International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 2, Issue 6, pp 28-34, August-2018

Biogas Energy Potential from Co-Digestion of Avocado Pulp with Cow Manure in Kaitui Location, Kericho County, Kenya

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***Abstract* - The over-reliance on fossil and wood fuels as primary energy source has led to problems such as global climatic change, environmental degradation and various human health complications. Biogas is a renewable energy that has the potential to counteract environmental impacts related to traditional wood fuel as well as fossil fuels. Biogas energy had not been widely adopted in Kaitui location due to reported system failures. Catalysis presents an opportunity for quality and quantity improvements. Co-digestion of cow manure with avocado pulp, bagasse and goat manure were studied and compared with cow manure alone. Feed stocks were collected and subjected to pre-anaerobic digestion treatments of pulverization, screening and mixing. The materials were blended at a ratio of 1:1 and mixed with water at a ratio of 1:2 then introduced to the bio-reactor as homogenized slurry after stirring. The study showed a 113.3% increase in biogas production when co-digestion with avocado pulp was done,30.0% for bagasse and 21.7% for goat manure, an indication that biogas production can be enhanced by blending cow manure with avocado pulp.**

Keywords: Biogas, Avocado pulp, manure, co-digestion, volume gradient.

I. INTRODUCTION

Energy is one of the most important factors to global prosperity. The overdependence on fossil fuels as primary energy source has led to environmental pollution and degradation, thus leading to human health problems. In Africa, access to energy is a major challenge; the rural poor are seriously affected by the depletion of their energy resources, especially firewood (Aremu & Agarry, 2012).

Solar energy, wind energy, different thermal & hydro sources of energy and biogas energy are all renewable energy resources. However, Biogas is an energy technology that has the potential to counteract many adverse social, economic, health and environmental impacts connected to the traditional biomass energy use in Kenya (Yimer and Sahu, 2014).The use of biogas as an energy option has proven itself adequate strategy in solving the problems of energy usage in rural areas of developing countries (Aremu and Agarry, 2012).

Different raw materials will produce different amounts of biogas and methane depending on their content of carbohydrates, fats and proteins indicated in the Table 1.0 (Luostarinen et al., 2011).

TABLE-1

Biogas /Methane contents

Substrate	Biogas (m^3/t)	Methane (m^3/t)	Methane content%
Carbohydrates	830	415	50.0
Fats	1444	1014	70.2
Proteins	793	504	63.6

The benefit of co-digestion of substrates usually outweighs that of single digestion because of synergistic effects. It enhances microbial biodegradability and result in 25-32% higher specific methane production compared to single substrate digestion of cow manure (Chukwumaet al., 2013).

Avocado is a dicotyledonous plant from the Ranales order and the Lauraceae family. There are 57 avocado producing countries in the world. In 2011, world avocado production reached 4.4 million tones, increasing about 20% from 2007 to 2011. Mexico is the largest avocado producer, accounting for 25% of the world production, followed by Chile with 8.5% (FAO, 2013). The increasing productivity has occurred due to advances in post-harvest technologies, reduction in trade barriers; strong health related claims, increased incentives and cultivated areas in the producing countries.

Avocado contains between 5 to 40% oil, the percentage varying with the variety, growing area and seasonal conditions. They contain many vitamins, particularly the B

ISSN (online): 2581-3048
Volume 2, Issue 6, pp 28-34, August-2018

complex and vitamins A and E, as well as folic acid and iron with no cholesterol. Avocados are also used in food, in high-quality cooking oils and in the manufacture of cosmetics (Dorantes et al., 2004).

Avocado growth and development is intense, differing from other fruit species. After harvest, the fruit completes maturation, with major changes in metabolism and higher respiratory rate, and thus high production of ethylene, being highly perishable under environmental conditions leading to the production of high amounts of waste. Hence avocado pulp processing can contribute to its best use, either as a food product or for oil extraction.

According to Patricia et al.,2016 the avocado pulp contains from 67 to 78% moisture, 13.5 to 24 % lipids, 0.8 to 4.8% carbohydrate, 1.0 to 3.0% protein, 0.8 to 1.5% ash, 1.4 to 3.0% fiber, and energy density between 140 and 228kcal.

In the production of biogas, feed stocks are allowed to decompose anaerobically producing a gaseous product which contains methane, carbon dioxide and hydrogen sulphide. This biogas, comprises mainly of methane, it has to be refined of CO_2 and H_2S in order to improve its efficiency and thermal content (Wante.H & Wante, 2016).

The objective of this study was to assess biogas energy potential from co-digestion of avocado pulp with cow manure compared to other substrates.

II. MATERIALS AND METHODS

For all the experiments which were conducted, Independent apparatus were used to allow simultaneous operations to save on the duration of research. Eight batch bio-reactors each of volume 15L were designed and used. The hydraulic retention time (HRT) was 30 days. 2 kg of each feedstock were collected and mixed with water in the ratio 1:2.The fermentation slurry was then poured into the 15L bio-reactors. To eliminate the high volume of CO_2 in the entire reaction process, biogas produced was bubbled through concentrated potassium hydroxide solution to absorb it since it is a strong alkali. Hydrogen sulphide gas was trapped by passing the gas through iron wool. Since biogas is insoluble in water, a pressure building up as a result of anaerobic digestion provided the driving force for displacement of the water in the gas jar. The volume of displaced water was measured as the amount of biogas produced since the gas is slightly soluble in water (Fig 1).

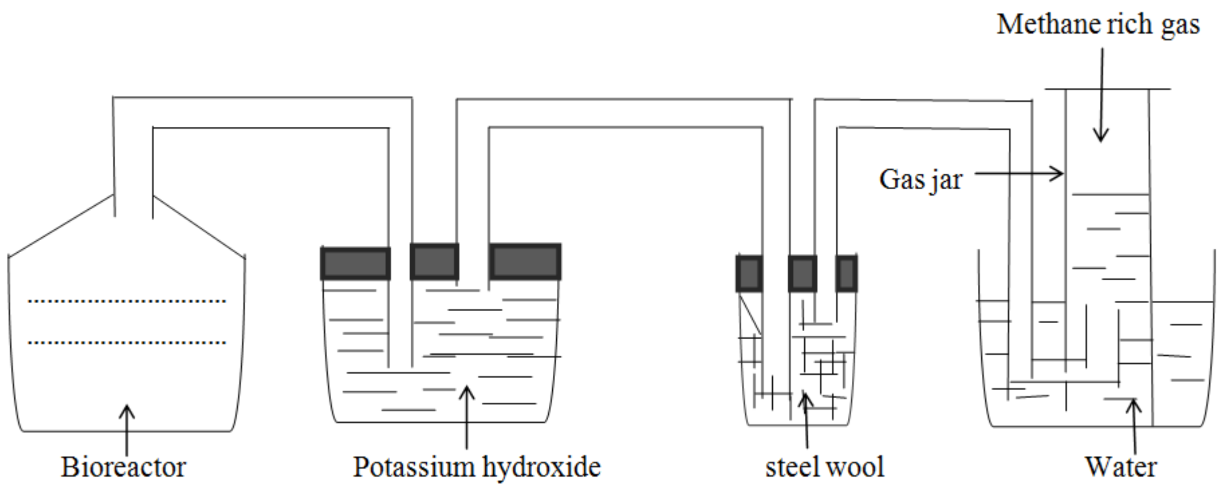

Figure-1: Experimental Set Up

For the purpose of co-digestion, there were four x: y proportions aimed at investigating the effect of co-digesting cow manure with avocado pulp and other substrates. The proportion of cow manure to other substrates in each digester was as in Table 2.0.Eight liters of water were added to each portion substrate mixture and the experiments similar to Figure 1 conducted for all substrates.

TABLE-2

Treatment of substrates

Treatment	Description	ratio(Kg)
D	C.M	4:0
D1	CM+GM	2:2
D2	CM:AP	2:2
D3	CM:B	2:2

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Measurement and monitoring of different parameters

Biogas generated was measured at specific time of the day (8:00am) to ensure 24hour gas production period. The volume of the gas in milliliters (ml) was measured by downward displacement of water in a calibrated measuring cylinder with 1ml scale range (Fig 2) and daily volume records kept (Table 3.0).

Figure-2: Experimental Setup

III. RESULTS AND ANALYSIS

The data for the daily and cumulative gas

TABLE-3

Daily/Cumulative gas volumes

	Daily gas volume (ml) (DGV)/ Cumulative gas volume(ml) (CGV)														
DAYS	C.M		G.M		A.P		B		CM+GM		CM+AP		CM+B	
	DGV	CGV	DGV	CGV	DGV	CGV	DGV	CGV	DGV	CGV	DGV	CGV	DGV	CGV
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	3	3	0	0
5	0	0	0	0	0	0	0	0	0	0	5	8	0	0
6	0	0	0	0	0	0	0	0	0	0	7	15	1	1
7	0	0	0	0	0	0	0	0	0	0	6	21	3	4
8	0	0	0	0	0	0	0	0	1	1	9	30	5	9
9	0	0	0	0	0	0	0	0	3	4	9	39	4	13
10	0	0	0	0	0	0	0	0	5	9	7	46	6	18
11	2	2	0	0	0	0	0	0	9	18	4	50	3	21
12	3	5	0	0	0	0	0	0	8	26	11	61	5	26
13	4	9	0	0	0	0	0	0	7	33	11	72	4	30
14	5	14	0	0	1	1	0	0	9	42	11	83	7	37
15	5	19	0	0	2	3	0	0	7	49	13	96	7	44
16	7	26	0	0	2	5	2	2	5	54	6	102	4	48
17	9	35	0	0	2	7	2	4	2	58	3	105	4	52
18	3	37	3	3	2	9	5	9	1	59	4	109	3	55
19	1	38	2	5	4	13	5	14	-	59	1	110	-	55
20	3	41	4	9	2	15	4	18	1	60	2	112	3	58
21	4	45	3	12	3	18	7	25	2	62	2	114	6	64
22	-	45	5	17	4	22	-	25	2	64	1	115	2	68
23	3	48	-	17	3	23	3	29	2	66	1	116	3	71
24	3	51	7	24	3	26	4	33	2	68	1	117	2	73
25	4	55	5	29	5	31	4	37	-	68	3	120	-	73

ISSN (online): 2581-3048

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26	1	56	4	33	2	33	7	44	1	69	3	123	2	75
27	1	57	5	38	5	38	5	49	1	70	1	124	1	76
28	-	57	6	44	4	42	3	52	1	71	1	125	-	76
29	1	58	4	48	4	44	-	52	-	71	1	126	1	77
30	2	60	-	48	3	47	3	56	2	73	2	128	1	78

Volumes were obtained through several experiments. Different feed stocks digested took different activation days before producing the gas (Table 3.0).At the end of HRT, different peak cumulative volumes were recorded for both single substrate digestion and co-digestions.

a) Co-digestion of cow manure with Avocado pulp

Biogas production from anaerobic digestion of fleshy parts of avocado fruit started from 14th day of HRT and attained peak cumulative gas volume of 47ml (Table 3.0).Upon co-digestion with cow manure, different results were obtained. The first volume of the gas produced was realized on the 4th day of HRT with a peak cumulative gas volume of 128ml being recorded.

The volume gradient for the co-digestion of avocado with manure was 5.17, λ=3and a goodness of fit (R2) of 0.92 (Fig 3) while that of single digestion of avocado was 1.63.Similary the gradient for the single digestion of cow manure was 2.61 with R2of 0.93 (Fig 3). Therefore the volume ratio (V.R),

$$V.R = \frac{(\mathrm{C.M + A.P})\,\mathrm{gradient}}{(\mathrm{A.P})\,\mathrm{gradient}}$$

$$V..R = \frac{5.17}{1.63}$$

$$V.R = 3$$

Similarly the V.R for co-digested (C.M+A.P) to single digestion of cow manure (C.M) gives:

$$V.R = \frac{(\mathrm{C.M + A.P})\,\mathrm{gradient}}{(\mathrm{C.M})\,\mathrm{gradient}}$$

$$V.R = \frac{5.17}{2.61}$$

$$VR = 2$$

This implies that co-digestion had a positive impact on the generation of the biogas in comparison with single substrate digestion.

$$(C.M + A.P) = 3\mathrm{A.P}$$

$$(C..M + A..P) = 2\mathrm{C.M}\ldots\ldots\ldots\ldots\ldots\ldots\mathrm{i}$$

From the V.R obtained it shows that the volume of biogas produced from co-digestion of cow manure with avocado fruits is 3 times the volume produced from single digestion of avocado and twice that of single digestion of cow manure (equation i).A positive deviation of 113.3% was recorded as a result of co-digestion (Table 4.0). The findings are in agreement with Luostarinen et al., (2011) who reported that the substrates with a high percentage of fats produce a lot of biogas compared to those with high percentage of proteins or carbohydrate.

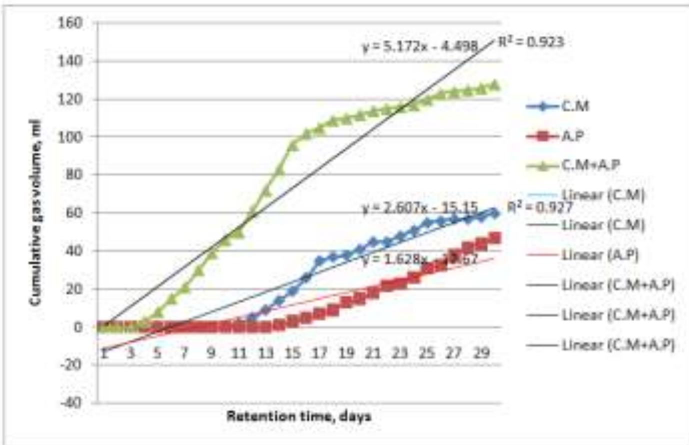

Figure-3: Cumulative gas volumes against Retention time for C.M & A.P

However these results show that higher volume of biogas is realized when substrates with high fat content is co-digested with cow manure to supplement other nutrients required by anaerobic bacteria for their survival.

These discrepancies in cumulative gas volumes could be tied to the chemical composition of avocado pulp. Avocado pulp contains high lipids content, which makes the pulp the portion of greatest interest. Lipids vary from 5 to 35%, being formed mostly by unsaturated fatty acids.

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 2, Issue 6, pp 28-34, August-2018

TABLE-4

Percentage deviation and lag phase

Substrate	C.G.V	Deviation, D	% Deviation	R^2	Lag phase, λ (days)
C.M	60	-	-	0.9270	10
C.M+G.M	73	13	21.7%	0.9132	7
C.M+A.P	128	68	113.3%	0.9230	3
C.M+B	78	18	30.0%	0.7946	5

High lipids and low carbohydrate levels remain in avocado pulp after water removal, conferring high dry matter content to the product. It is considered one of the cultured fruits presenting the lipid fraction as the major component (Patricia et al., 2016).

b) Co-digestion of cow manure with goat manure

In single substrate digestion, cow manure took 10 days for the gas to be produced (Table 3.0).Within the entire retention time, there were two instances of zero gas production and a peak cumulative volume of 60ml recorded. For the digestion of goat manure, gas production began on the 18th day and within the HRT, there were two days of negligible gas volume. A peak cumulative gas volume of 48 ml was realized.

Upon co-digestion, different results were obtained. The lag phase was reduced to 7 days and a peak volume of 73 ml was recorded.

A graph of cumulative gas volume against retention time for the three experiments indicates varying gradients with C.M having a volume gradient of 2.61 with R2 of 0.93, G.M with 1.57 and the co-digested (C.M+G.M) attaining 3.21with R2 of 0.91 (Fig. 4).

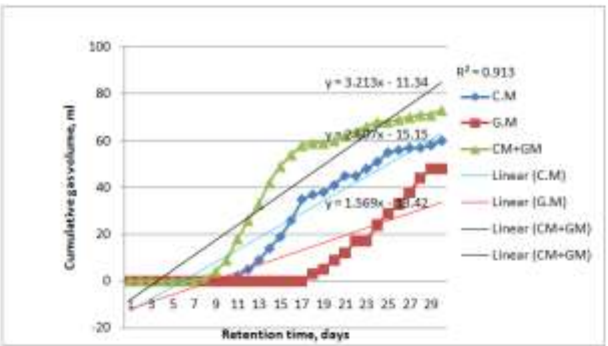

Figure-4: Cumulative gas volumes against Retention time for C.M & G.M

Co-digestion improved the gas return and reduced the initial period before gas yield commenced. This improvement in the volume gradient was attributed to positive change in the net C/N ratio. It is in agreement with what Wante et al., 2014 reported. The V.R for co-digestion of cow manure with goat manure to single digestion of cow manure is given by

$$(V.R) = \frac{(C.M + G.M)\text{gradient}}{(C.M)gradient}$$

$$(V.R) = \frac{3.21}{2.61}$$

$$(V.R) = 1.2$$

Similarly the V.R for (C.M + G.M) co-digestion to single substrate digestion of goat manure gives a different volume ratio

$$(V.R) = \frac{(C.M + G.M)\text{ gradient}}{(G.M)gradient}$$

$$(V.R) = \frac{3.21}{1.57} \quad (V.R) = 2$$

Comparing the volume ratios, it's evident that co-digestion increased the gas production volume by a coefficient of 1.2 & 2 with regard to single digestion of cow manure and goat manure respectively (equation ii). A positive deviation of 21.7% was also realized from co-digestion (Table 4.0).

$$(C.M + G.M) = 1.2C.M \quad (C..M + G.M) = 2G.M \ldots\ldots\ldots\ldots\text{ii}$$

c) Co-digestion of cow manure with bagasse

Single substrate digestion of bagasse recorded the initial gas from the 16th day of HRT and attained a peak cumulative gas volume of 56 ml (Table 3.0).

International Research Journal of Innovations in Engineering and Technology (IRJIET)

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Volume 2, Issue 6, pp 28-34, August-2018

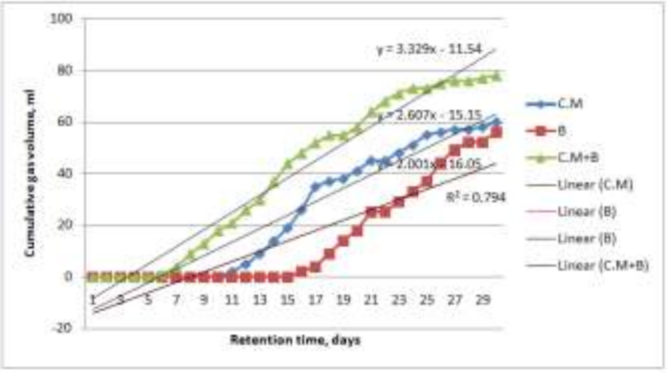

Figure-5: Cumulative gas volumes against Retention time for C.M & B

Upon co-digestion with cow manure, the time taken to evolve the initial measurable gas volume was reduced to 6th day of HRT and the peak cumulative volume of 78 ml reached. The volume gradient resulting from co- digestion of bagasse with cow manure was 3.33 but for single digestion of bagasse, it was 2.00.Similarly the single anaerobic digestion of cow manure gave a volume gradient of 2.61 (Fig 5). By calculating the volume ratios

$$V.R(\mathrm{C.M+B:B}) = \frac{3.33}{2.00}$$

$$V.R = 1.7$$

$$V.R(\mathrm{C.M+B:C.M}) = \frac{3.33}{2.61}$$

$$V.R = 1.3$$

From the V.Rs computed, it's clear that more gas was produced during co-digestion of bagasse with cow manure than in single substrate digestion. This could be attributed to the fact that though bagasse is fibrous and hard to digest, it contains a lot of sugar which makes it a good carbohydrate. This sugar will improve/ add nutrients to cow manure which can easily be digested thus increasing the gas production gradient. Bagasse is composed of cellulose (37% dry mass), hemi cellulose (28% dry mass) and lignin (21% dry mass) (Bon, 2007).

This is in agreement with Chomini et al., 2015 who reported that co-digestion of feed stocks give relatively higher average volume of biogas generation than the single substrates.

IV. CONCLUSION

The anaerobic digestion of substrates was found to be more effective during co-digestion than in single substrate digestion. The co-digestion of avocado pulp with cow manure produced the highest cumulative gas volume (128ml) within the hydraulic retention time of 30 days. Single digestion of cow manure reached a peak volume of 60 ml while single digestion of avocado pulp had a peak volume of 47 ml. Other co-digested feed stocks with cow manure were; goat manure which attained a peak volume of 73ml, and bagasse with a peak volume of 78 ml.

In terms of V.R, the co-digestion of cow manure with avocado had a much significant volume equivalence of (C.M+A.P) =3(A.P) compared to (C.M+G.M) = 2G.M and (C.M+B) = 1.7B. when cow manure is taken as the reference volume, its co-digestion with avocado pulp still had the highest quotient of(C.M+A.P) = $2C.M$, (C.M+B) =1.3C.M,(C.M+G.M) =1.2C.M.

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Citation of this article:

Kipngetich Langat, Paul Njogu, Joseph Kamau, "Biogas Energy Potential from Co-Digestion of Avocado Pulp with Cow Manure in Kaitui Location, Kericho County, Kenya", *International Research Journal of Innovations in Engineering and Technology (IRJIET)*, Volume 2, Issue 6, pp 28-34, August 2018.

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