EFFECT OF UREA ADDITION ON BIOGAS PRODUCTION FROM THE CO-DIGESTION OF RICE STRAW AND PIGGERY DUNG

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ABSTRACT

The anaerobic co-digestion of Rice straw (RS) and Piggery dung (PD) at initial Total Solid (TS) loading of 10% was studied. This paper has investigated the effect of supplementing this co-digestion of RS and CD at with urea with an objective of reducing pH as well as improving biogas yield. These experiments were also carried out at different substrate mixing ratios of RS-CD 1:1 and RS-CD 1:2. The anaerobic digestion was carried out in a digester designed and fabricated locally with retention time of between 40 days and 60 days. Results show that addition of 1g of urea improved the maximum Biogas Yield of RS-PD 1:1 by 17.7% and RS-PD 1:2 by 23.4%. Further experiments with 0.5g, 1.5g and 2g of urea added to a co-digestion of RS-CD 1:1 produced a Cumulative Gas Yield of 75 L/Kg, 85.2 L/Kg and 76 L/Kg respectively. Experiments also showed that increasing urea concentration also leads to an increased methane content of the biogas produced.

INTRODUCTION.

The growing need for food sustainability in Africa has led to increased food production in the last decade with massive investment in Agriculture particularly in rice production. Rice is one of the most consumed staples in Nigeria, with consumption per capita of 32kg [1]. Nigeria is the largest producer of Rice (paddy) in Africa and ranked as the 14th largest producer of rice in the world [2]. The increased farming of rice causes a huge accumulation of residues; stalks, straws and husks leading to agricultural residues that can be utilized for production of biogas. Over the years, animal wastes have been utilized as raw materials for biogas production. However recent years have seen interest in combining animal waste, plant biomass, food waste and municipal solid waste to produce biofuels in a process called co-digestion [3]. This study will investigate the co-digestion of rice straw and piggery dung. Both of these wastes are common agricultural residues in huge quantities that require disposal. Processing these organic materials to biogas remains a worthy waste valorization strategy.

The production of biogas involves the anaerobic digestion of organic biomaterials like carbohydrate, proteins and lipids by microorganisms through the following stages; Hydrolysis, acidogenesis, acetogenesis and
methanogenesis [4-5]. Biogas contains 50-60% methane (CH₄) and 30-40% Carbon IV oxide (CO₂) and some trace amount of water vapour, Ammonia and Hydrogen sulfide. It can be used for cooking and has potential for use as natural gas for power generation. The process also produces organic fertilizers as a by-product [6].

In our previous work, we investigated the effect of different substrate mixing ratios, effects of total solids and compared the co-digestion of rice straw with either piggery dung or cow dung [7-8]. However, during the anaerobic digestion process, it is observed that the breakdown of organic matter especially during the acidogenesis stage can lead to acidification in the bioreactor therefore creating a pH imbalance that inhibits the methanogenesis process. This can be reduced by addition of a substance that can increase pH. Urea is considered a cheap raw material readily available for use as fertilizer and can be utilized as a pH control. Besides its use to increase pH, it can also serve as a nitrogen source which can possibly enhance activities of methanogens [9].

In this study, we will investigate the effect of supplementing the co-substrates (Rice straw and Piggery Dung). This paper will consider a series of batch experiments carried out in 25L volumes and at different mixing ratios of Rice Straw and Piggery dung. It will also study the effect of different concentrations of urea on biogas yields.

**MATERIALS AND METHODS**

Piggery Dung (CD) was collected from a local farm located in Makurdi Benue State Nigeria while Rice Straw (RS) were collected from a demonstration farm in University of Agriculture Makurdi, Benue State. The Rice stalk was air dried and then pounded with a mortar and pestle to reduce particle size. A 25L drum type digester system was designed and fabricated locally as described and shown in our previous work [10]. It has three main parts, the inlet chamber, the body and the outlet chamber and inserted with a thermometer and pH metre. A thermometer was inserted through a drilled hole at the top of the drum to measure the temperature. The measuring cylinder inverted with water was used for volume measurement of gas through a process called upward delivery and downward displacement.

| Table 1: Table showing different mixing ratios of Rice Straw and Cow Dung at 10% Total Solid Concentrations |
|-------------------------------------------------|-------------------------------------------------|
| **RS-CD 1:2** | **RS-CD 1:1** |
| 10% TS | 0.666 | 1.334 | 1.000 | 1.000 |
The substrate was thoroughly mixed in the digesters. Each digester was manually agitated once a day to avoid stratification. The input slot was closed well with wax and hose clips to prevent leakage. The daily biogas production was recorded by measurement of displaced water both in the mornings and afternoons. This is done by noting the quantity of water displaced from the gas collected in the measuring cylinder. Collection of biogas for analysis was done by collecting it in a balloon for storage. The ambient temperature, digester temperatures and pH were measured at least twice a day both in the mornings and afternoons. Further experiments were also carried out by supplementing with addition of 1g of Urea. Effects of other concentrations of urea; 0.5g, 1.5g and 2g were investigated by addition on Day 20 when pH of the bioreactor has dropped significantly. The bioreactor was then agitated vigorously to ensure proper mixture of the urea. Biogas yield was monitored for an additional 40 days for those experiments so that the total retention time was 60 days. The composition of the biogas was determined with a gas chromatograph Chemito GC-8610 model using a thermal conductivity detector with oven at temperature of 50°C and injector temperature of 200°C. Calibration curve was used to determine concentration of methane.

RESULTS AND DISCUSSION

The effect of urea addition after a retention time of 20 days is studied. The Biogas yield is expressed as Cumulative Gas Yields (CGY) per gram TS of biomass loaded (L/Kg TS). Results from Figure 1 and 2 shows that addition of urea to the bioreactor improves biogas yields. For experiments carried out with Rice Straw (RS) and Piggery Dung (CD) combined at substrate mixing ratio of RS-PD 1:1, the Cumulative Gas Yields (CGY) after a digestion peaked at 71 L/Kg after 40 hours however for experiments where urea is added (RS-PD 1:1 with urea), the Cumulative Gas Yields (CGY) was improved to 86.3 L/Kg showing an increase of 17.7%.
Figure 1. Progress curve showing the Cumulative Gas Yield (CGY) and pH profile for the co-digestion of Rice Stalk (RS) and Cow Dung (CD) with a mixing ratio of RS-CD 1:1. Experiments carried in the presence and absence of 1g of urea at 10% TS. Urea added at Day 20.

Figure 2. Progress curve showing the Cumulative Gas Yield (CGY) and pH profile for the co-digestion of Rice Stalk (RS) and Cow Dung (CD) with a mixing ratio of RS-CD 1:2. Experiments carried in the presence and absence of 1g of urea at 10% TS. Urea added at Day 20.
The retention time was also extended to 60 days when urea was added to the substrates compared to 40 days for experiments carried out without addition of urea. Similarly, experiments carried out with (RS) and Piggery Dung (CD) combined at substrate mixing ratio of RS-PD 1:2 show that higher Cumulative Gas Yields (CGY) for experiments supplemented with urea (RS-PD 1:2 with urea) when compared with experiments without urea (RS-PD 1:2). Here, the addition of urea improved the biogas yield by 23.4%. A comparison of both experiments (RS-PD 1:1 and RS-PD 1:2) as shown in Figure 3 below implies that urea has a marginally higher percentage increase when urea is used to supplement RS-PD 1:2 compared to experiments with RS-PD 1:1.

<table>
<thead>
<tr>
<th>Cumulative Gas Yield (CGY) L/Kg TS</th>
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<tbody>
<tr>
<td><strong>RS-PD 1:1</strong></td>
</tr>
<tr>
<td>With Urea 90</td>
</tr>
<tr>
<td>without Urea 75</td>
</tr>
<tr>
<td><strong>RS-PD 1:2</strong></td>
</tr>
<tr>
<td>With Urea 85</td>
</tr>
<tr>
<td>without Urea 65</td>
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</tbody>
</table>

**Figure 3.** Comparison of the Cumulative Gas Yield (CGY) for the co-digestion of Rice Stalk (RS) and Cow Dung (CD) with a mixing ratio of RS-CD 1:1 and RS-CD 1:2. Experiments carried in the presence and absence of 1g of urea at 10% TS.

The obvious effect of urea addition is in its influence on the pH of the anaerobic digestion. Figure 1 shows that pH drops from an initial 8.32 and 8.34 at day 0 to 6.44 and 6.25 for RS-PD 1:1 and RS-PD 1:2 respectively at day 20. The addition of urea after day 20 increases the pH to 7.6 and 7.2 for RS-PD 1:1 and RS-PD 1:2. This is expected to improve biogas yield. The acidic condition of a substrate is known to affect bacteria activity as it breaks down organic matter to biogas and affects the growth of bacteria [11-12]. Methanogenesis is the most stage affected by lower pH. The optimal range of pH for maximum biogas yield is reported to be 6.5 to 7.5 [13] so the addition of urea at day 20 increases the likelihood of increased biogas yield. Similar observations

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were in studies by Gopinathan et al. 2015 [14] that show that 2% urea improves production of biogas by 19% when compared to control without urea supplementation. Another likely effect of urea on improved biogas yield is it has the ability to improve the C:N ratio for microbes to function more optimally. Manure from piggery is reported to have between 0.22-0.24% Nitrogen ([15-16].

Figure 4 shows the effect of different concentrations of urea on the co-digestion of RS-PD 1:1 at 10% TS. Results show that the highest Cumulative Gas Yield (CGY) is observed for experiments where 1g urea is added to the biodigester with a CGY of 86.5 L/Kg. For experiments carried out at 0.5g urea, 1.5g and 2g of urea, the CGY obtained from the experiments are 75 L/Kg, 85.2 L/Kg and 76 L/Kg respectively.

It is plausible that at concentrations above 1.5g of urea, the microorganisms are inhibited by urea and this could affect the bacteria particularly the methanogens. This agrees with previous studies by that high amount ammonia can be produced in the bioreactor causing inhibition to the microbes when urea is used in excessive amount [17-18].

Another effect of urea addition observed as seen in figure 5 is that the addition of urea causes an
increase in the methane content of the biogas analyzed. Experiments with 1.5 g urea added have a methane content of 71% while addition of 2g of urea gave 70%. However, experiments with 0.5g and 1.0g of urea gave 58% and 68% methane content respectively. This agrees with previous studies that suggest that increase in Nitrogen content leads to better yields of methane [9].

![Comparison of Cumulative Gas Yield (CGY) for the co-digestion of Rice Stalk (RS) and Cow Dung (CD) with a mixing ratio of RS-CD 1:1. Experiments carried at different concentrations of urea at 10% TS. Urea A; 0.5 g Urea, Urea B; 1g Urea, Urea C; 1.5 g Urea, Urea D; 2g Urea.](image)

**CONCLUSION**

This study evaluated the effect of urea addition on biogas production from the co-digestion of rice straw and piggery dung. It was observed that addition of 1g urea improved biogas yield by between 17.7% to 23.4%. Experiments also showed that increasing urea concentration leads to an increased methane content of the biogas. Although, the addition of urea above 1.5g leads to inhibition and reduced biogas yield.

**REFERENCES**


Ethiopia. MSc thesis Addis Ababa University, Addis Ababa Institute of Technology, Department of Chemical Engineering.