Biogas production from cassava waste: effect of concentration.

P Kohmuan, N Boonrod and A Wongkoblap*

1School of Chemical Engineering, Institute of Engineering, Suranaree University of Technology, 111 University Avenue, Maung District, Nakhon Ratchasima, 30000, Thailand

*e-mail: atichat@sut.ac.th

Abstract. In the lactic acid production from cassava, there is cassava waste generated from saccharification process. This study intends to investigate the effects of substrate concentration on fermentative methane and carbon dioxide from cassava waste using activated sludge obtained from the cassava production plant and the biogas production was determined in batch experiments. The ratio between cassava waste and sludge of 1:1, 1:2, 2:1 and 1:0 at 34°C were used in this investigation. The rate of fermentation and methane yield were observed during the fermentation. First, we investigated whether the biogas can occur without the additional microorganism. It was found that methane can occur within 6 days for the batch adding the biological sludge, while it cannot be observed in the case of the reactor free of adding the microflora. The suitable ratio in this study was found that cassava waste and sludge of 1:1 can produce the greatest biomethane in biogas. The quality of biogas occurred in batch reactor composed of 63.1% CH₄, 34.4% CO₂, 2.2% of oxygen and 0.3% of other gases. It is noted that at this ratio, the hydrogen sulfide (H₂S) was not detected while it was 4 ppm in the case of higher sludge added in the reactor.

1. Introduction

One of the worldwide aims of reducing fossil fuel consumption and pollution is the enhancement for renewable energy production by using organic waste [1]. Biogas is produced by an anaerobic digestion of biomass or organic waste with anaerobic microorganism. Typically, this process involves the biogas mixtures which mainly consists of methane (CH₄ 60%), carbon dioxide (CO₂ 35-40%) and traces of other gases such as hydrogen (H₂) and hydrogen sulfide (H₂S) (depending on the source of the organic matter being used) [2], so main components of biogas are combustible gas. Biogas can be used as biofuel for many applications such as cooking gas or fuel gas.

In Thailand, enormous amount of cassava waste consisting of peels and pulp are generated, i.e. ca. 0.47 ton for each ton of cassava processed [3]. In small and large scale cassava processing, the generated waste causes serious environment pollution [4]. Cassava waste is biomass that can be used as the bio resource for biogas production, the process of biogas production from cassava wastes have several problems that led the biogas production not optimal. The pH drops at beginning process because the rate of acid formation is too fast that causing death of microbial methanogens and slow degradation rate of cassava waste caused by the solids content in waste is still polysaccharide molecule. The substrate concentration of biomass is the important environmental and operation factors in biological processes [5]. Therefore, in this work, cassava waste was used as substrate for biogas production in batch reactor, we investigated the effect of substrate concentration on biogas generation.
2. Experiments
Cassava waste and biological sludge obtained from the cassava flour production plant in Nakhon Ratchasima were used as substrate for biogas production in batch reactors. Each reactor is about 20 liters made from polyethylene. Cassava waste and biological sludge were placed in the reactor, the mass ratio of cassava waste to biological sludge were 1:1, 1:2 and 2:1 with total mixture mass of 600g as shown in Table 1. Then water was added into each reactor until reached the liquid level of 12 liters. In this study, the slurry in batch reactor was not controlled pH and kept at room temperature. Biogas generation was observed by using pressure gauge and the composition of gas was measured by using gas analyzer (BIOGAS 5000, Geotech UK).

| Reactor | Mass ratio (cassava waste : biological sludge) | Weight of dry solid (g) | Cassava waste | Biological sludge |
|---------|-----------------------------------------------|------------------------|---------------|-------------------|
| A       | 1:2                                           | 200                    | 400           |
| B       | 1:1                                           | 300                    | 300           |
| C       | 2:1                                           | 400                    | 200           |
| D       | 0:1                                           | 0                      | 400           |

* Biological sludge: 400 g - 12L, 300g - 9L and 200 g - 6L

3. Results and discussion

3.1 Effect of substrate concentration
The experiment described in Section 2 was carried out under average temperature of 34°C, pressure in each batch reactors was measured for retention period of 60 days. The daily biogas production at different concentrations of substrate were shown in Figure 1. As one can observe, biogas occurred within 6 days in the reactor B and the rate of biogas production for 1:1 mass ratio was faster than 2:1 ratio. This may be due to that low mass ratio (low concentration of cassava waste) contained high water content, water can enhance the hydrolysis step faster such that the biogas product rate increased. In this study, the suitable condition for cassava waste degradation rate was observed in the reactor B (1:1) and then reactor C (2:1), A (1:2) and D (1:0), respectively. Moreover, reactor B also generated the highest methane composition of 63.1% while it was generated 58.7%, 55.4% and 2.5% in reactor C, A and D, respectively, as shown in Figure 2. The composition of biogases, methane, carbon dioxide, oxygen, hydrogen sulfide and other gases were shown in Table 2. It was noted that pressures in reactors A and D cannot be observed, this was due to the leakage between pressure gauge and the reactor instrument nozzle. Biogas in each reactor was measured its composition by using gas analyzer.

The reactor D was carried out to determine the activity of microorganism in the case of free of cassava substrate. It was found that biomethane can occur 2.5% as shown in Figure 2. The result indicated that the mixture of 1:1 ratio of substrate was the suitable condition for cassava degradation rate with balance nutrients for micro-organism. The peak of biogas production was 0.5 barg at 41 days of retention time, after that pressures decreased with time. This may be due to the shortage of substrate for microbial digestion and corresponding to the cell growth cycle.
Figure 1. The relationship between accumulation pressures and time for batch reactor.

Figure 2. Percent of methane content in the biogas produced from cassava waste.

Table 2. Composition of biogas produced from cassava waste

| Component | Percentages of each Components (%) | A (1:2) | B (1:1) | C (2:1) | D (0:1) |
|-----------|-----------------------------------|---------|---------|---------|---------|
| CH$_4$    |                                   | 55.4    | 63.1    | 58.7    | 2.5     |
| CO$_2$    |                                   | 322     | 344     | 360     | 1.6     |
| O$_2$     |                                   | 103     | 22      | 52      | 18.9    |
| H$_2$S    |                                   | 4 ppm   | 0 ppm   | 0 ppm   | 0 ppm   |
| Other     |                                   | 2.1     | 0.3     | 0.1     | 77.0    |
3.2 Biogas analysis

Having seen the effects of cassava concentration on biogas production, however in section 3.1, the final gas composition was measured at 60 days after filling the reactors. In this section, we repeated the experiment as described in section 3.1, however the biogas composition in each reactor was measured every week. The biogas obtained from the reactor with various substrate concentration were shown in Figure 3. The percentage of methane production increased with an increase in substrate concentration which was in agreement with the other work carried out for other substrates [5, 7]. This may be due to that high substrate concentration resulted in high volatile fatty acid (VFA) favoring to methane production [5, 8]. The methane concentration slightly decreased with increasing cultivation time and then it became constant. In contrary, the carbon dioxide concentration production slightly increased with reaction time. In the anaerobic environment, the predominance of CO2 over CH4 in biogas production at the initial stage indicated the strong activity of hydrolysis of cassava waste. In contrast, higher CH4 content over CO2 in the biogas production implied strong activity of the methanogens [9]. The oxygen content was zero for reactor C and D at 14 days and then increased, this may because of the nozzle leakage. It was observed that the hydrogen sulfide concentration in the biogas obtained from reactor D which contained only biological sludge was greater than 4000 ppm at the first week and reduce to 1124 ppm at the second week. The H2S concentrations in the range of 6 to 819 ppm for reactor A, 9 to 486 ppm for reactor B, and 32 to 1124 ppm for reactor C were measured and these values were in the limit of safe operating organic loading rate region [10]. The H2S levels of reactor A, B and C were significantly lower than reactor D. This may be implied that the biogas produced from cassava waste was safe for human use.
Figure 3. The percentages of gas components (%v/v, ppm) in biogas produced from cassava waste and time (week) for (a) methane, (b) carbon dioxide, (c) oxygen and (d) hydrogen sulfide.

4. Conclusion
In the present study, biogas production from cassava waste using anaerobic digestion was investigated to determine how substrate concentration can affect the biogas production. The suitable mass ratio of cassava waste to biological sludge was 1:1 which provided the faster biogas production. The biogas can occur within a week and its composition composed of 63.1% CH₄, 34.4% CO₂, 2.2% of oxygen and 0.3% of other gases such as nitrogen and hydrogen. The retention time of cassava pulp fermentation in the appropriate proportion is about 41 days. An increase of cassava waste can enhance the amount of biogas production.

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