Biochemical Methane Potential Analysis using Cow dung, Chicken manure and Pig manure under Mesophilic Conditions

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Abstract - In this study, we compared methane production by anaerobic mono-digestion and co-digestion of cow dung, chicken manure and pig manure under mesophilic conditions at the temperature of 37 ^{0}C using a ratio of 1:1. C/N ratio, pH, VS/TS and sulphur content were the parameters investigated. Results indicated that co-digesting of cow dung; pig manure and chicken manure enhanced biogas production and methane content. The results also imply that pig manure cannot be used alone to produce methane as it produced low methane. Chicken manure produced more on the first day (272 Nml) compared to pig manure (257.4 Nml) and cow dung (80.5 Nml). On the ninth day, chicken produced 884 .9 Nml and then on the tenth day it went up again to 1095.6 Nml, reached its peak on day 13 and stopped, chicken yielded better results compared to the cow dung and pig manure because chicken had a higher VS/TS percent which is desirable for methane production. Pig manure started producing methane on the first day which was 257.4 Nml and stopped on the second day with the volume of 262.3 Nml. Pig manure showed poor results compared to cow dung and chicken manure.

Keywords – Anaerobic digestion, mono-digestion, co-digestion, mesophilic temperature, degradation.

1. Introduction

The use of energy is of importance in the development of the society to control and adapt to the environment. In the industrialized world the development of energy resources has become essential for agriculture, transportation, waste collection, information technology, communications that have become prerequisites of a developed society. The increasing use of energy since the industrial revolution has also brought with it a number of serious problems, some of which, such as global warming, present potentially serious risks to the world.

South Africa currently relies almost entirely on fossil fuels (FF) (approx. 90 %) to satisfy its energy demand, with coal providing 75 % of this energy supply (Choudhuty et al., 2002). South Africa uses coal to produce energy. Due to that, South Africa is the 14th largest country in terms of GHG's release. However, South Africa is signatory country to the Kyoto protocol, which leads the country to reduce the emissions of GHG's (Robles-Gil, 2001). Instead of using coal as a prime source for energy for electricity, we can substitute with natural gas that can be produced with animal manure; cow dung, pig manure and chicken manure composition in AD.

Fossil fuels are continually being formed via natural processes, they are generally considered to be non-renewable resources because they take millions of years to form and the known viable reserves are being depleted much faster than new ones are being made. The use of fossil fuels raises serious environmental concerns (Robles-Gil, 2001). The burning of fossil fuels produces around 21.3 billion tonnes (21.3 gigatonnes) of carbon dioxide (CO_2) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tons of atmospheric carbon dioxide per year (one ton of atmospheric carbon is equivalent to 44/12 or 3.7 tons of carbon dioxide (Choudhuty et al., 2002). Carbon dioxide is one of the greenhouse gases that contributes to global warming, causing the average surface temperature of the earth to rise in response, which the vast majority of climate scientists agree will cause major adverse effects. A global movement towards the generation of renewable energy is therefore under way to help reduce global greenhouse gas emissions. Biogas is made of different gases using organic wastes as a raw material in the absence of oxygen. Anaerobic digestion process produces methane using organic materials; methane can be used to replace coal as a source of energy for both heat and power generation, it will also decrease the emissions of greenhouse gases and decreases the effect climate changes (Choudhuty et al., 2002).

A natural biological process that occurs when organic matter breakdown by the bacteria in the absence of oxygen is called anaerobic digestion. This process results in the production of methane gas. The organic waste is converted into biogas by degradation in the anaerobic digestion process (Monnet, 2003). There are four steps included in the biodegradation process namely (Willem, 2015 and Appels et al., 2011):

- Hydrolysis
- Acidogenesis
- Acetogenesis
- Methanogesis

Hydrolysis is the first step where organic compounds are broken down. The products of hydrolysis are absorbed by fermentative bacteria, which is the second step (Acidogenesis); where products of hydrolysis are absorbed by the fermentative bacteria. Fermentation products are acetate, fatty acids, alcohol and hydrogen. Fermentative products are oxidized to produce acetate and proteins are reduced to hydrogen, in the third step (Acetogenesis). Methanogenesis; consumption of hydrogen and producing hydrogen organisms are both presented in biomass, which is the 4th step. These reactions yield energy. Figure 1 shows the biodegradation process of the anaerobic digestion (Matheri et al., 2016, Matheri et al., 2017, Matheri et al., 2018).

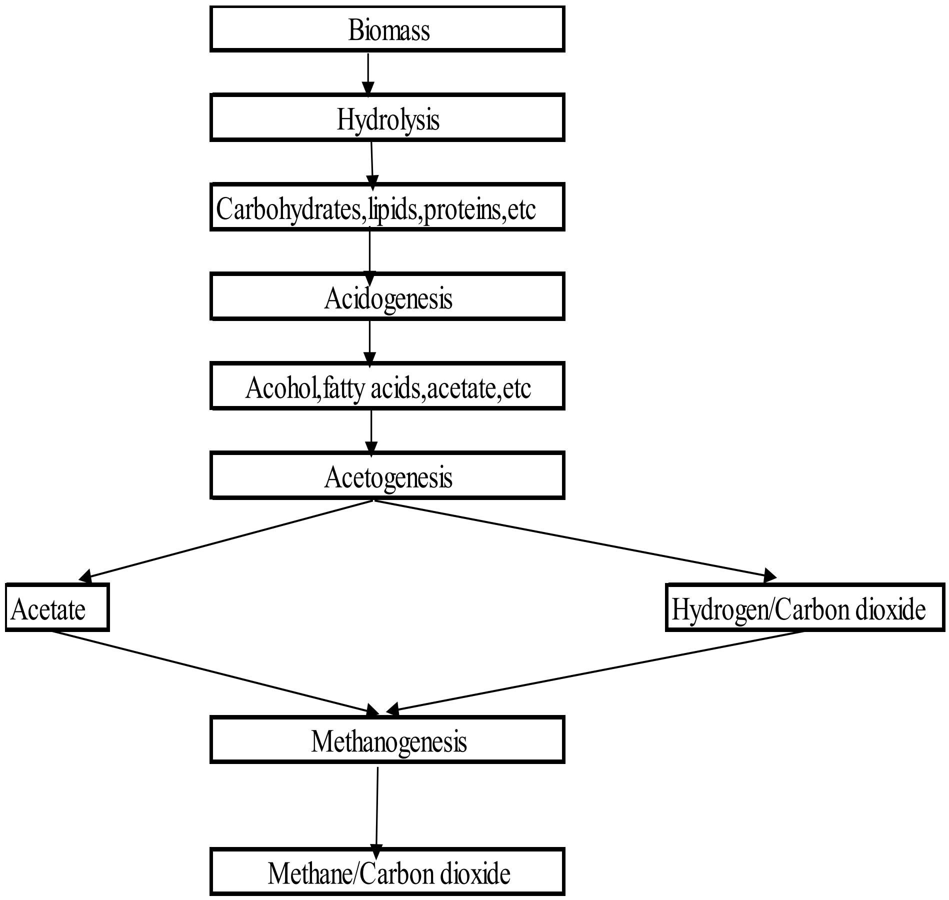

Figure 1. Biodegradation process of the anaerobic process

The objective of this study was to optimize methane biogas production using cow dung, chicken manure and pig manure as substrates. Mono-digestion and co-digestion were compared on which produces more biogas under mesophilic conditions.

2. Methodology

3.1 Substrate Characterization

Cow dung, chicken and pig manure were collected from two different farms. Cow dung and pig manure were collected from Nigel farm whereas the chicken manure was collected from Grootgeluk farm in KZN. They were collected using plastic bags and weigh before they were stored in a laboratory refrigerator at 4^{o}C until they were used for feeding into the digesters to prevent early fermentation. Deionized water was used to form slurry. Pretreatment: physical-removal of stones, chemical-adjustment of pH was done before feeding the digesters. Weighing of the substrates was done using analytical scale balance. Four samples were prepared in this experiment;(A) 20 g cow dung;(B) 20 g chicken manure;(C) 20 g pig manure, (D) mixture of all substrates in a ratio of 1:1:1.

To determine methane production rate, a batch digester was fed with the co-digested substrates (cow dung, chicken manure and pig manure) and inoculum (cow dung) under mesophilic condition at 37 ^{0}C and pH was neutralized by the by a solution of 8g NaOH in 100 ml and H_2SO_4. The digester was flushed with nitrogen to expel the oxygen and create an anaerobic condition. The digesters were immersed in the water bath and kept under the set temperature.

3.2 Method to determine Physical-chemical properties of the feed stock

3.2.1 Total solids

Three dishes with different samples of (cow dung, chicken manure and pig manure) were weighed before taken into the oven. The samples were placed in the oven shown in figure 2, which was preheated to 105 ^{0}C for 24 hours. They were cooled at room temperature and weighed again. The weight of the sample, which was left from the oven, gave the total solids and was represented in percentage basis:

$$TS = \left(\frac{Mdry}{Mwet}\right) \times 100\ \%$$

Where: M (dry) = dry mass and M (wet) = wet mass

Figure 2: Oven set @ 105 ^{0}C (Laboratory oven)

3.2.2 Volatile solids

Volatile solids content of the raw material was determined by drying the samples at 550 ^{0}C for duration of 2 hours in a furnace at the metallurgy laboratory, which is used to determine Ash content. Volatile solids were calculated using the following formula:

$$VS = \left(\frac{Mdry - Mash}{Mdry}\right) \times 100\ \%$$

Where: M (ash) = mass remained after burning

3.2.3 The carbon nitrogen ratio determination

The carbon nitrogen ratio was determined using the following equation:

$$\frac{C}{N} = \frac{F \times Cf \times S \times Cs}{F \times Nf \times S \times Ns}$$

Where:
C- carbon
N- nitrogen
C_f - carbon composition of the first substrate
C_S- carbon composition of the second substrate
N_f -represents nitrogen composition of the first substrate
N_S-represents nitrogen composition of the second substrate

The methane was analysed using an automatic methane potential test system (AMPTS II). AMPTS II has been developed for online measurements of ultra-low biogas and bio-methane flows produced from the anaerobic digestion of any biological degradable substrate at laboratory scale. The biochemical methane potential test provides a preliminary indication of the biodegradability of a substrate and of its potential to produce methane via anaerobic digestion. The gases are collected by downwards displacement method.

3. Results and Discussions

The results and discussion represent the experimental for the mono-digestion and co-digestion under optimized conditions. The substrates were cow dung, chicken manure and pig manure. During the experiment, the pH of the three substrates were measured before the anaerobic digestion (AD). This was within the optimal range of 7.2 to 7.9 that is required to achieve a maximal methane yield in anaerobic digestion. Initially, anaerobic digestion, the pH for cow dung was 7.86, for chicken manure 7.59 and for pig 7.15 with the temperature kept constant at 37 ^{0}C throughout the experiment.

3.1 Substrate Characterization

The characterization of the substrates was presented as showed in Table 1.

Table 1: Cow dung, chicken manure and pig manure characteristic results

Property	Unit	Cow dung	Pig manure	Chicken manure	Mixture
Wet	g	20.32	20.12	20.27	19.96
Dry	g	11.78	15.47	3.94	14.14
Burned	g	2.21	8.81	0.125	6.42
MC	%	43.03	23.11	80.56	29.16
TS	%	57.97	76.89	19.44	70.84
VS/TS	%	81.24	43.05	96.83	54.6

The methane produced was determined by the characteristics of the feed stock during anaerobic digestion process. According to Choudhury et al., (2002) for the material to be suitable for digestion it must have TS above 20 %. In this study TS for cow dung and pig manure were above 20 % (57.97 % for cow dung and 76.89 % for pig manure), which was suitable for digestion whereas TS for chicken was lower than 20 % (19.44), which was not within the required percentage.

In the case chicken, the TS percentage was lower meaning that it was not within the range. For co-digestion of cow dung, pig manure and chicken manure at the ratio of 1: 1, TS was found to be 70.84 % which was within the optimum range. VS/TS values of the three substrates were 81.24 % for cow dung, 43.03 % for pig manure and 96.83 % for chicken manure. The VS value for co-digestion of the three substrates was 54.6 %. This indicated that all three substrates had a significant organic solid content that could be converted to methane during the anaerobic digestion process. For chicken manure VS/TS value was 96.83 %, which was higher compared to the other two substrates, this indicated that chicken manure had higher organic content.

Table 2: Organic element analysis

Element	Cow dung	Pig manure	Chicken manure
Carbon	41.59	23.13	33.22
Hydrogen	5.49	3.42	3.51
Nitrogen	2.01	2.49	2.5
C/N Ratio	20.69	9.29	13.29

Where:
C – Carbon
H – Hydrogen

N – Nitrogen
TS – Total Solids
VS – Volatile

3.2 Bio-methane Potential (BMP)

Figure 3 showed the quantity of methane produced from each of the substrate used for mono digestion of cow dung, pig manure and chicken manure.

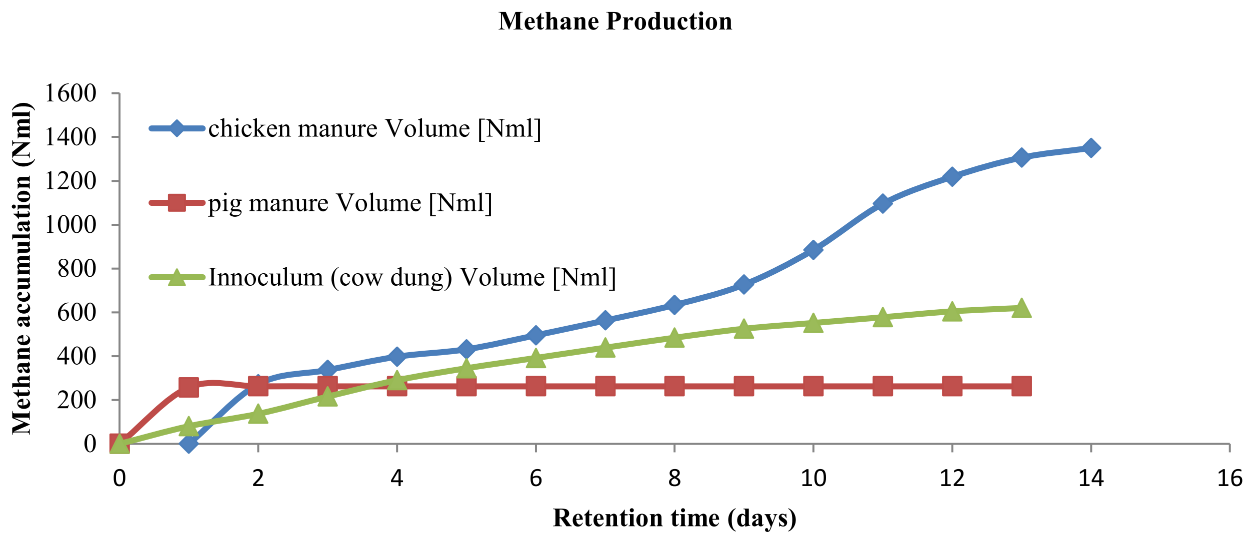

Figure 3: Methane production from mono-digestion

The peaks in Figure 3. showed the quantity of methane produced from each of the substrate used for mono digestion of cow dung, pig manure and chicken manure. Chicken manure produced more on the first day (272 Nml) compared to pig manure (257.4 Nml) and cow dung (80.5).On the ninth day chicken produced 884 .9 Nml and then on the tenth day it went up again to 1095.6 Nml, reached its peak on day 13 and stopped, chicken yielded better results compared to the cow dung and pig manure because chicken had a higher VS/TS percent which is desirable for biogas production. Pig manure started producing biogas on the first day which was 257.4 Nml and stopped on the second day with the volume of 262.3 Nml. Pig manure showed poor results compared to cow dung and chicken manure. VS/TS for pig manure was the lowest 43.05 % compared to chicken manure 96.83 % and cow dung 81.24 % and this resulted in pig manure producing less biogas. Cow dung followed chicken manure, it started producing 80.5 Nml on the first day which was less when compared to what pig manure and chicken manure produced, it started peaking up on the third day by producing 215.7 Nml and on the fourth day it produced 290.4 Nml. Cow dung showed a rapid increase in biogas production from day five onwards until it reached its highest peak, the highest cow dung yield was 620.1 Nml.

Figure 4 showed the effect of co-digestion in methane production.

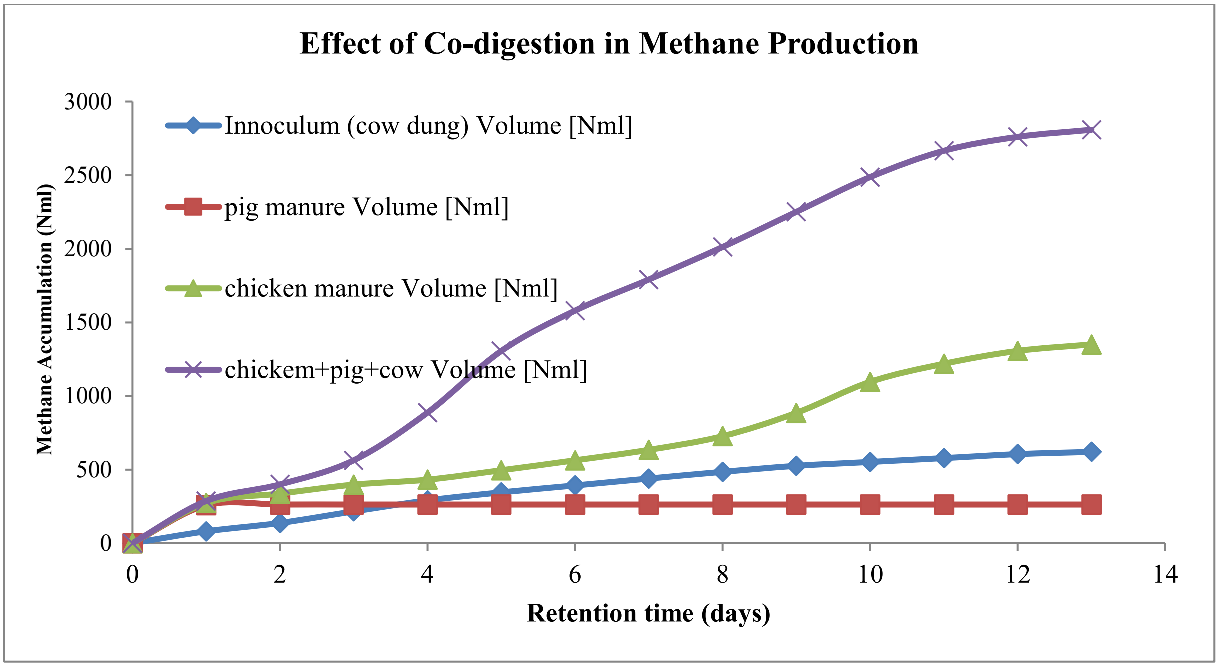

Figure 4: Effect of co-digestion in biomethane production

Figure 4**.** Showed the effect of co-digestion in methane production. Cow dung, chicken manure and pig manure were co-digested using the ratio of 1:1 under mesophillic condition in AD. Co-digestion results were very higher than that of mono digestion of the three substrates which resulted in co-digestion producing more methane biogas compared to mono digestion. According to Mata-Alvarez et al., (2000), co-digestion of animal manure with biomass was better than mono-digestion as it produced higher methane due to the synergistic effects of the co-substrates. The advantages of co-digestion of animal manure: buffering capacity increases and the accumulation of volatile fatty acids during digestion was possible (Campos et al., 1999), (Brummeler and Koster, 1990); it can avoid high concentrations and produces required pH for methanogenesis stage, high concentration of NH_3 can be avoided; it can also provide the required C: N ratios by the methanogens (Angelidaki and Ahring, 1997).

4. Conclusion

This study evaluated the methane production from cow dung, chicken manure and pig manure. It showed that mono-digestion and co-digestion of cow dung, chicken manure and pig manure enhanced biogas production and methane content under mesophilic condition (37 ^{0}C). The results indicated that there was substantial methane production potential from chicken manure and cow dung. Chicken produced the best methane production compared to the other two wastes. Pig manure indicated poor results in producing methane. When mono-digestion and co-digestion were compared, co-digestion was better than mono-digestion. The result for co-digestion of cow dung, chicken manure and pig manure yielded higher biomethane, biogas accumulation and a higher methane content than that of mono-digestion.

5. Acknowledgment

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