Evaluation of animal manure as a feedstock for the production of biogas in comparison with sewage water microalgae

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Abstract: The use of fossil fuels as energy sources have impacted the environment and the economy negatively as they are the major sources of carbon emission to the environment. It is therefore important to find cheap and clean sources of energy options to protect the environment. In this study, the use of animal manure: cattle and chicken drops were assessed in comparison with microalgae as sources of feedstock for the production of flammable biogas. Semi quantitative and qualitative data analyses were carried out to evaluate the biogas produced from these feedstock sources. The biogas from chicken manure was not flammable indicating the presence of high concentration of carbon dioxide compared to other feedstock sources. High quality of biogas was produced when microalgae was digested by the cellulose degrading microorganisms. However, the initiation of the decomposition process and production of gas took a little longer time compared to the chicken and cattle manure. Though, the chicken drops shown high volume of CO_2 production, the mix of feed stock with other carbon sources such as microalgae to maintain the C:N balance, would enhance the decomposition process faster to produce a flammable biogas.

Keywords: Biogas, Chicken drops, Methane, Cattle manure, Microbial decomposition, Microalgae.

1. Introduction

Fossil fuels have been used across the globe as the means of energy for many years. In the world 88% of the annual primary consumption accounts for fossil fuels [1]. Fossil fuels are the largest contributor of greenhouse gases to the biosphere and are responsible for 99% of carbon dioxide into the atmosphere [6]. So fossil fuels contribute to the pollution of the environment and increase the greenhouse effect that brings climate change. Natural processes are unable to remove the greenhouse gases from the atmosphere at the rate they are being emitted hence the effects of global warming are severe. Besides, there are frequent rises in fuel prices due to the diminishing reserves of fossil fuels [4].

Waste water microalgae, human and animal excreta can be used as the alternative sources of biofuel through their anaerobic digestion. Anaerobic digestion is a biological process performed by many classes of bacteria and generally consists of four steps namely hydrolysis, acidogenesis, acetogenesis and methanogenesis [7]. Moreover, the final product of this process which is methane can be used as fuel for vehicles or co- generation of electricity and heat thereby leading to reductions in greenhouse gas emissions. Anaerobic digestion of microalgae was extensively analyzed and concluded to represent an essential step in the development of an integrated and cost efficient microalgae-based process of carbon dioxide capturing and methane production [9].

2. Materials and Methods

Sample collection area:

All samples: sewage water microalgae, chicken manure, cow manure and waste water were collected from the farm site at the National University of Lesotho. Samples were collected in 5L water collecting containers and carried to the Microbiology laboratory, department of biology.

Treatment formulation:

Two sets of experimental approaches with or without cellulose degrading microorganisms were designed. A mass of 300g of each of the collected samples were measured and placed in 5L bottles which served as

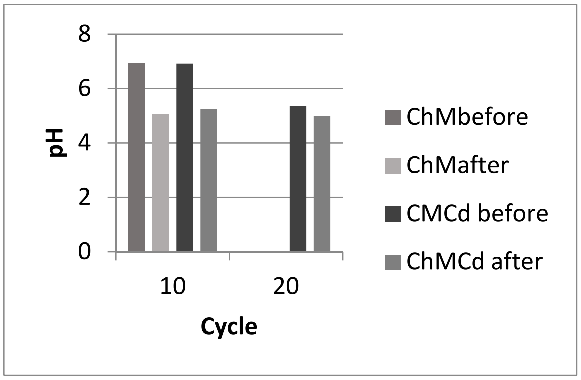

Figure 1. pH of water before and after bubbling with biogas produced from chicken and microalgae feedstocks.

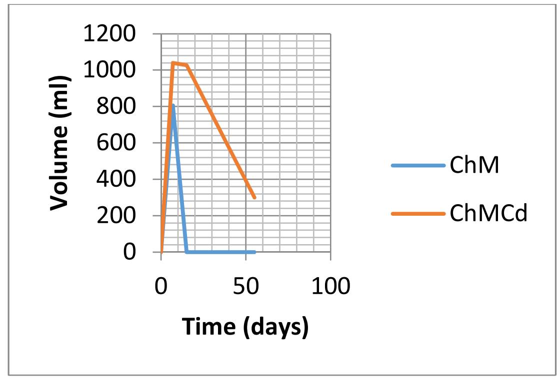

Figure 2. Volume of biogas produced.

anaerobic digesters. Equal volume of waste water from the donga (0.45L) were used to the chicken and cattle manure as a starter, which latter was filled up by adding 3.5L of tap water. Containers with microalgae were filled with microalgae sewage water (4L) The experiment was done in duplicates and repeated once.

Digester assembly and incubation:

A 5L capacity plastic bottles were used as laboratory scale anaerobic digesters and dry infusion bags were fitted on each digester to collect the biogas. The lids of the digesters were tightly fitted and carefully punctured at the center. Needles and tubes were used to connect the digester to the infusion bags. Careful folding of the tubes was taking care of as ensured to prevent any kinks which may impede gas transfer. The anaerobic digester contents were incubated at the greenhouse temperature maintained between 27-30^{o}c and daily inspection of the gas production was done by observing the swelling of the bags.

Determination of gas volume:

Displacement method was used to determine the volume of gas present in the infusion bags.

Determination of pH:

The gas was bubbled through distilled water and the pH measured for the analysis of the presence of acidic gases present. The pH of the distilled water was measured before and after bubbling with distilled water.

Flame test:

Flame test was carried out using a small needle to determine the gases color produced from the end of the needle flame. The gas was then bubbled through aqueous $Ca(OH)_2$ for the determination of the presence

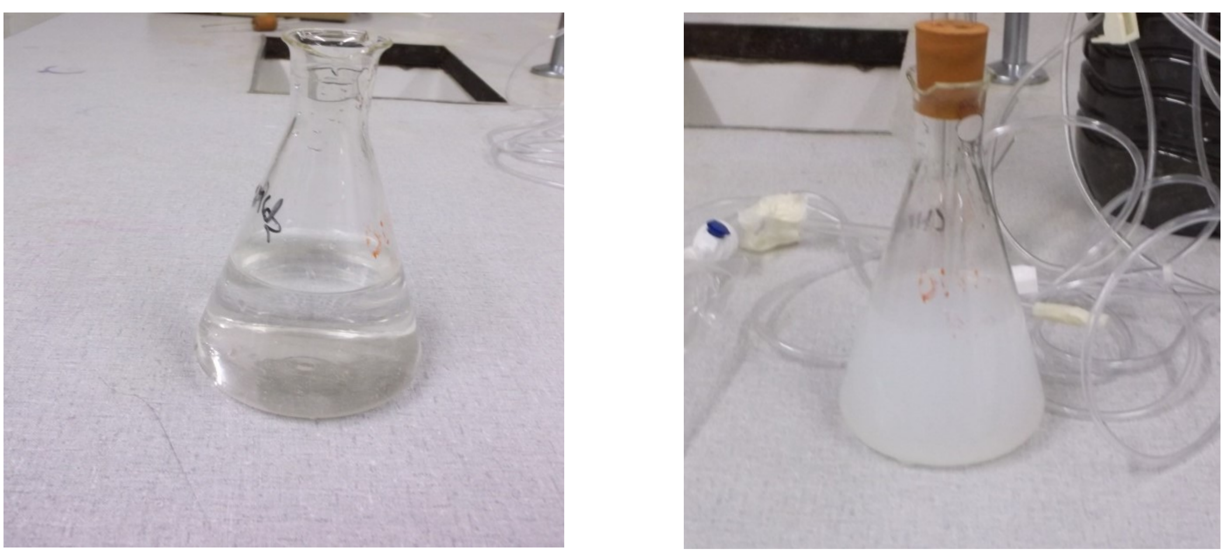

Figure 2. Calcium hydroxide before (left) and after (right) after bubbling with biogas.

of CO_2 in the gas.

3. Results and Discussion

Determination of gas pH:

The pH of water during both the first and second cycles dropped below neutral after bubbling with biogas from the digesters (Figure 1).

In this study, it was observed that the pH of the gas determined from the feedstocks digestion in the simulated lab scale anaerobic digesters was acidic (Figure 1). The acidity could be due to the presence of volatile fatty acids in the reactor. The build-up of volatile fatty acids due to acidogenic bacteria present in the bioreactor results in the decrease of pH [2]. The pH drop could also be due to the action of sulfate-reducing bacteria present in the reactor. Under anaerobic conditions, sulfate reduction microorganisms may have also produced hydrogen sulfide (H_2S) which lowers the pH significantly [8]. Moreover, the presence of carbon dioxide (CO_2) due to the action of acetogenic as well as sulfate reducing bacteria has an effect on the acidity of the content in the system. Carbon dioxide produces carbonic acid in the presence of water ($CO_2 + H_2O \leftrightarrow H_2CO_3$). The presence of H_2S and CO_2 in the gas makes it unsuitable to use since H_2S contributes to sulfur dioxide emissions and can be corrosive when present with moisture. CO_2 on the other hand reduces the heating capacity of the gas.

Determination of gas volume:

Higher gas volumes were collected from digesters inoculated with cellulose degrading microorganisms (ChMCd) than in chicken manure alone (ChM) (Figure 2). Moreover, these digesters further produced gas while those without cellulose degraders could not.

The production of gas in chicken manure started three days after the anaerobic digesters were capped. The manure was fresh from the farm and had high moisture content. According to [3], water is one of the necessary requirements for growth of microorganisms. This says that even before the manure was to be anaerobically digested there was already a large number of microorganisms present in the manure. Moreover, chicken manure is very rich in nitrogen which is one of the macromolecules necessary for bacterial growth [3]. Being exposed to the anaerobic conditions, the already large number of facultative and aerotolerant microorganisms proliferated and as they metabolized they produced sufficient volumes of gas. As illustrated in Figure 3, the highest gas volume was seen in the digesters inoculated with cellulose degrading microorganisms (ChMCd) and such digesters continued to produce gas. The cellulose degrading microorganisms further degraded any cellulose present in the manure through hydrolysis thereby providing substrate for acedogenic microorganisms [10]. This therefore seems to improve the gas production, as the cellulose degrading microorganisms provide the carbon substrate for the acedogenic microorganisms.

Figure 4. Royal blue microalgae biogas flame.

Test for carbon dioxide:

The white precipitate was observed when the gas was bubbled through water (Figure 3).

A white, milky precipitate was observed when the gas was bubbled through calcium hydroxide ($Ca(OH)_2$) solution (Figure 3), which represented by the following reaction:

$$CO_{2(g)} + Ca(OH)_{2(aq)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$$

Carbon dioxide is one of the major compounds found in biogas and its percentage can be as high as 45% depending on the substrate used for anaerobic digestion [5]. In this study, it was investigated that the cattle and chicken manure when used as a feed stock alone, the amount of CO_2 produced was very high and the flame test shows negative result due to the nature of the gas produced, i.e Carbon dioxide is produced in all the stages involved in the anaerobic process except during hydrolysis. So, it is advisable to use a mix biomass feed for the anaerobic digester.

Flame test:

Chicken manure is very rich in nitrogen and during its anaerobic digestion ammonia is generally abundant in high concentrations. Ammonia inhibits the methanogenic bacteria thereby lowering the rate at which methane is produced [2]. In general, gases that are present in higher concentrations are those that do not support burning e.g carbon dioxide and ammonia, and those that are toxic when burned e.g hydrogen sulfide. So, it is advisable to use a mix of biomass

Table 1. Burning characteristics of the gas

digester	characteristic
ChM	No burning
ChMCd	No burning
Ma	Blue flame
Ma +cd	Blue flame

sources to be used as a feedstock for the production of biofuel. Gas from anaerobic digestion of microalgae (Ma) burned with a blue flame which is an indicator that methane is the dominating gas produced (Figure 4).

4. Conclusions

Biogas from chicken manure is of poor quality and it is not advisable to use as a source of fuel. Therefore, night soil due to its similar composition to the chicken manure is not advisable to use as a source of fuel too. Co-digestion of the chicken manure with other substrates that will increase the C/N ratio to a level suitable for biogas production should be fed into the digester, however proper care should be taken to adjust the proportions so that the correct ratio is met. The gas should also be purified before being used in order to avoid health risks to people using it. Biogas from microalgae on the other hand burns perfectly and does not require any purification before it is used. It is therefore wise to opt for the use of biogas from waste water microalgae since it is safe and clean for both human beings and the environment.

5. References

1. L. Brennan and P. Owende; Biofuels from microalgae - A review of technologies for production, processing, and extractions of biofuels and co-products; Renewable Sust. Energy Rev. **14** 2010 557-577.

2. I.H. Franke-Whitte, A. Walter, C. Ebner and H. Insam; Investigation into the effect of high concentrations of volatile fatty acids in anaerobic digestion on methanogenic communities; Waste Management (New York) **34** 2014 2080-2891.

3. M.T. Madigan, J.M. Martinko, D.A. Stahl and D.P. Clark; Brock Biology of Microorganisms; 13th Ed. Benjamin Cummings U.S.A. 2012.

4. P.J. McGinn, K.E. Dickinson, K.C. Park, C.G. Whitney, S.P. MacQuarrie, F.J. Black, J. Frigon, S.R. Guiot and S.J.B. O'Leary; Assessment of the bioenergy and bioremediation potentials of the microalga Scenedesmus sp. AMDD cultivated in municipal wastewater effluent in batch and continuous mode; Algal Res. **1** 2012 155-165.

5. U.C. Okonkwo, E. Onokpite and A.O. Onokwai; Comparative study of the optimal ratio of biogas production from various organic wastes and weeds for digester/ restarted digester; J. King Saud Univ. http://dx.doi.org/10.1016/j.jksues.2016.02.002

6. J.W. Richardson, D. Myriah, M.D. Johnson and J.L. Outlaw; Economic comparison of open pond raceways to photo bio-reactors for profitable production of algae for transportation fuels in the Southwest; Algal Res. **1** 2012 93-100.

7. R. Sebola, H. Tesfagiorgis and E. Muzenda; Production of Biogas through Anaerobic Digestion of various Waste: Review; Int. Conf. on Chemical, Intergrated Waste Management and Environmental Engineering; April 15-16 2014 Johannesburg.

8. D. Stepan; More methane, less acid gas". Biomass magazine 2017 Available from biomassmagazine.com/ articles/1741/more-methane-test-acid-gas
Accessed on 5 May 2017.

9. B. Tartakovsky, F.M. Lebrun and S.R. Guiot; High-rate biomethane production from microalgal biomass in a UASB reactor; Algal Res. **7** 2015 86-91.

10. W. Wu, Y. Chen, S. Faisal, A. Khan, Z. Chen, Z. Ling, P. Liu and X. Li; Improving methane production in cow dung and corn straw co-fermentation systems via enhanced degradation of cellulose by cabbage addition; Scientific Reports 2016.