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Co-digestion of Livestock Wastes for Biogas Production

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Abstract Co-digestion of cow dung, poultry dropping and pig manure was carried out in batch digesters at mesophilic temperature for twenty-eight days to determine the biogas generating potentials. The wastes were also digested individually for the same period and under the same conditions. The physicochemical and bacteriological characteristics were determined using standard techniques. The range of $_{P}H$, temperature, percentage moisture content, percentage chemical oxygen demand, percentage carbon content, and the bacterial loads of the wastes slurries before digestion were 6.4- 6.8, 28.0^{0}C - 29.0^{0}C, 80.0 - 80.2, 9.2 - 11.0, 32.0-46.0 and 3.7 x 10^6cfu/ml -6.2 x 10^6 cfu/ml respectively and 6.6-7.5, 27.6^{0}C -28.5^{0}C, 80.2-91.6, 7.0-9.4, 35.0-58.0 and 1.6 x 10^6 cfu/ml-5.2 x 10^6 cfu/ml respectively at the end of digestion. The biogas yield from the digestion of the cow dung, poultry dropping and pig manure individually were 185ml, 220ml and 170ml respectively while the co-digestion of the substrates yielded more biogas. The cumulative biogas yield from the digestion was 2780ml. The slurry containing 48g: 144g: 48g of cow dung, poultry dropping and pig manure gave the highest biogas yield. This study showed that though the digestion of a single livestock waste can yield some biogas, co-digestion of such wastes has the potential to generate more biogas.

Keywords Co-digestion, Biogas, Cow Dung, Poultry Dropping, Pig Manure

1. Introduction

Biogas is a renewable energy source produced by the biological breakdown of organic matter in the absence of oxygen. It is environmentally friendly, carbon dioxide neutral and is produced by the anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal wastes, green wastes, plant materials and crops [1].

Biogas comprises primarily methane (50-75%) carbon (iv) oxide (25-45%), nitrogen (<2), hydrogen sulphide (<1%), water (2-7%) and oxygen (<2%), though its composition varies according to the different types of substrates utilized for its fermentation [2].

In Nigeria, the identified substrates for economically feasible biogas production include water lettuce, water hyacinth, animal dung, cassava peels, industrial wastes, agricultural wastes, sewage, waste paper, brewery wastes, food wastes and municipal wastes [3-5]. Animal wastes that have been utilized for biogas production include poultry wastes and cow dung [6].

Biogas production involves anaerobiosis and is carried out in an anaerobic digester. Firstly, the substrate is made available, treated and fed into the digester. Secondly, anaerobic fermentation takes place in the digester, producing biogas. Lastly, the gas is purified, stored and utilized [7].

Anaerobic digestion is a technology widely used for the treatment of organic wastes for biogas production. The anaerobic fermentation of manure for biogas production does not reduce its value as a fertilizer supplement, as available nitrogen and other substances remain in the treated sludge [8].

Biogas production is a complex biochemical reaction which takes place under the action of microorganisms particularly bacteria. Three major groups of bacteria (hydrolytic, acidogens/acetagens and methanogens) are responsible for banking down the complex polymers in biomass wastes to produce under anaerobic conditions [9]

Co-digestion is the simultaneous digestion of more than one type of wastes in the same unit. Studies have shown that co-digestion of several substrates such as banana and plantain peels, spent grains and rice husks, pig wastes and cassava peels, sewage and brewery sludge among others have resulted in improved methane yield by as much as 60% compared to that obtained from a single substrate [10].

The rapid growth of the livestock industry in Nigeria creates environmental problems related to the wastes generated at dairy, swine and poultry farms. Traditionally, these wastes have been handled directly or after composting as fertilizer in the agricultural sector. This waste contributes methane emissions to the environment resulting in global warning, surface and groundwater contaminations, odour, flies and pathogens accumulation.

One of the most important challenges of Nigeria's economic development is electrical power. The rising price of petroleum products has led to the interest in renewable energy sources, the exploitation of biogas technology. The objective of this research was to produce biogas from blends of wastes generated at dairy and poultry farms in Awka, Anambra State of Nigeria.

1.1. Significance of the Research

It is expected that the co-digestion of the substrates will lead to the production of more biogas than the use of the substrates individually. The use of the substrates for biogas production will also contribute immensely to a reduction in wastes volumes, unpleasant local odours and flies; a reduction of pathogens through improved sanitation; a mitigation of possible pollution from livestock wastes and maintenance of environmental quality.

2. Materials and Methods

2.1. Samples Collection and Processing

Cow dung, poultry dropping and pig manure were purchased from dairy, poultry and pig farms in Awka Anambra State. They were sun-dried for twenty days and crushes mechanically with a mortar and pestle. The temperature, $_pH$, percentage moisture content, percentage chemical oxygen demand, percentage carbon content and the bacterial loads of the individual wastes as well their blends were determined before co-digestion and at weekly intervals during co-digestion using standard methods [11].

2.2. Experimental Design

A set of seven batch digesters (4 litres) were used. Four of them were used for co-digesting cow dung, poultry dropping and pig manure while the other three were used for digesting the individual substrates only. An opening was made at the top cover of each digester, through which was passed a delivery tube which ran through, into a transparent bucket containing acidified brine and thence into an upturned burette inside the bucket. The upturned burette was supported in its position with a retort stand. The acidified brine was prepared by adding three drops of sulphuric acid to a saturated solution of sodium chloride. The digesters were labeled A, B, C, D, E, F and G respectively. The compositions of the digesters are shown in Table 1. The biomasses were mixed with sterile water and corked to exclude air. The contents were allowed to ferment for a period of twenty-eight days at ambient temperature and agitated twice daily at morning and evening hours.

2.3. Temperature and $_pH$ Measurements of the Slurries before and during Digestion

The temperature and $_pH$ were measured with a thermometer (Stuart Engineering Limited, England) and $_pH$ meter (JENWAY) respectively. The temperature was measured by dipping the thermometer into the slurries. The values were taken when the readings stabilized. The $_pH$ was standardized with phosphate buffers before use and its electrode was dipped into the waste slurries and the values were also taken when the readings stabilized.

2.4. Determination of the Moisture Content of the Slurries before and during Digestion

One gram was collected from each of the slurries and introduced into a weighed crucible. The slurries were thereafter dried in an oven at 105^0C until a content sample weight was obtained.

The percentage moisture content was calculated as follows:

$$\% \text{ moisture content} = \frac{\text{Initial Sample Weight} - \text{Final Sample Weight}}{\text{Initial Sample Weight}} X100$$

2.5. Determination of the Chemical Oxygen Demand Of the Slurries before and during Digestion

Organic and inorganic substances in the slurries were oxidized using Potassium Dichromate in 50% sulphuric acid solution of reflux temperature. Silver sulfate was used as the catalyst for the reaction and mercuric sulfate was introduced to remove chloride interference. The excess dichromate was titrated with Standard Ferrous Ammonium Sulfate using Orthophenanthroline Ferrous complex as the indicator.

The percentage chemical oxygen demand was obtained from the formula

$$\frac{8000\ (b-s)\ n}{\text{Sample Volume}} X100$$

Where b = Volume of Ferrous Ammonium Sulfate used in the blank sample

s = Volume of Ferrous Ammonium Sulfate in the original sample

n =normality of Ferrous Ammonium Sulfate

2.6. Determination of the Carbon Content of the Slurries before and during Digestion

One gram of the dried sample of the slurries was placed on a tablespoon and burnt using a kitchen stove until it charred. The weight was thereafter measured. The percentage carbon content was calculated from the formular

$$\% \text{ carbon} = \frac{\text{Initial Sample Weight} - \text{Final Sample Weight}}{\text{Initial Sample Weight}} X100$$

2.7. Determination of the Bacterial Load of the Slurries before and during Digestion

One milliliter of each of the slurries was aseptically withdrawn from the reactor and diluted serially using physiological saline. 0.1 ml of the serially-diluted sample ($x10^6$) was introduced into a sterile petri dish containing prepared, sterilized and solidified nutrient agar and evenly spread on the agar surface using a sterile glass rod. The petri dish was covered and incubated in an inverted position at 28^0c hours for twenty four under carbon dioxide tension. The bacterial colonies that grew were counted and expressed as colony forming unit per milliliter.

2.8. Characterization and Identification of the Bacteria Isolates from the Slurries before and during Digestion

The bacteria isolates were characterized on the basis of their morphological and biochemical characteristics. Gram staining, catalase, spore, motility, coagulase, methyl red, voges proskaeur, citrate utilization, sugar fermentation, indole, nitrate reduction and hydrogen sulphide production tests were carried out as done by Cheesbrough [12]. They were identified according to the scheme of Holt et al [13].

2.9. Measurement of Biogas Production

As biogas production commenced in the reactors, the gas was delivered to a chamber containing acidified brine solution. The acidified brine solution was prepared by introducing same drops of sulphuric acid to a saturated solution of sodium chloride. Since the biogas was insoluble in the acidified brine solution, a pressure build up provided the driving force for the displacement of the solution. The amount of biogas was thereafter measured by the liquid displacement method as done by Itodo et al [14].

3. Results

The composition of each of the digesters used for the experiment is shown in Table 1. Digesters A-D contained livestock slurries (cow dung, poultry droppings and pig manure) mixed in varying proportions while digesters E, F and G contained only cow dung, poultry dropping and pig manure respectively.

Table 1. Composition of the digesters

Digester	Cow dung (g)	Poultry dropping (g)	Pig manure(g)	Volume of water (1)
A	80	80	80	2.4
B	144	48	48	2.4
C	48	144	48	2.4
D	48	48	144	2.4
E	240	0	0	2.4
F	0	240	0	2.4
G	0	0	240	2.4

Table 2. Physicochemical Characteristics and Bacterial Load of the Livestock Wastes Slurries before digestion

Slurry Ratios (DC:PD:PM)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	Percentage Carbon Content %	Bacterial load ($x10^6$ cfu/ml)
80:80:80	28.7	6.8	80.0	10.8	41	4.4
144:48:48	28.5	6.7	80.1	10.8	40	3.7
48:144:48	29.0	6.7	80.2	9.6	46	6.2
48:48:144	29.0	6.7	80.1	11.0	43	5.0
240:0:0	28:4	6.8	80.2	9.0	34	4.6
0:240:0	28.2	6.6	80.1	10.7	37	4.0
0:0:240	28.0	6.4	80.0	9.2	32	3.7

CD = Cow Dung

PD = Poultry Dropping

PM= Pig Manure

Table 3. Physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 80g; PD,80g; PM, 80g) during digestion

Time (days)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	% Carbon Content	Bacterial Load (x10^{6}cfu/ml)
7	28.6	6.5	82.7	10.8	42.3	2.6
14	28.3	6.7	84.7	10.8	43.6	3.3
21	28.0	7.0	85.4	9.6	46.4	2.7
28	27.6	7.3	86.0	9.0	50.0	2.3

CD = Cow Dung

PD = Poultry Dropping

PM= Pig Manure

Table 4. Physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 144g; PD,48g; PM, 48g) during digestion

Time (days)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	% Carbon Content	Bacterial Load (x10^{6}cfu/ml)
7	28.3	6.8	81.6	10.8	41.2	2.1
14	28.2	6.9	82.9	10.6	43.5	2.4
21	28.0	7.0	83.0	10.4	44.8	1.8
28	27.9	7.1	84.7	9.3	46.0	1.6

CD = Cow Dung

PD = Poultry Dropping

PM= Pig Manure potato

Table 5. Physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 48g; PD,144g; PM, 48g) during digestion

Time (days)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	% Carbon Content	Bacterial Load (x10^{6}cfu/ml)
7	28.9	6.8	84.0	9.6	50.0	5.8
14	28.8	6.9	87.2	9.2	54.7	6.1
21	28.6	7.0	89.6	8.1	56.3	5.4
28	28.5	7.5	91.6	7.0	58.0	5.2

CD = Cow Dung

PD = Poultry Dropping

PM= Pig Manure

The physicochemical characteristics and bacterial load of the livestock wastes slurries before digestion are presented in Table 2. The temperature ranged from 28.^{0}C to 29.^{0}C, $_p$H from 6.4 to 6.8, percentage moisture content between 80.1 and 80.2, percentage chemical oxygen demand from 9.2. to 11.0, percentage carbon content from 32.0-46.0 while the bacterial load ranged between 3.7 x 10^6 cfu.ml and 6.2 x 10^6cfu/ml.

The physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 80g; PD, 80g; PM 80g) during digestion are presented in Table 3. The temperature was 27.6^{0}C;-28.6^{0}C; pH, 6.5-7.3; percentage moisture content, 82.7-86.0; percentage chemical oxygen demand, 9.0-10.8; percentage carbon content, 42.3-50.0 and the bacterial load, 2.3 x 10^6cfu/ml-3.3 x10^6cfu/ml

The physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 144g; PD, 48g; PM, 48g) during digestion are shown in Table 4. The temperature ranged from 27.9^{0}C to 28.3^{0}C, pH, 6.8-7.1; percentage moisture content, 81.6-84.7; percentage chemical oxygen demand, 9.3-10.8; percentage carbon content, 41.2-46.0 and the bacterial load, 1.6 x 10^6cfu/ml-2.4cfu/ml.

In Table 5 is shown the physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 48g; PD, 144g; PM, 48g) during digestion. The temperature, pH, percentage moisture content, percentage chemical oxygen demand, percentage carbon content and bacterial load were 28.5^{0}C-28.9^{0}C, 6.8-7.5, 84.0-91.6, 7.0-9.6. 50.0-58.0 and 5.2 x 10^6 cfu/ml-6.1 x10^6 cfu/ml respectively.

The physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 48g; PD, 48g; PM, 144g) during digestion are shown in Table 6. The temperature values were 27.8^{0}C- 28.8^{0}C; pH, 6.7-7.4; percentage moisture content, 83.2-89.2; percentage chemical oxygen demand, 8.5-11.0; percentage carbon content, 48.3-55.6 while the bacterial load ranged from 3.8 x 10^6 cfu/ml to 4.2x 10^6 cfu/ml.

Table 6. Physicochemical characteristics and bacterial load of the livestock wastes slurries (CD, 48g; PD, 48g; PM, 144g) during digestion

Time (days)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	% Carbon Content	Bacterial Load (x10^{6}cfu/ml)
7	28.8	6.7	83.2	11.0	48.3	4.0
14	28.5	6.8	85.7	9.8	50.4	4.2
21	28.0	7.0	87.7	9.0	53.2	3.9
28	27.8	7.4	89.2	8.5	55.6	3.8

CD = Cow Dung

PD = Poultry Dropping

PM= Pig Manure

Table 7. Physicochemical characteristics and bacterial load of the cow dung slurry (240g) during digestion

Time (days)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	% Carbon Content	Bacterial Load (x10^{6}cfu/ml)
7	28.3	6.6	80.7	8.9	36.0	4.0
14	28.2	6.9	80.9	8.8	38.3	4.2
21	28.0	7.0	81.4	8.7	40.1	3.8
28	27.9	7.2	82.0	8.6	42.0	3.6

Table 8. Physicochemical characteristics and bacterial load of the poultry dropping slurry (240g) during digestion

Time (days)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	% Carbon Content	Bacterial Load (x10^{6}cfu/ml)
7	28.1	6.5	80.5	10.5	37.4	3.0
14	28.0	6.6	81.6	10.1	37.9	3.2
21	27.9	6.8	82.8	9.7	38.3	2.6
28	27.9	6.9	83.1	9.4	39.0	2.4

Table 9. Physicochemical characteristics and bacterial load of the pig manure slurry (240g) during digestion

Time (days)	Temperature (^{0}C)	$_p$H	% Moisture Content	% Chemical Oxygen Demand	% Carbon Content	Bacterial Load (x10^{6}cfu/ml)
7	27.9	6.5	80.1	9.1	33.3	3.2
14	27.9	6.5	80.1	9.0	33.8	3.5
21	27.8	6.6	80.2	9.0	34.6	3.0
28	27.8	6.6	80.2	8.9	35.0	2.7

Table 10. Bacterial isolates from the livestock wastes slurries before and after digestion

Bacterial isolates before digestion	Bacterial isolates after digestion
Escherichia coli	*Clostridium spp*
Enterococcus faecalis	*Methanobacterium spp*
Staphylococcus aureus	*Methanococcus spp*
Serratia marcescens	*Methanosarcina spp*
Micrococcus luteus	
Proteus vulgaris	
Shigella flexneri	

Table 11. Volume of biogas (ml) generated from the livestock wastes slurries during digestion

		Time (Days)				
Digester	Slurry ratios (CD:PD:PM)	7	14	21	28	Total
A	80:80:80	98	121	152	97	468
B	144:48:48	80	90	110	54	334
C	48:144:48	210	260	300	161	931
D	48:48:144	100	115	155	102	472
E	240:0:0	40	52	60	33	185
F	0:240:0	51	62	65	42	220
G	0:0:240	37	50	53	30	170
	Total	616	650	895	519	2780

The physicochemical characteristics and bacterial load of the cow dung slurry (240g) during digestion are presented in Table 7. The temperature ranged from 27.9^{0}C to 28.3^{0}C; pH, 6.6-7.2; percentage moisture content, 80.7-82.0; percentage chemical oxygen demand, 8.6-8.9; percentage carbon content, 36.0-42.0 and the bacterial load from 3.6 x 10^6 cfu/ml to 4.2 x 10^6 cfu/ml.

Table 8 showed the physicochemical characteristics and bacterial load of the poultry dropping slurry (240g) during digestion. The values were 27.9^{0}C-28.1^{0}C; 6.5-6.9; 80.5-83.1; 9.4-10.5; 37.4-39.0 and 2.4 X 10^6 cfu/ml-3.2 X 10^6cfu/ml for the temperature, pH, percentage moisture content, percentage chemical oxygen demand, percentage carbon content and the bacterial load respectively.

The physicochemical characteristics and bacterial load of the pig manure slurry (240g) during digestion are shown in Table 9. The temperature values were 27.8^{0}C-27.9^{0}C; pH, 6.5-6.6; percentage moisture content, 80.1-80.2; percentage chemical oxygen demand, 8.9-9.1; percentage carbon content, 33.3-35.0 and the bacterial load, 2.7 x 10^6cfu/ml-3.5 x10^6cfu/ml.

The bacterial isolates from the livestock wastes slurries before and after digestion are shown in Table 10. Escherichia coli, Enterobacter faecalis, Staphylococcus aureus, Serratia marcescens, Micrococcus luteus, Proteus vulgaris and Shigella flexneri were isolated from the slurries before digestion while Clostridium spp, Methanobacterium spp, Methanococcus spp and Methanosarcina spp were isolated from the wastes slurries after digestion.

The volume of biogas generated from the livestock wastes slurries during digestion is shown in Table 11. Digester A containing 80g: 80g: 80g of cow dung, poultry dropping and pig manure respectively yielded 468 ml of biogas; digester B, 334ml; digester C, 931ml; digester D, 472ml; digester E, 185ml; digester F, 220ml and digester G, 170ml of biogas. Altogether, 2780ml of biogas was generated during the experiment.

4. Discussion

The temperature of the livestock wastes slurries before digestion ranged between 28.0^{0}C and 29.0^{0}C (Table 2) but ranged between 27.6^{0}C and 28.9^{0}C (Tables 3-9) at the end of digestion. The temperature decreased progressively during the period of digestion. The temperature values were however within the optimal range for biogas production.

It was observed that the pH of the livestock wastes slurries before digestion ranged from 6.4 to 6.8 (Table 2) but ranged between 6.6 and 7.5 at the end digestion (Tables 3-9). The pH rose from the acidic range to the alkaline range during the period of digestion. The final pH values were however within the optimum range for biogas production. The increase in pH during digestion can be attributed to the production of ammonium compound by ammonia-producing organisms present in the slurries.

Kapadiya et al [15] however reported that the increased pH may be because the accumulated ammonium compound was not easily reduced because there were no biodegradable materials as buffer like composite vegetable waste, grass etc in the medium. Momoh et al [4] also reported an increase in pH values of biomass (cow dung and water hyacinth) mixture after digestion.

The percentage moisture content of the livestock wastes slurries before digestion ranged between 80.0 and 80.2 (Table 2) but increased to between 80.2 and 91.6 during digestion (Tables 3-9) indicating partial digestion of the fermentation substrates due to decrease bacterial population. The percentage chemical oxygen demand of the wastes slurries were 9.2-11.0 before digestion (Table 2) but decreased during the period of digestion to 7.0-9.4 (Tables 3-9). Similar observation was made by Saev et al [5] on the anaerobic co-digestion of wasted tomatoes and cattle dung for biogas production.

The percentage carbon content of the livestock wastes slurries ranged between 32.0 and 46.0 before digestion and increased to between 35.0 and 58.0 at the end of digestion (Tables 3-9) probably due to the partial digestion of the fermentation substrates as a result of decreased bacterial population.

The bacterial loads of the livestock wastes slurries before digestion were 3.7 x 10^6cfu/ml – 6.2x10^6cfu/ml (Table 2). As the bacteria stabilized, they increased in population till the fourteenth day and thereafter decreased progressively till

the end of the digestion (Tables 3-9). The decrease may be attributed to the production of metabolites that may be antagonistic to the growth of the bacteria during the digestion. In addition, a reduction in the nutrient status of the fermentation substrates during digestion may have contributed to the decrease in bacterial load.

The bacterial isolates from the livestock wastes slurries before digestion were Escherichia coli, Enterococcus faecalis, Staphylococcus aureus, Serratia marcescens, Micrococcus luteus, Proteus vulgaris and Shigella flexneri (Table 10). These organisms are facultative anaerobes and are probably involved in the transformation of the insoluble organic materials and higher molecular weight compounds such as lipids, proteins, fats, nucleic acids and polysaccharides in the fermentation substrates into the soluble organic compounds such as monosaccharides, amino acids and simple organic compounds. Clostridium spp, Methanobacterium spp, Methanococcus spp and Methanosarcina spp were isolated from the slurries at the end of the digestion indicating that the digestion process was strictly anaerobic.

Biogas production was observed on the first day of the fermentation indicating that the bacteria in the wastes must have aided the faster digestion, leading to immediate biogas production. Similar result was obtained by Uzodinma and Ofoefule [16] who produced biogas from a blend of field grass (panicum maximum) and some animal wastes.

The cumulative volume of biogas generated within the study period was 2780 millilitre (Table 11). 240g of poultry dropping only (digester F) produced more gas than the 240g of cow dung only (digester E) and 240g of pig manure only (digester G). This result agreed with the report of Nnabuchi et al [17] that 100% chicken manure produced more gas per unit weight as compared to the 100% cow dung. Compared to the single substrates, the co-digestion of cow dung, poultry dropping and pig manure generated more biogas.

The maximum biogas yield was attained with the mixture in the proportion of 48:144:48 of cow dung, poultry dropping and pig manure respectively (Table 11). Ranade et al [18] produced biogas from market wastes and attributed the higher biogas yield in the mixture containing more poultry dropping to the presence of the native micro flora in the Chicken dropping. The lower biogas yield in the mixtures containing more cow dung or pig manure in this study may be because of the low biodegradable materials in them as well as the low carbon-nitrogen content. Results of co-digestion of food wastes and dairy manure in a two-phase digestion system conducted at laboratory scale showed that the biogas production rate was enhanced by 0.8 to 5.5 times as compared to the digestion with dairy manure alone [20].

Nordberg and Edstrom [19] carried out the co-digestion of energy crops and the source-sorted organic fraction of municipal solid waste and reported that the biogas production rate in batch condition is directly proportional to the specific growth rate of the methanogenic bacteria in the bio-digester. This study showed that though the digestion of a single biodegradable substrate can generate biogas, the co-digestion of biodegradable substrates can greatly enhance the biogas process leading to higher yield of methane.

5. Conclusions

The anaerobic digestion of cow dung, poultry dropping and pig manure for biogas production is feasible at mesophilic temperature. It was established in this study that by using a mixture of the animal wastes in various proportions, a stable anaerobic co-digestion can be achieved. The maximum biogas yield was attained with the mixture in the proportion of 48g: 144g: 48g of cow dung, poultry dropping and pig manure respectively. The gradual reduction of the percentage chemical oxygen demand clearly indicated the stability of the process. Co-digestion of cow dung, poultry dropping and pig manure yielded more biogas in this work than the use of a single livestock waste and is hereby recommended for enhanced biogas production in Nigeria.

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