Batch anaerobic co-digestion of cow dung and donkey manure

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Abstract. Biogas from anaerobic digestion can be a solution to current and future energy needs in South Africa. One option for improving biogas yield of anaerobic digestion of organic matter is co-digestion. Cow dung and donkey manure were co-digested together. The co-digested experiments were conducted using 1.0 m^3 batch biogas field digesters that were designed and constructed. The biogas volume of biogas produced was measured daily by a biogas flow meter. Highest biogas yield was obtained from a mixing ratio of 50% cow dung to 50% donkey manure, however lowest biogas yield was obtained from cow dung. The study revealed that donkey manure has a higher caloric value and produces more biogas with higher methane content than cow dung. The investigation proved that co-digestion is a simple way to optimize biogas production rate.

1. Introduction

South Africa is the most industrialized country in Africa and is highly dependent on convectional fuels, non- renewable sources such as coal, oil and natural gas. This makes the country be one of the largest emitters of greenhouse gases in the world. Coal in South Africa, provides around 75% of fossil fuel demand and accounts for 90% of power generation in the country (Zahlten, 2011). These non-renewable sources are dwindling and becoming increasing expensive and environmentally damaging.

Biogas from anaerobic digestion can be a solution to current and future energy needs in South Africa. Compared to other renewable energy sources, such as solar and wind power, the biogas can easily be stored and transported. The implementation of biogas technology is not affected by geography of a particular area. Biogas technology involves the use of biogas digesters that are constructed vessel in which animal waste and other bio-degradable materials are broken down by bacteria complete absence of oxygen to produce biogas. The biogas digester is free from theft risks as compared to solar installations. Biogas consists of different component gases, mainly methane (CH_4), carbon dioxide (CO_2), with traces of hydrogen sulphide (H_2S) and hydrogen (H_2) gas (Bajracharya *et al*., 2010). The energy content of biogas is 9.8 kWh/m^3 (Thours 2007).

During digestion 80% of the pathogens and solids are eliminated and more effective liquid fertilizer is created as micro-organisms transform the organic pollutants into dissolved nutrients (Thy *et al*., 2003, Botero and Hernandez, 2005; Lansing *et al.,* 2008). The anaerobic digestion process is divided into four steps, hydrolysis, acidogenesis, acetogenesis and methanogenesis (Davidsson 2007; Leksell 2005).

- **Hydrolysis** is the first stage of anaerobic digestion where insoluble organic compounds such as proteins, fats, lipids and carbohydrates are converted into soluble organic components such as amino acids, fatty acids, monosaccharides, and other simple organic compounds.
- **Acidogenesis or Fermentation** is the second step where soluble compounds produced in the first stage are further degraded resulting in the production of carbon dioxide (CO_2), hydrogen (H_2) gas, organic acids, alcohols and some organic sulphur compounds (Gerardi, 2003).
- **Acetogenesis** is the third stage in which lactic acid, alcohols and glycerol, are converted by the acetogenic micro-organisms into acetic acid, hydrogen and carbon dioxide (Wiese *et al.,* 2009).
- **Methanogenesis** is the last stage where fermentation products such as acetate and hydrogen are converted to methane and carbon dioxide (Schön, 2009).

Efforts have been dedicated in recent years to find ways of improving the performance of digesters by treating different biomass. Co-digestion is the simultaneous digestion of homogenous mixture of two or more substrates (Wu, 2009). The use of co-substrates usually improves the biogas yields from anaerobic digester due positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates (Mata- Alvarez *et al.,* 2003).

The aim of this study is to optimize methane content of biogas through co-digestion. Donkey manure and cow dung were used as co-substrates in the study. Current literature survey shows that co-digestion of donkey manure and other organic wastes in anaerobic digestion have not been carried out hence the current study to investigate the effect of co-digestion of cow dung and donkey manure. The results of the study indicate that co-digestion increases biodegradability of substrate and increases the amount of methane produced per unit of volatile solids.

2. Methodology

2.1 Biogas digester construction

A cylindrical batch biogas digester was constructed on a sunny site. The volume of the digester was 1.0 m^3. The biogas digester foundation was filled with concrete. The ratio of cement, sand and aggregate for the concrete was 1:2:3. The concrete was 20cm deep. The concrete was rammed to increase strength. The concrete was allowed to solidify for seven days. Before any construction, the concrete slab was covered with a black plastic sheet to avoid any moisture transfer from the ground into the digester. It was a brick wall digester with double walls. For mortar, the ratio of cement to sand was 1: 3. Dry soil was put between the double walls. This was done to insulate the digester thereby minimizing temperatures fluctuations within the digester. The brick wall was reinforced in order to strengthen the structure. The top dome part of the digester was also reinforced with concrete and steel rods. The digester was plastered. For inside plastering it was one part cement: two parts sand and outside plastering it was one part cement to three parts sand. Epoxy paint was used for painting the inside of the digester. Epoxy paint is one of the best paints on the market that prevents moisture transfer from inside or outside the biogas digester. A designed mechanical stirrer was used for agitation. Figure 1, shows the diagram of the constructed field-batch biogas digester.

2.2 Substrate preparation

Samples of fresh cow dung and donkey manure were obtained from University of Fort Hare Honey dale farm. The wastes were crushed mechanically to ensure homogeneity. The substrates were weighted on a digital scale. The water content for each sample was determined using the recommendation for better biogas production as reported by Ituen *et al*., (2007), that is, a total solid (TS) of 8% in the fermentation slurry.

2.3 Determination of substrate parameters

Total solids (TS), volatile solid (VS), ammonia-nitrogen (NH_4-N), pH, total alkalinity (TA), and chemical oxygen demand (COD) were determined by using the standard methods of the American Public Health Association (ALPHA), 2005. Calorific value (CV) of prepared slurry was measured using a calorimeter (CAL2K-ECO) and pH of slurry was measured by a digital pH meter. pH values were performed at the start, during and end of the biodegradability process. Temperature of the digester slurry was measured during biodegradability test by type K thermocouple thermometers.

2.4 Biogas analysis

The pressure of the biogas was measured daily by means of a pressure gauge fixed on top on the batch biogas digester. Methane and carbon dioxide contents in the biogas were sensed by Non-Dispersive Infra red sensors. Palladium/Nickel sensors were used for sensing hydrogen and hydrogen sulphide in biogas. CR 1000 data logger processed and stored data from different sensors. The output from data loggers was displayed on a computer screen. The system was powered with dc rechargeable battery that was connected to 20 W photovoltaic modules. Daily biogas production from the digester was measured by a biogas flow meter. The biogas digester was stirred by a mechanical stirrer. The stirring was done once a day for 25minutes. Previous studies noted higher reaction rates with higher agitation frequency (Cubas *et al.,* 2011). Figure 1, is the schematic diagram of the experimental set-up.

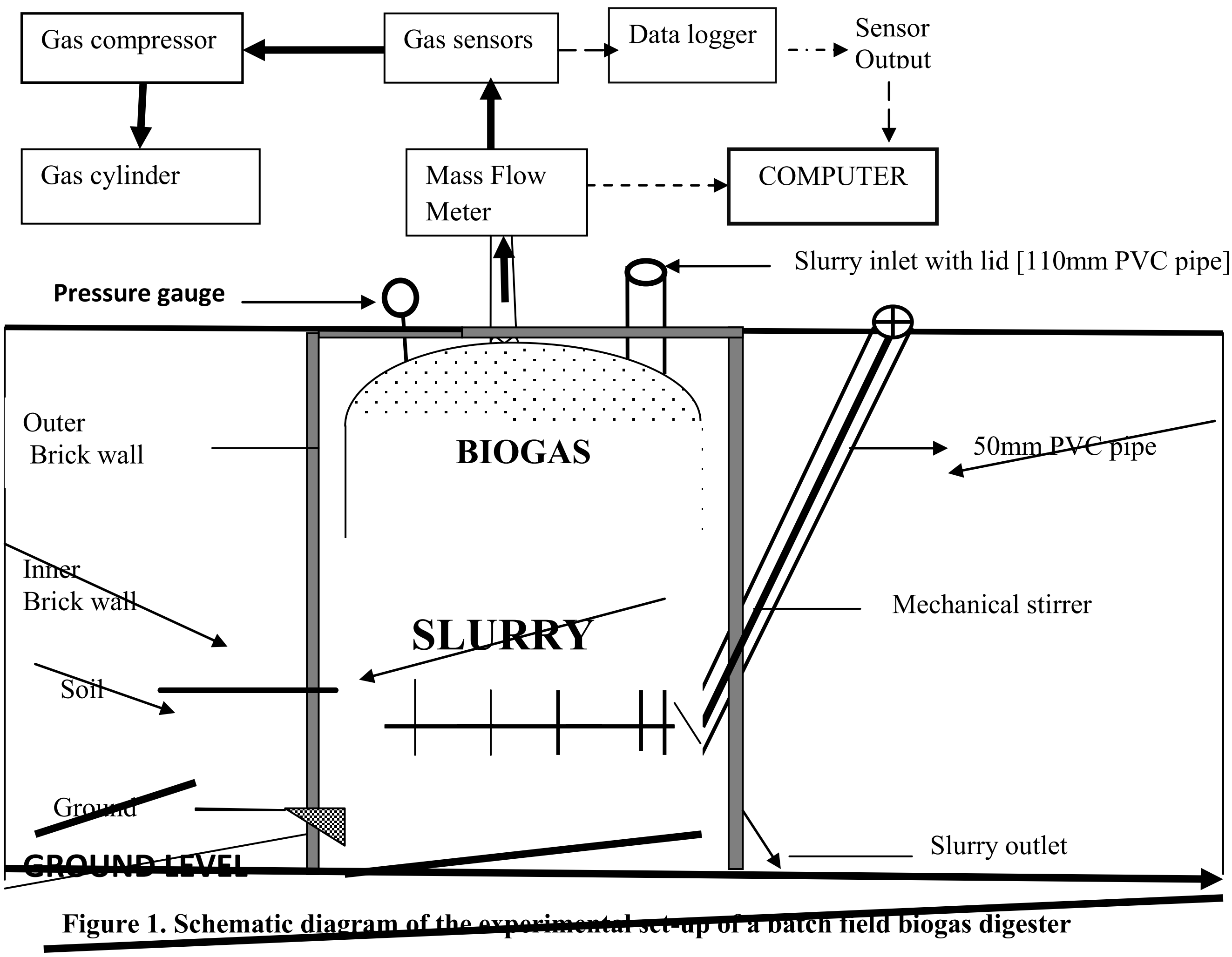

Figure 1. Schematic diagram of the experimental set-up of a batch field biogas digester

3. Results and Discussions

Table 1 shows characteristics of the two samples and Table 2 shows biogas composition for each sample. The composition of biogas was mainly methane, carbon dioxide and hydrogen. There were some traces of hydrogen sulphide. The methane yield for donkey manure was 50-65% and cow dung was 50-60%. Co-digestion of 50% of cow dung and 50% donkey manure produced 60-75% methane. Donkey manure had more CV, VS and COD than cow dung, hence more biogas.

Figure 2, shows a graph of variation of gas yield for the samples. For all the substrates the gas yield increased with time and then attains a constant value. However the co-digestion of cow dung and donkey manure attained maximum gas yield on 26th day while for cow dung it was on 30th day and for donkey manure it was on 28th day. From the graph, it can be observed that donkey manure has a higher gas yield (390*l*) as compared to cow dung (365*l*). However, the gas yield was observed to increase if donkey manure was mixed with cow dung. If cow dung is mixed with donkey manure in the ratio 1:1 the gas yield increases by approximately by 56%.

Table 1. Substrate characteristics of different samples

Parameter	Cow dung	Donkey dung
TS%	16.83	19.88
TS (mg/l	168160.48	198778.83
VS (mg/l)	117370.89	144189.99
VS/TS%	69.80	72.54
TA(mg/L)	5678-6260	6230-6536
COD(mg/L)	39754-40150	40110-41248
N-NH_3	125-230	135-250
Calorific value (MJ/g)	25.39	29.83
Temperature ^{0}C	28.0	28.0

Table 2. Biogas composition of different samples

Parameter	Cow dung	Donkey dung	50% cow dung and 50% donkey dung
pH [of slurry]	6.45-7.4	6.58- 7.5	6.6-7.7
CH_4%	40-60	50-60	60-75
CO_2%	30-45	35-45	20-30
H_2S%	0	0-0.1	Trace
H_2%	1-8	1-6	1-6

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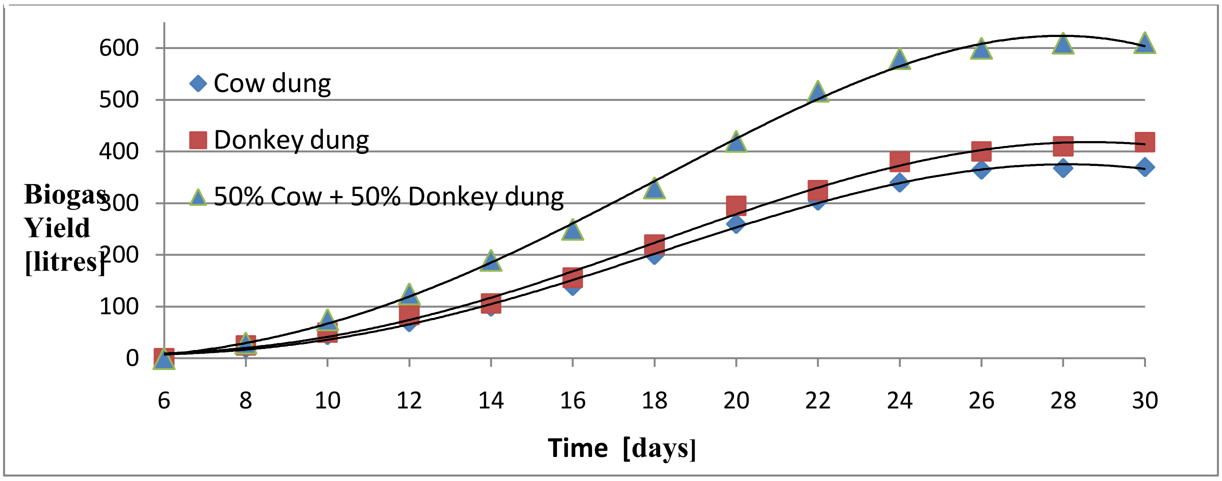

Figure 2. Biogas yield for single and co-substrates

Regression analysis was used to find the gas yield prediction and equations 1 to 3 gives predictions of the gas yield (Y) for each day (X).

Cow and donkey manure: $Y = 0.000X^5 - 0.006X^4 + 0.204X^3 - 0.659X^2 - 0.825X$ $\quad R^2 = 0.999$

Donkey manure: $Y = 0.000X^5 - 0.009X^4 + 0.273X^3 - 2.106X^2 + 5.254X$ $\quad R^2 = 0.996$

Cow manure: $Y = 0.000X^5 - 0.014X^4 + 0.400X^3 - 3.425X^2 + 0.64X$ $\quad R^2 = 0.997$

There was a strong positive relationship between gas production and % of co-substrates used (R^2 = 0.999) as shown on equation 1. For co-digestion of cow dung and donkey manure gas production was highest between 18-26 days. From 30 days and above biogas production decreased until it became negligible because all the food in the digester had been consumed and there was no supply of food for the methanogens. For cow dung, gas production increased as between 16-28 days. However, cow dung produces less biogas than donkey manure. The highest gas yield from sample C was attributed by stable pH. The slurry mixture was able buffer its, hence highest biogas yield. Higher biogas yield from donkey manure was attributed by high VS, COD, CV and suitable pH. Low biodegradability material in cow dung resulted in low biogas yield. Donkeys process food more efficient than cattle and this is also a contributory factor for higher gas yield in donkey manure. In all samples the effluent pH fell within the range 6.45 to 6.6 while the final ranged from 7.4 to 7.7 (Table 2). Maximum insulation of the batch biogas digester resulted in negligible temperature variations.

4. Conclusions

Co-digestion of donkey manure and cow dung is highly desirable for increasing methane yield. Biogas production rate was different for different wastes because bacteria involved in the decomposition of the wastes were different. Co-digestion of cow dung and donkey manure increases the gas yield by about 56%. The biogas technology can be viable development option for Eastern Cape region of South Africa where plenty of donkeys and cattle are kept. Introduction of inocula in batch digesters has been noted as a way of reducing hydraulic retention time. The study also needs to highlight that there is need to keep more donkeys in rural areas because there have the following studied advantages:

- Take less food compared to cattle
- Have a longer life span (over fifty years)
- Produce more energy per gram than sheep, goats and cattle
- Can be a source of food (meat and milk)
- Produce more biogas with high methane content when co-digested with other wastes.

5. References

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