560	590
15	815	840	1340	840	1170	1690
20	650	875	1125	780	895	1390
25	660	780	930	720	785	995
30	535	660	830	590	670	875
35	485	600	650	530	635	745
40	365	475	580	465	565	650
45	295	430	485	285	395	590
Total	4355	5325	6700	4865	5935	7822

Analysis of Variance (ANOVA) Tables 2 and 3 revealed that there was significant variation in the biogas generation from the digesters with and without starter culture. It was also observed that positive correlation exist between biogas from digesters with and without starter culture as shown in Fig. 5.

4. DISCUSSION

Potentials of biogas generation from the combination of the four substrates water hyacinth, cassava peels, poultry dropping and cow & dung.

Comparatively the combination of the four substrates generated the highest optimal, total and percentage biogas at the shortest retention time than all the treatments, including the single double and triple mixture. Indicating the best performance in all the treatments. The generation of biogas from treatment combination of water hyacinth, cassava peels, poultry droppings and cow dung with or without starter

culture (mls/day) within 5 – 45 days were estimated via two way ANOVA (Table 2). From the results, biogas volume generated from the prescribed treatment combinations vary significantly with inoculums [F(2, 16) = 14.93, P < 0.001] and without starter culture [F(2, 16) = 19.42, P < 0.001] at the 1% level of significance due to weights. There was also significant difference [F(2,16) =16.45,P<0.001] with starter culture and [F(2,16)=25.05, P<0.001] without starter culture. Positive coorelation was observed in biogas production with and without starter culture. These results indicate that the amount of biogas generated from the above treatment (WH + CP + PD + CD) could be facilitated in the presence or absence (with or without) of starter culture. It also implies that a combination of four or more substrates could be used to generate biogas as there is evidence of synergy in the consortium of wastes if well selected and pre treated appropriately. [8] in a similar study reported that the rumen fluid inoculated to biodigester gave significant effect in biogas production, (P<0.05). Rumen fluid starter culture caused biogas production rate and efficiency increases two to three times compared to manure substrates alone. In their work with chicken manure, cow manure, piggery manure and Olive pomace, [15] concluded that coupling chicken manure and piggery digestate is more suitable for biogas production.

Table 2. Analysis of variance (ANOVA) summary results showing comparative biogas from combinations of water hyacinth, cassava peels, poultry droppings and cow dung with and without starter culture

Sources of variation	Starter culture	DF	Significance	MSS	F-Cal	P-value	F-critical
Weight	Without	2	498130.30	249065.10	14.93***	11.00	0.00022
	With	2	308538.90	154269.40	19.42***	11.00	5.25E-05
Periods	Without	8	2195169	274396.10	16.45***	6.19	2.32-06
(Days)	With	8	1591867	198983.30	25.05***	6.19	1.2E-07
Error	Without	16	266922.40	16682.65			
(Without)	With	16	127094.40	7943.403			
Total	Without	26	2960222				
	With	26	2027500				

*** = Significant at 1% level*

Source = Derived from Author's experimental data (2008)

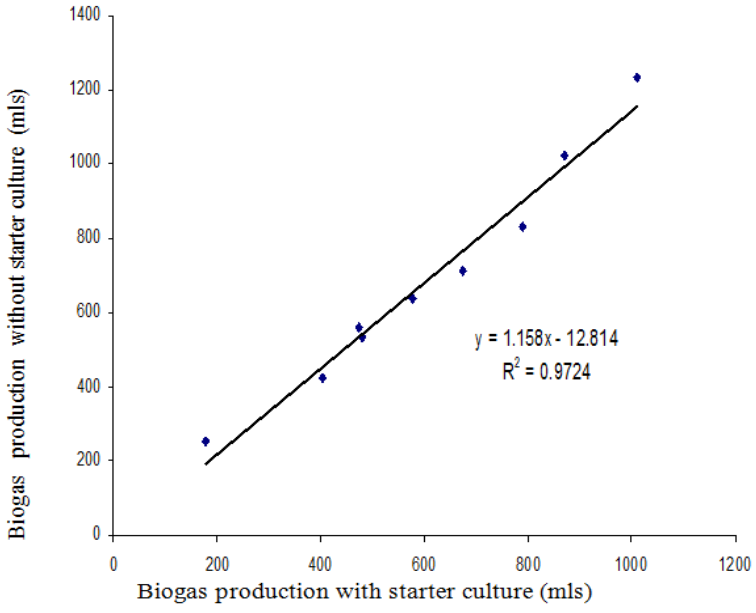

Fig. 5. Relation between biogas production from water hyacinth, cassava peels, poultry droppings and cow dung with and starter culture

Table 3. Total viable bacteria and fungi counts from substrates slurry before and after anaerobic digestion without starter culture

Treatments	Raw substrates	Bacteria counts before digestion (BCBD), ($cfug^{-1}$)	bacteria counts after digestion (BCAD) ($cfug^{-1}$)	Fungal counts before digestion (FCBD) ($cfug^{-1}$)	Fungal counts after digestion (FCAD) ($cfug^{-1}$)
T_1	WH	5.46×10^7	3.55×10^5	1.46×10^4	1.20×10^2
T_2	CP	3.80×10^7	2.25×10^5	5.60×10^4	2.95×10^2
T_3	PD	8.63×10^7	5.54×10^5	3.42×10^4	2.26×10^2
T_4	CD	8.65×10^7	6.45×10^5	3.55×10^4	2.25×10^2
T_{15}	WH+CP+PD+CD	7.86×10^7	5.45×10^5	3.35×10^4	2.45×10^2
T_0	Control (water only)	4.50×10^7	3.45×10^5	2.10×10^4	1.25×10^2

4.1 Digester Design

The anaerobic digesters designed and used in the study demonstrated potentials to produce biogas from the various substrates at controlled pH, temperature, retention time and proximate compositions. However, it was observed that the digester produced from aluminium metal by local metal makers (commonly called thinkers) were prone to leakages which affected biogas production unlike digester from Iron metals (used refrigerator cylinders) which were modified and reconstructed to suit the study. This was more efficient in biogas production in quantity and quality. The poor output demonstrated by the locally designed aluminium metal worker could be due to technological incompetence and facility to design a completely airtight digester. If given the required technological know how and exposure to the right technology they could successfully design a workable anaerobic digester that could be used by the rural dwellers for biogas production.

The study has revealed that there may be no solutions to the energy crisis in Nigeria except we develop an indigenous technology suitable and convenient to our peculiar circumstances especially, with respect to technological know how, raw material availability, human and economic resources and applicability by rural dwellers. This is because no developed country may be ready to transfer its developed technology based on political power play, economic and capitalistic monopoly as well as security.

Nigeria and indeed Cross River State is blessed with abundant, diverse and unexploited renewable energy resources and raw materials especially organic waste, for biogas that are yet to be used for providing clean fuel and help end energy crisis and poverty. [4] reported that, the rural energy problem in developing countries like Nigeria has not changed in the last 20-30 years, and millions of people still lack enough energy inputs to sustain economic development.

The Potential of organic waste to generate biogas- methane if maximally tapped and harnessed, could undoubtedly proffer the much desired solution to the energy crisis in Nigeria. More so, it will help to reduce the global problem of climate change arising from green house gases.

The potentials of biogas can be influenced by the proximate composition of moisture content, total solids, volatile solids, Carbohydrates or carbon content, Nitrogen, Crude fats proteins, Ash content Caloric value crude vibre and other chemical composition. Physical properties such as temperation, pH, agitation/stiring, retention time can greatly influence biogas production.

Microorganisms especially bacteria, fungi and Metahnogens play very important roles in the successful production of biogas. Some of the microorganisms are involved in the hydrolysis stage, some in the acidigenesis, others in the acetogenesis while the methanogens are actively involved in the production of biogas from. Total viable bacteria counts decreased after anaerobic digestion without and with starter culture indicating that the system can be used to purify contaminated waste, especially sewage. Total viable fungi counts was higher in the substrates slurry with cassava peels indicating the ability of fungi to survive more in acidic environment than bacteria. Total viable bacteria and fungi increased after mixing with pristine soil indicating active role and multiplication during plant growth. Lower biogas volume was however obtained from substrate slurry with cassava peels singly

and in combination with other substates, probably due to the presence of cyanogenic acids which tend to inhibit bacteria activities.

Cow dung produced the highest biogas out of the single substrate supporting the work of other researchers recommending cow dung and other animal dung as starter cultures.

In this study, poultry droppings did not generate the expected high biogas. This is probably because of the mixture of the droppings with other components, such as saw dust and feeds. There is need to use pure poultry dung free from other impurities for optimal biogas yield.

The combination of water hyacinth and cow dung produced significantly (P>.001) the highest biogas yield without and with inoculums throughout this study. This is because they provide adequate nutrients and proximate combination which support microbial metabolisms that favour biogas generation.

In the combination of three substrates, the mixture of water hyacinth with poultry droppings and cow dung generated significantly the highest biogas volume. This is also because there was nutrient blend which support microbial metabolic pathway in favour of biogas generation. The poultry droppings provided the Nitrogenous and protein requirement while the water hyacinth and cow dung provided the carbohydrate and carbon for proportionate carbon Nitrogen ratio (C:N).

However all the other substrates slurry also showed significant (P>.001) potentials for biogas generation at 1% level. The lowest percentage methane of 30% was obtained from treatment 2 without inoculums, consisting if cassava peels while the highest percentage yield was 70% from treatments 7 and 15, consisting of the mixture; water hyacinth+cow dung and Water hyacinth+cassava peels+poultry dropping +cow dung respectively. In the treatments with inoculums the lowest percentage methane of 40% was obtained from treatment 2 (1 kg and 2 kg weights consisting of cassava peels while the highest percentage yield was 80% from treatments 7 consisting of the mixture; of water hyacinth+cow dung.

5. CONCLUSION

One of the major challenges of anaerobic digestion is the use of local technology to design a digester which will be sufficiently air tight to prevent leakage or introduction of air into it. This is because Methanogenic bacteria are highly sensitive to oxygen or air hence the entire system is destabilized and it takes a longer time to recover if ever it does. It is also obvious that higher temperature supports biogas generation at a shorter retention time than ambient temperature used in this study. There is the need to further research on a digestion model which will support biogas generation at ambient temperature since this conserves energy and can easily be applied by the rural dwellers. Methanogens naturally grow very slowly and this increases retention time, there is therefore the need for further study to screen novel bacteria and fungi which can grow faster with increased biogas generation. There is a further need to design a more effective way of storing the biogas generated for further use, especially by rural dwellers. Finally there is the challenge for sustainable research on biogas technology for it to create the expected impact as a source of renewable energy and a reliable alternative to the non renewable fossil fuel energy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/19453