# Effect of co-digestion of food waste and cow dung on biogas yield

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**Abstract.** This paper aims at finding the effect of co-digestion of cow dung and food waste on total biogas yield. Biogas production was improved through co-digestion of cow dung and food waste (FW) containing a small fraction of inoculum under mesophilic temperature (37ºC) over a retention time of 24 days. Co-digestion ratios of 1:1, 2:1 and 3:1 for cowdung/foodwaste were used for the study on anaerobic digestion on the co digested matter. Tests were carried out starting with the preparation of substrates, substrate characterization to determine the moisture content (MC), total solids (TS), volatile solids (VS) and ultimately batch anaerobic digestion experiments under thermophilic conditions (370C). The moisture content, volatile solids and total solids for food waste were 78, 22 and 90.7% respectively while the characteristics for cow dung were 67.2, 32.8 and 96.0 % respectively. From the study, a mixing ratio of cow dung: food waste of 1:2 was found to be the optimum substrate mixture for biogas production at 25595.7 Nml. The accumulated gas volumes of 18756.6, 14042.5, 13940.8 and 13839.1 Nml were recorded for cow dung: food waste ratios of 2:1, 1:1, 1:3 and 3:1 respectively. For a co-digestion containing more of the food waste than cow dung, a higher volume of biogas is produce.

## 1. Introduction

Anaerobic digestion is a multistep chemical and biological process where organic matter (food waste, cow dung, human excreta etc) is broken down in the absence of oxygen and coonverted into biogas via complex interactions of microorganisms [1]. The process usually takes place in specifically designed plants known as bio-digesters under set conditions or occurring naturally in marshes and land fills.The production of biogas from biodegradable matter is not limited to using only one type of feedstock at a time. When different feedstocks are used for anaerobic digestion, this is known as co-digestion. It stabilizes nutrients in the digester while also increasing the amount of feedstock available for digestion [2]. Many feedstocks in Botswana such as cow dung, food waste, agricultural biomass have been identified as feedstock for biogas generation. Biogas is a combustible mixture of gases produced through anaerobic digestion of organic matter. The main constituents of the gas are methane ($CH_4$) which makes about 55-70% and carbon [1] dioxide ($CO_2$) making about 30-45% of biogas. Hydrogen sulphide makes less than 2% of the gas and with other gases in small traces. Biogas offers benefits such as; used as an energy source, environmental protection etc. The global shift towards renewable energy is happening at a phenomenal pace and Botswana is lagging behind but with so much potential. Botswana's sole electricity supplier is Botswana Power Corporation (BPC) which produces electricity from coal via the Morupule coal power station. Less than 2% of the energy supplied comes from renewable sources. According to the Botswana's annual agricultural survey, cattle population in Botswana has over the years increased to over 2.2 million indicating that there is great potential for biogas production.

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## 2. Experimental Method

### 2.1. Materials and Chemicals

Food waste (FW) as well as cow dung were used in this study as substrates for anaerobic digestion. FW was collected from the Botswana International University of Science and Technology (BIUST) students cafeteria that is located on campus while cow dung was sourced from a farm house in the local vicinity of Palapye, Botswana. The substrates were co-digested at different ratios to determine their effect on biogas production and the mono-digested cow dung from previous study , was used as an inoculum. Substrates were stored in the refrigerator at 4℃ until the day of digestion for the prevention of early fermentation taking place. Tap water was used to suspend the substrate or to form the slurry, and the effect of ions present in the water in bacteria was assumed negligible. NaOH was used as a neutralizing material to ensure balancing of substrate pH levels. Fig. 1 and Fig. ***2*** show the samples of food waste and cow dung respectively

**Fig. 1.** Food waste substrate

**Fig. 2.** Cow Dung

## 2.2. Equipment used

A refrigerator was used to preserve the substrates before use. An electric hot air-oven was used to dry the samples to remove all the moisture. Moisture content and total solids (TS) were determined as a result. These samples were placed on crucibles then put into the oven. The volatile solids (VS) were determined using a furnace. For weighing out of the samples, a calibrated analytical balance was used. A knife was used for size reduction of the cow dung. pH measurements were done using a Jenco pH 6810 – Handheld pH/mV/Temperature meter pH meter. The Biochemical Methane Potential (BMP) test was conducted in the Automatic Methane Potential Test System (AMPTS II). The AMPTS II has a fixing unit for carbon dioxide, measuring device for gas volume, bioreactor agitation system. The AMPTS II Software was used to analyze the results.

## 2.3 Procedure

### *2.3.1 Preparation of substrates*

Food waste and cow dung were removed from the refrigerator and sundried. Thereafter the samples were taken through a pre-treatment stage which involved communition, sieving to remove large solid particles (e.g rocks, inorganic materials) and mixing to obtain a homogeneous sample. This step was necessary to reduce unwanted materials in the samples at the same time increasing the surface area for the digestion process.

### *2.3.2 Characterization tests*

Chemical Characterization of the samples such as proximate analysis were carried out to determine the moisture content (at a constant temperature of 105$^{o}$C), total solids, Volatile Combustible Matter (VCM) in a sealed crucible (temperature adjusted to 550$^{o}$C), Fixed Carbon (a by-product from VCM) and Ash content with a temperature of 950$^{o}$C in an open crucible.

### *2.3.3 Total solids, Volatile solids and Moisture Content*

Freshly collected samples in a crucible were weighed using an analytical balance. 3 grams of a representative sample was added into the dish and placed in a hot electric oven heated to 105 °C and left in the oven for 20 hours to allow the volatiles to evaporate. The dish was then allowed to cool in a desiccator for 2 hours. The final mass of the dish was measured and the dry mass was calculated. For determining volatile solids, sample from the total solids test was taken for further heating in a furnace at a temperature of 550 °C for 2 hours to burn all the organic matter. The difference in weight between the sample after heating at 105 °C and 550°C shows the VS content of the biomass. The samples moisture content which is simply the amount of water in the sample was easily determined from Eq. 3.

$$TS = \frac{m_{dried}}{m_{wet}} \ x\ 100\% \quad (1)$$

$$VS_{initial} = \frac{m_{dried} - m_{burned}}{m_{wet}} \ x\ 100\% \quad (2)$$

$$MC = \frac{m_{wet} - m_{dried}}{m_{dried}} \ x\ 100\% \quad (3)$$

Where:
TS is the total solids (%), $m_{dried}$ is the amount of dried sample (g), $m_{wet}$ is the initial amount of wet sample (g), VS is the volatile solids (%), $m_{burned}$ Is the mass of sample after heating at 550 °C (g) and $MC$ is the moisture content (%)

### *2.3.4 Determining the Bio-Methane Potential (BMP)*

As shown in Fig. 3, the bioprocess control AMPTS II is made up of three sections being the digesters, carbon dioxide fixing unit and the gas collection system. The experimental setup was made up of 2000 mL glass bottles which were used as reactors with a working volume of 1800 mL and headspace of 200 mL. The glass bottles were sealed with a rubber stoppers with two metal tubing for purging and gas exit and a plastic cap fitted with a stirrer and motor. The mixture was then transferred to the assay bottles and put in a water bath and covered with a lid to maintain the mesophilic temperature of 37 ˚C. 500 mL glass bottles with 350 mL working volume were used as $CO_2$ scrubbers which were fitted with plastic screw caps and rubber stoppers with two metal tubing for sealing the bottles. A scrubbing solution was prepared (NaOH) following standard procedures to a desired concentration of 3M. A pH indicator solution was added to determine the saturation point for the scrubbing solution to be replaced.Gas collecting unit was made up of a water bath which included a water tank, flow cell holder, 15 injection mould flow cells containing magnetic metal pieces, base and protection plate and plastic glass lid for the water tank. The water tank was filled with deionized water to the max level. The motors were switched on and the flow cell calibrated. The AMPTS II software was now used from the computer to start the process by first filing the experimental data and start the run. The experiments were run for 21 days.

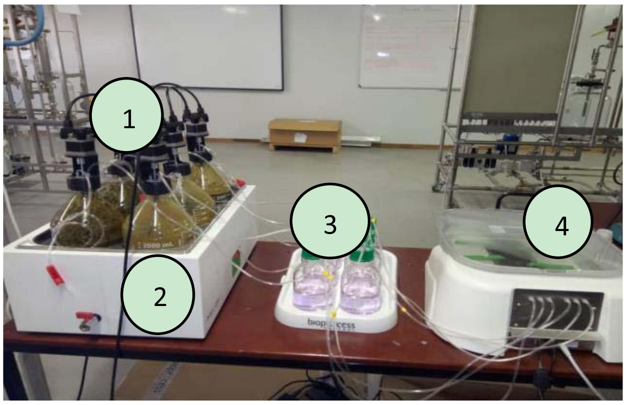


**Fig. 3.** AMPTS (II) for Biochemical Methane Potential test, (1) Water bath (Thermostatic), (2) Glass reactor, (3) Fixing Unit for Carbon Dioxide and (4) Measuring Device for Gas Volume [3].

## 3. Results and Discussion

### 3.1 Characterization of the samples

Feedstock characterization is of great significance in the AD process. Knowledge of the general characteristics such as the composition of the substrate (feed stock) is pivotal for calculating the amount and composition of biogas produced as well as the amount of energy in the biogas [4]. The quality of biogas (methane) produced, in particular is mainly dependent on the characteristics of the feed stock during anaerobic digestion. Tab.1 shows the characteristics of the material used during co-digestion of food waste with cow dung.

**Tab.1.** Characteristics of food waste and cow dung

| Property | Food waste | Cow dung |
|---|---|---|
| Moisture content (%) | 78 | 67.2 |
| Total solids (%) | 22 | 32.8 |
| Volatile solids (%) | 90.7 | 96.0 |

### 3.2 Co-digestion of food waste and cow dung

According to [2], the yield and quality of anaerobic digestion products can be improved by the co-digestion of cow dung and food waste (FW) containing a small fraction of inoculum under optimized conditions. According to [2] single substrates probably lacks buffering and desired nutrient content therefore resulting in an inadequate anaerobic digestion environment. Co-digestion offers several advantages when compared to digestion of single feedstock, such as better balance for nutrients (e.g. C/N ratio) [5], good capacity for buffering [6], less inhibition effects (e.g., accumulation of $NH_3$ and VFA), and increased stability for the process [2].

In studying the effect of co-digestion on biogas yield, 6 batch bio-digesters were set up for cow dung to food waste mixtures at ratios of 1:1, 2:1, 3:1, 1:2 and 1:3 under a mesophilic temperature (37°C). The substrates used for this study where those whose characterisation is shown in Tab.1.

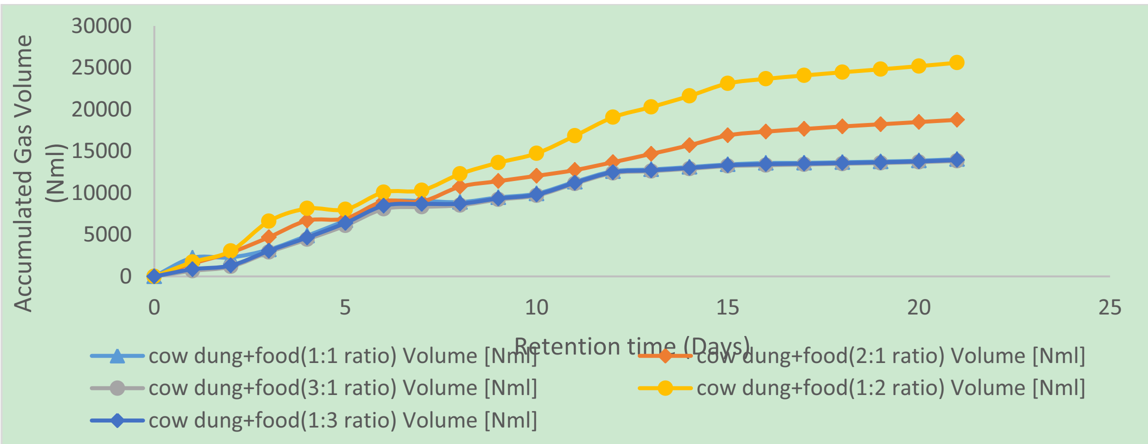


**Fig. 4.** Accumulated gas volume with time

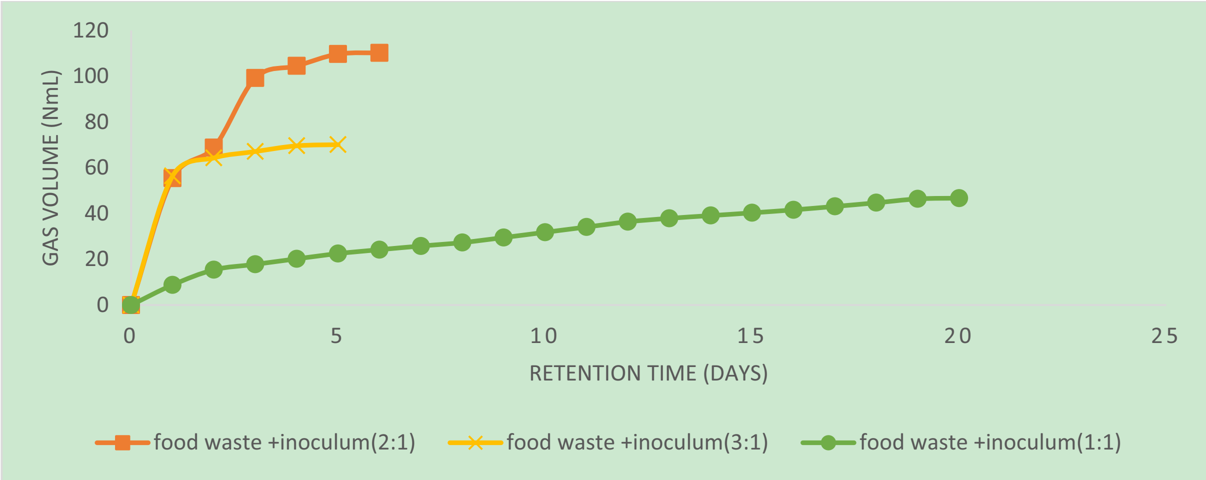


**Fig. 5.** Accumulated gas volume for mono-digested food waste

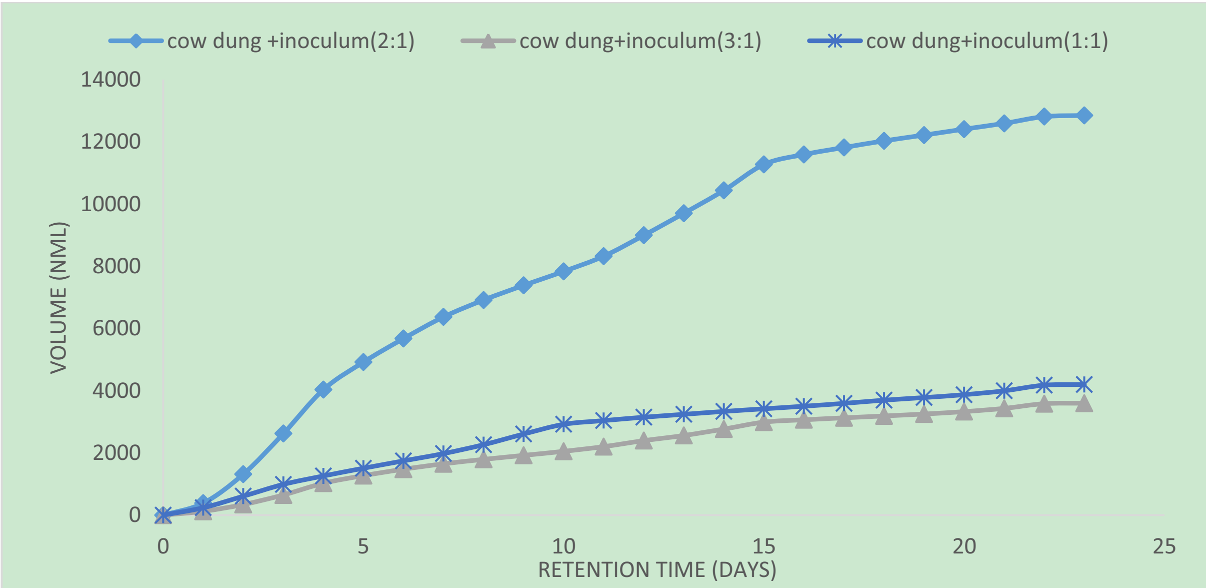


**Fig. 6.** Accumulated gas volume for mono-digested cow dung

Experimental results reveal that there is an increase in biogas yield from co-digestion of cow dung with food waste when compared with mono-digestion of the same substrates under the same conditions as shown in Fig. 4. A higher accumulated gas volume was obtained from a digester that was loaded with cow dung/food waste at a ratio of 1:2 (25595.7 Nml). The accumulated gas volume from other digesters were recorded to be 18756.6, 14042.5, 13940.8 and 13839.1 Nml for cow dung/ food waste ratios of 2:1, 1:1, 1:3 and 3:1 respectively.
Mono-digestion of cow dung in Fig. 6 had yielded a maximum volume of 12847.4 Nml whereas the mono digestion of food waste as shown in Fig. 5 yielded a maximum accumulated volume of 110.2 Nml at a ratio of 2:1 for food waste to inoculum. An increase of 49.8% in the total biogas production for co-digestion was recorded.
More gas was produced where the ratio of cow dung to food waste was 1:2. According to [7], this is because cow dung has relatively lesser methane yield, but acts as an excellent inoculum due to its better buffering capacity and high nutrient contents. On the other hand, [8], measured the rate of hydrolysis step in food waste and cow dung in both mono digestion and co-digestion processes using biomethane potential assays. The results showed an increased rate of hydrolysis for co-digestion of food waste and cow dung compared to mono digestion~~,~~ the observation was attributed to dilution of inhibitory compounds. The optimum cow dung/food waste ratio was found to 1:2 at which methane production increased by 48.9%.

## 4. Conclusion

According to the experimental results obtained, a mixing ratio of cow dung:food waste of 1:2 was found to be the optimum substrate mixture for biogas production. This mixing ratio yielded the highest biogas production. The accumulated gas volume from other digesters in were recorded to be 18756.6, 14042.5, 13940.8 and 13839.1 Nml for cow dung/ food waste ratios of 2:1, 1:1, 1:3 and 3:1 respectively. One important note from the study is that co-digestion with food waste at a higher mixing ratio than cow dung produced more biogas when compared to ratios that had more cow dung in the mixing ratio. It was also observed that food waste to cow dung ratio that is made up of 50% or less of either of the substrates produces more biogas compared to ratios with more than 50% of the substrates. Individual substrates have shown to produce a lower yield of biogas compared to when they are co-digested.

## 5. References

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