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Mesophilic Anaerobic Co-Digestion of Cow Manure, Chicken Manure and Pig Manure at Different Feed Ratios

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***Abstract*:** *This experiment investigated the effect of anaerobic co-digestion of cow manure, chicken manure and pig manure at the different feed ratios under mesophilic conditions. Experiments were conducted, and results obtained from a batch anaerobic digester operating at mesophilic temperature of 37 0C and pH of around 7 was used to determine the accumulation of biogas production. The carbon/nitrogen (C/N) ratios of cow, chicken and pig manure mixtures were found to be 17,07 %, 9,91 % and 9,08 % respectively which is reasonable considering the fact that only manures are digested. The results show that a ratio of 4:1:1 cow, chicken and pig manures performed best during the experiment and it is further recommended that these mixtures should be co-digested with grass or food wastes to better results.*

Keywords: *Anaerobic, Co-digestion, Kinetics, Mesophilic Temperature, Modified Gompertz.*

1. Introduction

During the last century, the energy demand has increased by a factor of two to three times more than before. This demand has caused different problems for our society such as our resources depleting and environmental problems. Anaerobic digestion (AD) was introduced in the 1970's after the first energy crisis. It has since experienced rapid growth and is now considered as a mature technology. AD is a biological treatment performed in the absence of oxygen and produces biogas. Biogas which is the main product of AD, has been regarded as a good alternative source of energy. It can be used for the generation of electricity. It can be converted to methanol and the purification of biogas can be fed into gas distribution grids. The benefits of AD are clearly evident not only as a source of energy but an alternative to divert organic wastes and reduce greenhouse gas emissions from landfills [1, 2].

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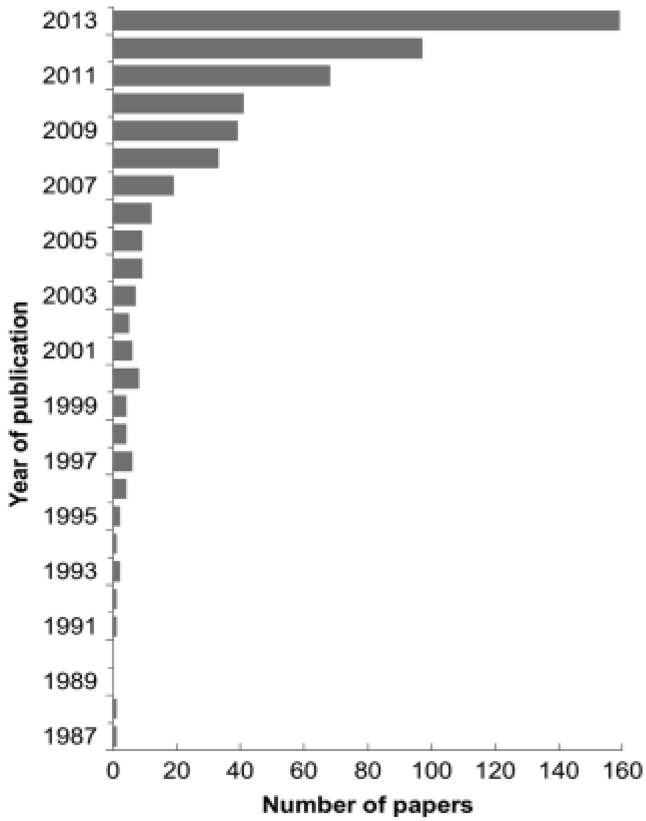

Fig. 1. Evolution of number of papers published with the words co-digestion or co- digestion in its title [1]

Anaerobic co-digestion is a biological process that takes place in the absence of oxygen and it stabilizes organic matter to produce mainly methane and carbon dioxide also known as biogas.

The production of biogas takes place in four steps: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Bactericides carry out the hydrolysis step. This is the stage where large organic matter is broken down into simple sugars, fatty acids and amino acids. The next stage is acetogenesis during this stage fermentation produces low alcohol and organic acids. In the next step acetogenesis, the products of acidogenesis are converted to hydrogen, acetic acid and carbon dioxide through the help of the acetogenic bacteria. In the final stage, methanogenesis, the methanogenes bacteria converts hydrogen to acetic acid. Hydrolysis is followed by acidogenesis where low alcohol and organic acids are produced through fermentation process utilized by fermentative bacteria. This includes volatile fatty acids (acetic acid, butyric acid and propionic acid), gases like carbon dioxide, ammonia and hydrogen and aldehydes. In third step (acetogenesis), the products of acidogenesis are converted to acetic acid, hydrogen and carbon dioxide by acetogenic bacteria. Methanogenesis is the final stage whereby methanogenes bacteria converts hydrogen, acetic acid and carbon dioxide to methane and carbon dioxide [3].

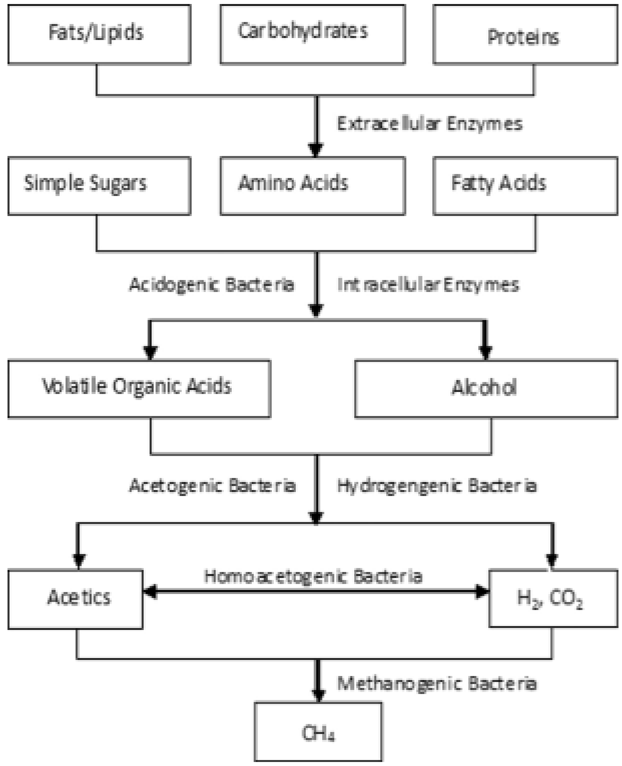

Fig. 2. Anaerobic Digestion process model [2]

The factors that affects biogas production is: pH, temperature, the nature of the substrate, C/N ratio and the exposure of oxygen to the process [4].

The main objective of this study was to investigate the effect of co-digestion at different feed ratios in the production of biogas from cow manure, pig manure and chicken manure under mesophilic conditions.

2. Methodology

2.1. Substrate Characterization

Cow manure, pig manure and chicken manure were collected at the Nigel farm in Gauteng province, South Africa. Waste characterization was done to determine the composition of the substrates. This included physical and chemical composition with regards to C/N ratio, volatile solids, total solids and elemental analysis for Carbon, Nitrogen, Sulphur and Hydrogen in accordance with the standard methods [4].

The cow manure, pig manure and chicken manure were weighed with a mass scale and their masses recorded. This process consists of weighing, sizing and recording data.

The biogas production rate was determined using a batch digester with an inoculum to substrate feed ratio of 1:1. This was followed by preparing the digester bottles with ratios of 4:1:1, 1:4:1 and 1:1:4 which was 60 ml of composite sample. The remainder to make 400 ml samples was filled up with distilled water. The selected conditions for this experiment was a temperature of 37 0 C and pH of around 7. To create anaerobic conditions, the digester was flushed with nitrogen to eliminate the oxygen and make the environment anaerobic. The digesters were placed in the water bath bypassing the CO2 fixing bottles and connected to the flow cells. This was followed by connecting the internet cable and the gas measuring device to the computer.

The methane and biogas produced in each sample was automatically recorded in the software both in hours and in days [5].

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Fig 3: Biogas Production set-up from left to right, Gas Chromatograph, Digesters, CO2, Collection bath

3. Results and Discussion

3.1. Characteristics of the Substrates

Table I. Main characteristics of the substrates and co-substrates (Cow manure, Chicken manure and Pig manure)

Properties	Units	Cow Manure	Chicken Manure	Pig Manure	Mixture
Moisture Content(MC)	%	1.81	0.88	0.97	1.22
Total Solids(TS)	%	98.19	99.12	99.03	98.78
Volatile Solids(VS)	%	47.10	34.78	33.08	38.32
C/N Ratio 4:1:1	-	20.69	13.28	9.08	17.07
C/N Ratio 1:4:1	-	20.69	13.28	9.08	9.91
C/N Ratio 1:1:4	-	20.69	13.28	9.08	9.08

Table 1 shows the characteristics of the material used during co-digestion of cow manure together with chicken manure and pig manure. The mixture consisted of ratios of 4:1:1, 1:4:1 and 1:1:4. The characteristics of the feed will have a quality and quantity effect on anaerobic digestion. Depending on the characteristics of the feed stock used during anaerobic digestion (AD) this will have an effect on the quality and quantity of biogas produced per day [6].

In this report, the TS of cow manure chicken manure and pig manure were 98.19 %, 99.12 % and 98.78 %. VS values were found to be 47.10 %, 34.78 % and 33.08 %. The respected results found falls within the range for suitable anaerobic digestion as determined by [7].

The role of the C/N ratio is very important during the anaerobic digestion process. If the nitrogen is consumed to rapidly, the C/N ratio will rise and this leads to lower gas production. This can lead to the accumulation of ammonia which cause the pH levels to rise above 8.5

The C/N ratio for the mixture of cow manure, chicken manure, pig manure at ratios of 4:1:1, 1:4:1, 1:1:4 was found to be 17.07 %, 9.91 %, and 9.08 %, which is within the optimal range [8].

3.2. Effects of Co-Digestion of Cow manure, chicken manure and pig manure

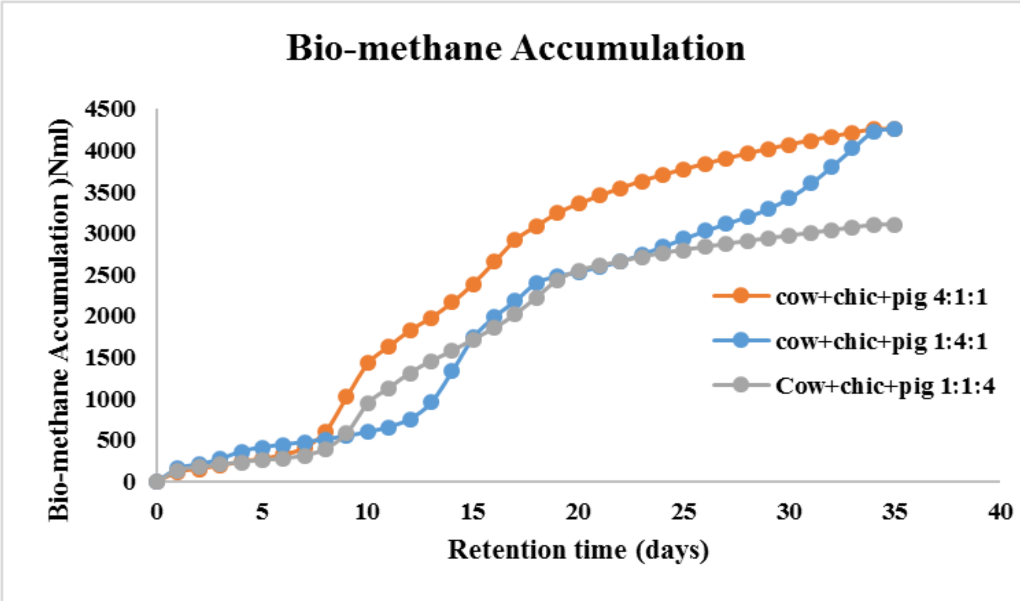

Fig. 4. Bio-Methane production vs days

The biogas that is produced and the methane accumulated of the co-digestion of cow manure, chicken manure and pig manure mixtures with different ratios are shown in figure 4. The results show that the substrates used for anaerobic digestion gives a good yield of biogas. From Fig 4 it can be observed that the ratio 4:1:1 produced the best results as compared to the ratios 1:4:1 and 1:1:4. These observations may be associated with the continuous growth of the bacteria which favors the production of biogas.

The biogas production started from day two of the experiment in all digesters, this increased with time. A spike in production occurred in all three mixtures and the mixture with a ratio of 4:1:1 steadily increased from day twenty. This is due to the fact that the pH dropped and favored conditions for the bacteria to produce biogas. A drop means that more H2S is formed.

3.3. Effects of pH

Table II : pH results before and after digestion

Substrate Ratio	pH Before	pH After
Cow Chicken Pig 4:1:1	7.13	6.22
Cow Chicken Pig 1:4:1	7.36	6.01
Cow Chicken Pig 1:1:4	6.91	5.75

The pH is an indication of the acidity- alkalinity of a solution. The microorganisms involved in the anaerobic digestion require pH values between 6-7. The production of biogas is sensitive to changes in the pH and these optimal conditions take place within a narrow pH interval. It is difficult to adjust the pH during the experiment as the equipment does not allow for it. It is seen from the experiments that the pH value ranges for cow, chicken and pig manure as is seen in table 2.

The pH results for the substrates tested indicated that the digester systems were at approximately optimum pH levels. However, the pH of a digester system is quite sensitive to the partial pressures of CO2 as well as to the relative concentrations of acid and alkaline components found in its liquid phase. This could completely stop the anaerobic process [9].

4. Conclusion

Biogas production from co-digestion of cow manure, chicken manure and pig manure was established to be feasible at temperature of 37 ^{0}C. It is seen in the experiment that more than two different animal manures can be co-digested together to produce biogas.

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