Biogas Yields Variance from Anaerobic Co-Digestion of Cow Dung with Jatropha Cake Under Mesophilic Temperatures

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Abstract-
Anaerobic co-digestion requires the digestion of two or more homogenous substrates to produce biogas. The superlative participated condition is when principal amount of most important substrate (example manure or sewage sludge) is combined and fermented with each other with lesser quantities of single, or a variety of additional substrate. The co-digestion of one or more substrates commonly improves the biogas output from anaerobic digesters owing to positive improvement brought about in the digestion medium and the furnishing of missing nutrients in one substrate by another. Anaerobic co-digestion of cow dung and jatropha cake for biogas production was carried out in the batch digester in the absence of oxygen at ambient temperature with different mixing ratios for 40 days. The result indicated that treatment with 75% jatropha 25% cow dung had the highest volume of biogas at the rate of 24.41% and treatment with 100% jatropha released has the highest percentage quality of biogas produced (methane) at the rate of 59.6%. Treatment with 50% cow dung 50% jatropha cake was found to be the appropriate mix ratio, since it was rank 2nd in both qualitative and quantitative analytical point of view from the experiment performed.

Key words: cow dung; jatropha cake; mix-ratio; anaerobic digestion; biogas

1. Introduction

Anaerobic digestion, which is an acceptable renewable method for generation of energy, is the process by which biomass (also referred to here as substrate or feedstock) is converted to biogas by the decomposing action of methanogenic microorganisms [1]. Biogas composes mainly of methane and carbon dioxide and appears to be a substitute to traditional methane gas being used majorly for domestic cooking [2]. Usually, the composition of biogas consists of 60-65% of methane that support combustion processes. With the improvement on biogas utilization, it is now one of the most employed means of converting waste/residue to energy [2]. Renewable energy is now dependable because of its favourable outcome in gas to power from biogas process.

All over the world, anaerobic digestion is one of the biological waste treatment methods used in waste treatment plants. In this case, the gases released in the processes are brought together in a confined place and used as a gaseous fuel product rather than allowing it to move freely. Besides, biogas generation has the capacity to alleviate poverty since it provides substitute to high cost fuels and commercial fertilizers, increase agricultural and aqua cultural products, discourage local deforestation, generate employment and income, as well as strengthen local
technological knowledge and skills [3]. Energy is an indispensable factor at homes, socials and industries. To maintain our socio-economic mode of living, equal and regular quantity of energy for industrial and domestic intentions is required. Energy is needed always to meet several intents, particularly at the household levels. Failure to have enough and constant energy supply for domestic needs makes life unbearable. Availability and cost are the two important factors that dictate the use of energy for domestic intention, it means that energy must be available always and affordable for people especially the low-income earners. Economic development of a specific society is calculated based on energy availability to its people.

Biogas production from agricultural biomass and residue can be a relative means of overcoming the problems of energy shortage, reducing high cost of energy, providing better ways of waste management and bringing in sustainable development all around the world [4]. As a result of relative deficiency and fleeting of fossil fuel resources, there is a need for improvement in renewable energy generation most especially biogas, which is a sustainable replacement for Natural Liquefied gas (NLG). Agricultural operations are predominant activities in Africa, therefore the use of local resources from agricultural residues to produce energy is of great value.

Recently, *Jatropha curcas* was discovered as one of the most suitable sources, among many other species, that has relative high yield of oil for biodiesel production. Jatropha seed cake is a waste material due to the presence of toxic materials (crucin, saponins etc.) in the cake, it can neither be used for animal feeding nor applied directly as fertilizer on the farm [5]. Hence, proper utilization of the cake for biogas production is required to overcome the problem of disposal in benefit of energy generation. The gas produced from this cake can be used for heating, cooking, lighting, running internal combustion engines while the digested cake slurry can be directly used as organic manure in boosting soil fertility.

To improve the digestibility of agricultural residue, many efforts have been made with different pretreatment methods [1]. In light of this, mixing of agricultural residues with animal manure is usually recommended for optimizing their Carbon:Nitrogen (C:N) ratio [6]. In order to increase the stability of the process and improve the economic values in the commercial anaerobic digesters, co-digestion is usually used [7]. Due to the positive interactive effects created amongst substrates, co-digestion has the potential to increase methane production [6], [8] and improve the economic value of the process [9]. Also, feedstock like cow dung from livestock is an abundant unpleasant waste whose management is a subject of concern. Therefore, appropriate mix ratio of both jatropha cake and cow dung can result into higher yield of biogas production which can go a long way to solve energy and waste management problems. The aim of this study is to investigate appropriate mix ratio of the jatropha cake and cow dung for higher yield of biogas in a batch digester at ambient temperature.

2. Methodology

2.1 Materials

The materials and equipment used for the study includes; substrates (cow dung and jatropha cake), five 5-liters containers, Gas analyzer (Multi 4 Stage Biogas Analyzer), five tyre tubes,
flexible pipe, five thermometers (-10 to 1100), five pressure gauge (sphygmomanometer), digital weighing scale and five 2-ways taps. Five 5-liters containers, which served as the main digesters, were used for the experiment. The design of a laboratory batch digester reported by Barthelmeß [10] was adopted. Proximate analysis was carried out on the substrates fed into the digesters.

2.2 Anaerobic co-digestion of substrates

Similar to the anaerobic co-digestion method adopted by Olojede et al. [11] for quality biogas production from cow dung varied with sunflower leaves, potato and pawpaw peels, five digesters (A, B, C, D and E), as shown in Figure 1, were set up simultaneously and observed at constant ambient temperature and pressure. The substrates were checked for stones and other unnecessary materials before mixing. The substrates were mixed with water in a ratio of 1:2, a standard mixture for optimum biogas production [12]. The substrates were properly stirred before they were mixed in varying proportions. The quantity of the substrate loaded in the digesters are as follows: Digester A, 7 kg of cow dung; Digester B, 5.25 kg of cow dung and 1.75 kg of jatropha cake; Digester C, 3.5 kg of cow dung and 3.5 kg of jatropha cake; Digester D, 1.75 kg cow dung and 5.25 kg jatropha cake and Digester E, 7 kg jatropha cake. The ratio of the cow dung and jatropha cake as indicated in Table 1 was adopted from Chrish [13] and Julian [14].

![Batch digesters set-up for co-digestion of cow dung with jatropha cake](image)

### Table 1: Proportions for Different Treatments

| Treatments | Mixture Proportions                     |
|------------|----------------------------------------|
| A          | 100% cow dung                          |
| B          | 75% cow dung and 25% jatropha cake     |
| C          | 50% cow dung and 50% jatropha cake     |
| D          | 25% cow dung and 75% jatropha cake     |
| E          | 100% jatropha cake                     |
Daily ambient temperature and pressure together with the slurry temperature and pressure were taken by 12 noon daily. The set-up was left for a retention time of 30 – 40 days as recommended by Ostrem et al. [15]. The collection of biogas was done using tyre tubes that were tightly fixed to the gas outlets of the digester. Quantity of the biogas produced was obtained with the use of Equation 3 [16].

\[
R_0 = \frac{R}{M} \times \% \text{ composition} \\
R_{0 \text{ mixture}} = R_{CO_2} + R_{CH_4} \\
V = \frac{R_{0 \text{ mixture}} \times T_{\text{digester}}}{P_e}
\]

Where:
- \( R_0 \) = specific gas constant of a gas (J/kgK),
- \( R \) = universal gas constant (J/kgK),
- \( M \) = molecular mass of the gas concerned,
- \( R_{0 \text{ mixture}} \) = total specific gas constant of the assumed biogas composition (i.e. CH\(_4\) and CO\(_2\)),
- \( P_e \) = estimated daily pressure of the digester,
- \( T_{\text{digester}} \) = estimated daily temperature (°C) and
- \( V \) = volume of biogas generated (m\(^3\)).

The Gas analyzer (Multi 4 Stage Biogas Analyzer) was used to determine the gas compositions at intervals depending on the production rate.

3. Results and Discussion

The result of the proximate analysis of the substrates is shown in Table 2. The organic dry matter of the substrates is considerably high, ranging from 84.80% to 92.22%. This indicates that there is high buffering capacity of the selected substrates for adequate anaerobic process. Cow dung has the highest C/N ratio of 15.7 while jatropha cake has C/N ratio of 10.2. The combination of cow dung and jatropha cake formed an excellent mixture of substrate for biogas yield owing to their very high C/N ratio. This experiment follows the submission of Verma [17] that optimum C/N ratio of the substrates can be achieved by co-digestion of high and low C/N ratios such as organic solid waste mixed with sewage or animal manure.

| Parameters                  | cow dung | jatropha cake |
|-----------------------------|----------|---------------|
| Dry Matter, DM (%)          | 40.69    | 96.00         |
| Organic Dry Matter, ODM (%) | 84.80    | 92.22         |
| Potassium (%)               | 1.12     | 3.22          |
| Moisture Content, MC (%)    | 59.31    | 4.00          |
| Carbon (%)                  | 27.57    | 37.40         |
| Nitrogen (%)                | 1.76     | 3.69          |
| C/N ratio                   | 15.7:1   | 10.2:1        |
| Phosphorous (%)             | 0.06     | 2.09          |
Figures 1 and 2 show the daily biogas yield and cumulative biogas yields respectively for the period of 40. The results were analyzed and the volume of each sample was determined from the general gas law at standard pressure of 760 mmHg and volume of 22.4 litres. In the first four days, there was no production of gas in all the digesters. This was the result of lagging in the growth and spread of inoculums and methanogenic bacteria as proven by Lalitha et al. [18]. The methanogenic bacteria could also be undergoing a change in their growth process by consuming methane precursors produced from the initial activity [18]. As reported by Vicenta et al. [19] and Cuzin et al. [20], acid forming bacteria produce Volatile Fatty Acids (VFA) at the initial stages of the overall retention period which leads to diminishing pH level and inhibition of methanogenic bacteria growth. On the 5th day, 0.21, 0.29, 0.24, 0.21 and 0.15 litres of biogas were recorded for A, B, C, D and E, bio-digesters respectively. The biogas production rate started with low volumes and was found to be a function of temperature. Based on temperatures instability, highest biogas production was recorded at the highest temperature value.
Figure 2: Cumulative biogas yields for the different mix ratio

The total volume of biogas produced from different mix ratio of cow dung and jatropha cake is 468.43 litres. From the results obtained, treatment A (100% cow dung) produced 86.49 litres, treatment B (75% cow dung and 25% jatropha) produced 114.30 litres, treatment C (50% cow dung and 50% jatropha cake) released 96.0 litres, treatment D (25% cow dung and 75% Jatropha cake) produced 89.47 litres and treatment E (100% jatropha cake) released 82.0 litres of biogas. The percentage biogas yields were 18.46%, 24.41%, 20.49%, 19.11%, and 17.53% of total gas produced from treatment A, B, C, D, and E, respectively. The qualitative analysis of percentage composition of biogas produced from different mix ratio (treatment) is shown in Table 3.

Table 3: Composition of biogas produced from different mix ratio

| Mix ratio | CH₄ (%) | CO₂ (%) | H₂S (%) | CO (%) |
|-----------|---------|---------|---------|--------|
| A         | 54.29   | 39.49   | 1.62    | 4.6    |
| B         | 53.9    | 41.1    | 1.6     | 3.6    |
| C         | 58.47   | 36.59   | 1.93    | 3.01   |
| D         | 57.4    | 37.9    | 2.1     | 2.6    |
| E         | 59.6    | 35.4    | 1.1     | 3.9    |

The results show that treatment A (100% cow dung) produced 54.29% methane, B (75% cow dung and 25% jatropha cake) yielded 53.9% methane, C (50% cow dung and 50% jatropha cake) released 58.47% of methane, D (25% cow dung and 75% jatropha cake) released 57.4% methane and E (100% jatropha cake) released 59.6% methane. Treatment E has the highest quality biogas with methane content (the most important component of biogas) of 59.6%, followed by treatment C with 58.47%. The methane contents from all the treatments fall within the range reported by World Energy Council [21] and Madu and Sodeinde [22] while treatments C, D and E satisfied the range reported by Hanjie [23] and Steffen et al. [24], but none of the treatments can be compared to what is reported by Khanal [2].
4. Conclusions

From the experiment the followings were revealed:

i. Treatment B (75% cow dung 25% jatropha cake) produced the highest volume of biogas with yield of 24.41% of the total volume.
ii. Treatment E (100% jatropha Cake) produced the highest quality of biogas with 59.6% methane.
iii. Treatment C (50% cow dung 50% jatropha cake) was found to be the appropriate mix ratio, since it was ranked 2nd in both quantitative and qualitative analytical point of view from the experiment performed.

Acknowledgements

The authors wish to acknowledge the support offered by University of Johannesburg in presenting this research work for publication.

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