

Biogas Production Using Anaerobic Biodigester from Cassava Starch Effluent

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Abstract - *IKMs' factory activity in Margoyoso produces liquid and solid wastes. The possible alternative was to use the liquid effluent as biogas raw material. This study focuses on the used of urea, ruminant, yeast, microalgae, the treatment of gelled and ungelled feed for biogas production, pH control during biogas production using buffer Na₂CO₃, and feeding management in the semi-continuous process of biogas production that perform at ambient temperature for 30 days. Ruminant bacteria, yeast, urea, and microalgae was added 10% (v/v), 0.08% (w/v), 0.04% (w/v), 50% (v/v) of mixing solution volume, respectively. The pH of slurry was adjusted with range 6.8-7.2 and was measured daily and corrected when necessary with Na₂CO₃. The total biogas production was measured daily by the water displacement technique. Biogas production from the ungelling and gelling mixture of cassava starch effluent, yeast, ruminant bacteria, and urea were 726.43 ml/g total solid and 198 ml/g total solid. Biogas production from ungelling mixture without yeast was 58.6 ml/g total solid. Biogas production from ungelling mixture added by microalgae without yeast was 58.72 ml/g total solid and that with yeast was 189 ml/g total solid. Biogas production from ungelling mixture of cassava starch effluent, yeast, ruminant bacteria, and urea in semi-continuous process was 581.15 ml/g total solid. Adding of microalgae as nitrogen source did not give significant effect to biogas production. But adding of yeast as substrate activator was very helpful to accelerate biogas production. The biogas production increased after cassava starch effluent and yeast was added. Requirement of sodium carbonate (Na₂CO₃) to increase alkalinity or buffering capacity of fermenting solution depends on pH-value.*

Key Words: *biogas cassava; C/N ratio; ruminant, bacteria; semi-continuous biodigester; yeast*

I. INTRODUCTION

Indonesia is the third country of cassava producer after Brazil and Thailand, and has 1,205,440 hectares planted area and 21,990,381 tons cassava production/year (BPS, 2009). Mostly, cassava root was produced for tapioca starch. There are 399 small-medium scale industries (IKMs) in Margoyoso, Pati, Central Java, Indonesia, which have average production capacity 10 tons cassava/IKM-day. So, demand of cassava root was approximately 3,990 tons/day with total water consumption 15,960 m³/day. Consequently, the IKMs' factory activities produce liquid and solid wastes. The problem was that the effluent from tapioca starch factories was released directly into the river before properly treatment. To treat the effluent, we can conduct coagulation and flocculation process (Malhotra, et.al., 1994). But the recovery result of the product can not be used for food

product because of chemical residue. The possible alternative was to use the effluent as raw material of biogas.

Biogas production was conducted in the semi-continuous biodigester. Urea and microalgae were used as source of nitrogen in the biodigester. In this anaerobic process, ruminant bacteria was added as biocatalyst to enhance biogas production. This study focuses on the used of urea, ruminant, yeast, microalgae, the treatment of gelled and ungelled feed for biogas production, pH control during biogas production using buffer Na₂CO₃, and feeding management in the semi-continuous process of biogas production.

II. MATERIALS AND METHODS

2.1 Preparation of the Materials for Biogas Production

Cassava starch effluent was made synthetically with total solid 1% (w/v). 25 gr of cassava starch was dissolved in 2,500 ml of mixing solution. Prepare urea as much as 0.04% (w/v) of mixing solution volume, ruminant bacteria as much as 10% (v/v) of mixing solution volume, yeast as much as 0.08% (w/v) of mixing solution volume, and microalgae as much as 50% (v/v) of mixing solution volume. Mixing solution was heated and agitated for making the gelling solution. Na₂CO₃ was also prepared if necessary for rising the alkalinity of pH solution.

2.2 Variables. Urea and ruminant bacteria were used as dependent variable, while yeast, microalgae, and the treatment of gelled and ungelled feed for biogas production as independent variable.

2.3 Experiment Procedures

a. *Study of biogas production from cassava starch effluent by adding microalgae as nitrogen source and yeast as substrate activator with the treatment of gelled and ungelled feed.* The production of biogas from cassava effluent was performed using anaerobic biodigester of 5 L digestion volume (Figure 1), but the volume of mixing solution was half of biodigester reactor. On batch process, Tank 1 was fed ungelling mixture of cassava starch effluent, yeast, ruminant bacteria, and urea, Tank 2 was fed ungelling mixture of cassava starch effluent, ruminant bacteria, and urea, Tank 3 was fed gelling mixture of cassava starch effluent, yeast, ruminant bacteria, and urea, Tank 4 was fed ungelling mixture of cassava starch effluent, ruminant bacteria, urea, and microalgae, Tank 5 was fed ungelling mixture of cassava starch effluent,

ruminant bacteria, urea, yeast, and microalgae. While on semi-continuous process, the tank was fed ungelling of cassava starch effluent, yeast, ruminant bacteria, and urea. This study was conducted in duplicate sample at ambient temperature for 30 days to obtain the volume of biogas production. The total biogas production was measured daily by the water displacement technique. The pH was measured daily and corrected when necessary with an alkaline buffer solution (Na_2CO_3). The equipment components to measure the total biogas were fabricated as in Figure 1.

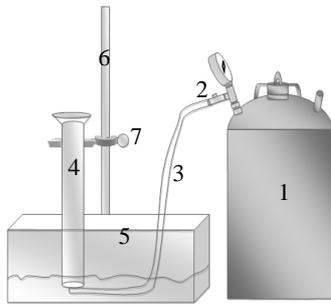


Figure 1. Water Displacement Technique; 1. Anaerobic biodigester 5L, 2. Valve, 3. Hose, 4. Measure glass, 5. Wash basin, 6. Statif, 7. Clamp

b. *Study of pH control during biogas production using buffer Na_2CO_3 .* The pH was measured daily and corrected when necessary with an alkaline buffer solution (Na_2CO_3).

c. *Study of feeding management in the semi-continuous process of biogas production.* Cassava starch effluent was fermented to achieve maximum output of biogas and reduction of total solids with minimum retention time under ambient conditions. In semi-continuous process, fresh feed (2 grams of total solid) was added every two days in order to displace the same amount of digested material to maintain the constant biogas production volume. Fresh yeast (0.08% (w/v)) was also added every five days to stimulate biogas production.

III. RESULTS AND DISCUSSION

3.1. Batch Process.

The biogas components and biogas yield depend on a feed materials due to the difference of material characteristics in each raw material (Anunputtikul, 2004).

3.1.1. *Study of biogas production from cassava starch effluent by adding microalgae as nitrogen source and yeast as substrate activator with the treatment of gelled and ungelled feed.*

Figure 2 shows that a significant increasing in biogas production per day was found when the feed was gelled (Tank 3). At the beginning of fermentation, the biogas production per day from the ungelling feed of Tank 2, 4, and 5 were relatively low but the biogas production per day from the ungelling feed of Tank 1 was high from the beginning.

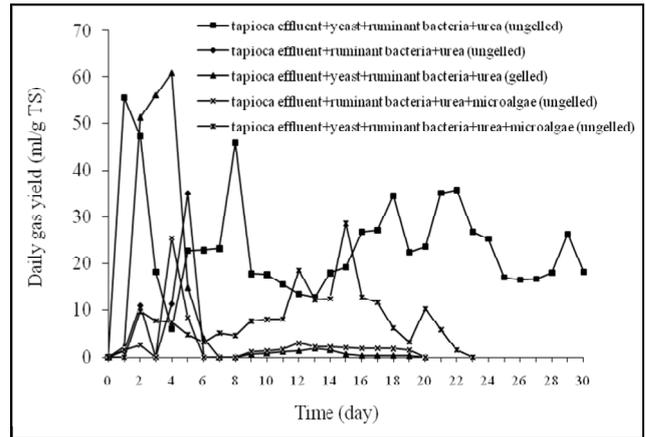


Figure 2. Daily Biogas Production per Gram Total Solid (ml/g total solid) from Various Feed Compositions Performed in Anaerob Biodigester of 5 L Digestion Volume.

The maximum of biogas production per day from Tank 1 was 55.52 ml/g total solid at the first day retention time. The maximum of biogas production per day from Tank 2 was 35.2 ml/g total solid at fifth day retention times. The maximum biogas production per day of Tank 3 and 4 were 60.8 ml/g total solid and 25.44 ml/g total solid, respectively at fourth day retention times. The maximum of biogas production per day from Tank 5 was 28.6 ml/g total solid at day twelve retention times. The fermentation reactions of Tank 1, 2, 3, 4 and 5 were ceased after operating for 40, 6, 20, 20, and 23 days, respectively.

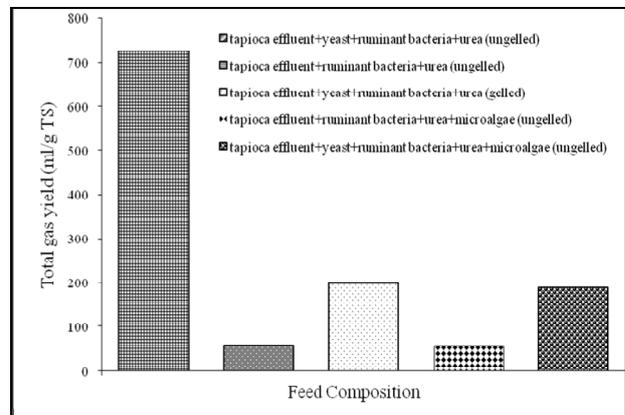


Figure 3. Total Gas Yield per Gram Total Solid (ml/g total solid) from Various Feed Compositions Performed in Anaerob Biodigester of 5 L Digestion Volume.

The total biogas yield from Tank 1, 2, 3, 4 and 5 were 726.43, 58.6, 198, 58.72 and 189 ml/g total solid, respectively (Figure 3). The maximum of total biogas yield of this experiment was obtained from ungelling mixture of cassava starch effluent, yeast, bacteria ruminant, and urea (726.43 ml/g total solid).

If total biogas yield from Tank 2 and 4 were compared, adding microalgae as nitrogen source did not give significant effect to biogas production. Microalgae did not influence biogas production exceedingly. At Tank 1, 3, and 5 which used yeast as substrate activator, adding

of yeast was very helpful to accelerate biogas production, so it also was used for semi-continuous process.

The steps employed in this study were as Milono, et al (1981). In the first stage, which was the fermentative stage, organic materials (protein, cellulose, lipid, and starch) were broken down by fermentative microorganism to lower molecular weight molecules. The second stage was the acid-forming stage. In this stage, products from the first stage were converted by acetogenic bacteria (acetate and H₂-producing bacteria) into acetate, hydrogen gas, carbon dioxide, and few other VFA such as propionic and butyric acid. The third stage was the methanogenic stage. The methanogenic bacteria or methane-forming bacteria produce methane, carbon dioxide, trace gases (e.g., H₂S), and water. It was almost that 70% of methane was formed from acetate, and the rest was formed from carbon dioxide and hydrogen.

a. pH from various feed compositions

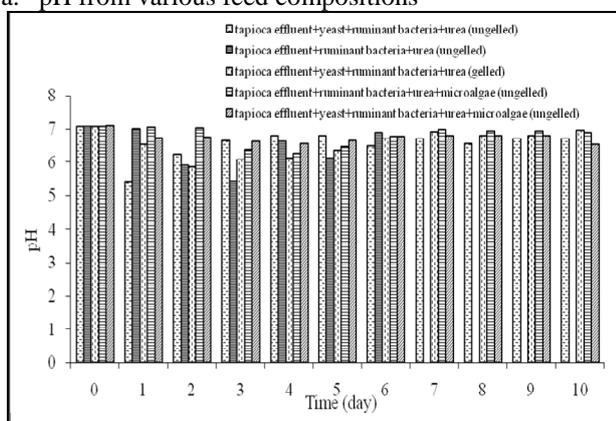


Figure 4. pH from Various Feed Composition Performed in Anaerob Biodigester of 5 L Digestion Volume.

Figure 4 shows that the pH ranges of 5.84-6.94; 5.38-7.07; 5.38-6.9; 6.25-7.03; and 6.53-7.07 were found in the Tank 1, 2, 3, 4 and 5, respectively. The pH was corrected with Na₂CO₃ when the pH below 6.8. Based on previous study that the relation of percentage adding of Na₂CO₃ to delta pH solution was expressed by equation $y = 3.914x + 0.042$, so 0.39% of Na₂CO₃ was added in Tank 1 because the pH decrease from 7.1 to 5.4 at the first day fermentation. At the second, third, and sixth day, the pH was 6.2, 6.6, and 6.5 as a result 0.19%, 0.09%, 0.117% of Na₂CO₃ was added, respectively. In Tank 2, at the second, third, fourth, and fifth day, the pH was 5.9, 5.41, 6.6, and 6.12 therefore of 0.27%, 0.395%, 0.09%, and 0.21% of Na₂CO₃ was added, respectively. In Tank 3, 0.28%, 0.22%, 0.21%, 0.15% of Na₂CO₃ was added at second, third, fourth, and fifth days. In Tank 4, 0.18% of Na₂CO₃ was added at fourth day. In Tank 5, 0.1% of Na₂CO₃ was added at fourth day.

When the digester was initially heavily fed, acid forming bacteria quickly produced acids. The drop of pH was caused acid forming bacteria produce acetate, hydrogen gas, carbon dioxide, and few other VFA such as propionic and butyric acid. A low pH value inactivated microorganisms involved in the biogas production especially methanogenic bacteria (Vicenta et al., 1984).

In order to allow the methanogenic bacteria to grow, digester should be properly fed and buffered to rising alkalinity. In this study, Sodium carbonate (Na₂CO₃) was used to increase alkalinity or buffering capacity of fermenting slurry. It was added to the digester whenever the pH below 6.8.

Since the reaction rate involving acid-forming bacteria proceeded much faster than the reaction involving methanogenic bacteria, a larger population of methanogenic bacteria must be fed and maintained. The methanogenic bacteria population might not be adequate to consume the acids produced and maintain a neutral pH resulting in declining pH below the neutral pH and diminishing growth of methanogenic bacteria and methanogenesis. The pH could be maintaining by adding Na₂CO₃ to increase alkalinity. The pH was the key indicator of operational stability (Tanticaroen et al., 1984). Methanogenic bacteria could occasionally grow at the pH range of 6.5-8.2 (Anunputtikul, 2004). Viswanath et al. (1992) mentioned that there was a perfect link of the acidogenic and methanogenic phases when the pH was remained at 7 and there was no drastic increase in acidity or alkalinity.

b. Temperature from various feed compositions

During 30 days of operation, the temperature ranges of 30.5-33°C, 29.5-33°C, 31-33°C, 30-32.5°C, and 30.5-32.5°C were found in the digester 1, 2, 3, 4 and 5, respectively (Figure 5). At the initial retention time, the temperature was fluctuative from 29.5°C until 33°C, but since the day thirteenth the temperature of mixtures stabilized. A slightly difference of temperature between the gelling feed and ungelling feed was occurred but they still in the range of mesophilic temperature (29.5-33°C).

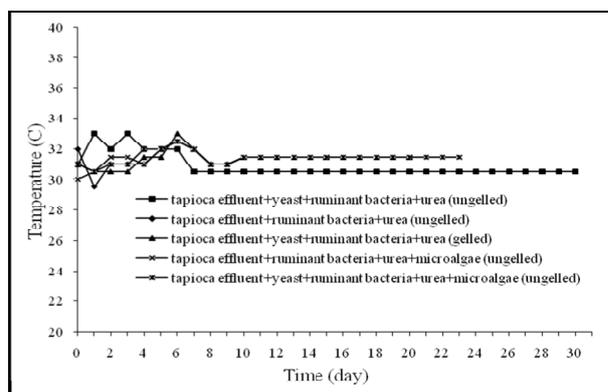


Figure 5. Temperature from Various Feed Composition Performed in Anaerob Biodigester of 5 L Digestion Volume.

As the temperature falls, microbial activity decreases and the biogas production decreases. As the temperature increases some microorganisms begin to die, once again the production of biogas decreases.

3.2. Semi-continuous Process

In semi-continuous experiment, 1% (w/v) of total solid of cassava starch effluent, 0.08% (w/v) of yeast, 10% (v/v) of ruminant bacteria, and 0.04% (w/v) of urea were mixed in the tank. According to Sitohang (2000), adding of fresh feed was conducted when biogas production achieve the maximum yield condition. In

previous batch experiment, the maximum yield condition was occurred at second days, consequently adding of fresh feed was conducted every two days with constant amount of feeding (2 grams per two days). The aim of this feeding management was increasing of biogas production (Sitohang, 2000).

a. Biogas production

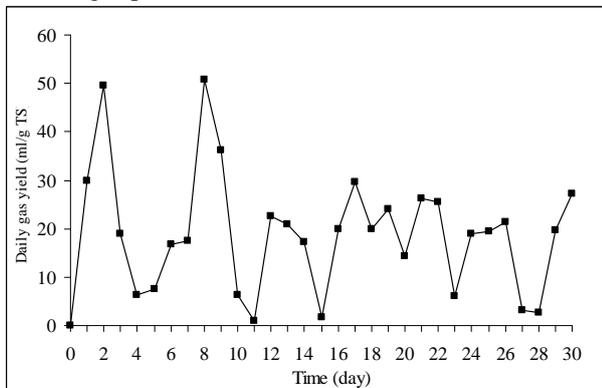


Figure 6. Daily and Accumulation Biogas Production from Cassava starch Effluent using Yeast, Ruminant Bacteria, and Urea in Anaerob Biodigester of 5 L Digestion Volume.

Figure 6 shows that at the beginning of fermentation, the biogas production per day was relatively high. On the third day, the biogas production per day decreased. The addition of cassava starch effluent did not influence the activities of microorganisms to produce biogas directly. This can be seen on the fourth and fifth days, the biogas production per day still decreased. Yeast was added on fifth day and the biogas production per day increased on sixth and seventh days. It was occurred because the yeast as substrate activator accelerates hydrolysis of substrates by microorganisms, then converts it into biogas. A significant increase in biogas production was occurred on the eighth day retention time (50.69 ml/g total solid/day), after the addition of cassava starch effluent and yeast. On the next day, the biogas production increased and decreased fluctuatively. Overall, a high biogas production was occurred during the early days (1-10 days). The biogas production normally increased after cassava starch effluent and yeast was added. But the addition of cassava starch effluent has been effect in increasing the biogas production after 3-4 days. A significant effect in increasing the biogas production was occurred after yeast was added every 5 days. The maximum of biogas production per day 50.69 ml/g total solid/day was obtained at eighth day retention times (Figure 6) and the total biogas production was 581.15 ml/g total solid.

The rising of biogas production was caused by fresh feed replace the fermented substrate. However, the increasing of feeding-value will increase biogas production until certain value, then biogas production was decrease exactly. It was based on substrate retention time in biodigester. More adding feeding-value, retention time in biodigester was shorter, consequently also shorter in reaction time because substrate was push out before the reaction complete.

b. pH and Temperature

During 30 days of operation, the pH ranges of 5.52-7.06 was found (Figure 7). The initial drops in pH from 7.04 to 5.52 was observed at first day retention time. At that time, a low pH value inactivated microorganisms involved in the biogas production especially methanogenic bacteria (Vicenta et al., 1984), so adding of Na_2CO_3 (0.37%) was needed to raising alkalinity in order to keep microorganisms alive. On the second day, the pH stabilized at neutral pH. pH stability stayed awake until the 30-day because there were the addition of cassava starch effluent and yeast, so the activities of microorganisms remained stable.

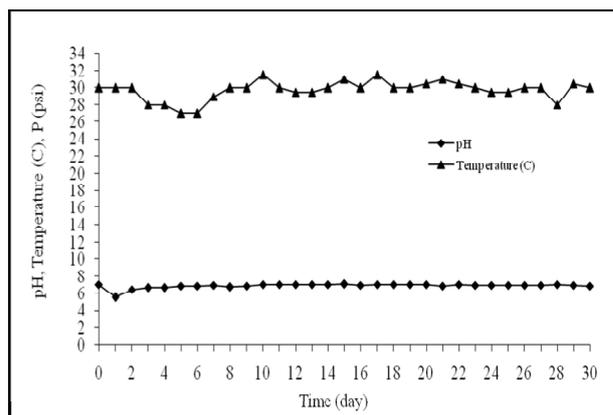


Figure 7. pH and Temperature Performed in Anaerob Biodigester of 5 L Digestion Volume.

Biogas production the simple anaerob semi-continuous digester volume of 5 L digestion volume was performed at ambient temperature (27-33 °C) for 30 days at mesophilic level. From Figure 7, there was maximum temperature for maximum biogas production: 30°C for 50.69 ml biogas/g total solid/day.

IV. CONCLUSIONS

Based on the discussion above, it can be concluded as follow:

- Adding of microalgae as nitrogen source did not give significant effect to biogas production. But adding of yeast as substrate activator was very helpful to accelerate biogas production.
- The biogas production increased after cassava starch effluent and yeast was added.
- Biogas production from the ungelling and gelling mixture of cassava starch effluent, yeast, ruminant bacteria, and urea were 726.43 ml/g total solid and 198 ml/g total solid.
- Biogas production from ungelling mixture without yeast was 58.6 ml/g total solid.
- Biogas production from ungelling mixture added by microalgae without yeast was 58.72 ml/g total solid and that with yeast was 189 ml/g total solid l.
- Biogas production from ungelling mixture of cassava starch effluent, yeast, ruminant bacteria, and urea in semi-continuous process was 581.15 ml/g total solid.
- Requirement of sodium carbonate (Na_2CO_3) to increase alkalinity or buffering capacity of fermenting solution depends on pH-value.

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REFERENCES

- [1]. Anunputtikul, W., Rodtong, S., Investigation of The Potential Production of Biogas from Cassava Tuber, Abstracts of the 15th Annual Meeting of The Thai Society for Biotechnology and JSPS-NRCT Symposium, Thailand, 2004, p. 70.
- [2]. Anunputtikul, W., Rodtong, S., Laboratory Scale Experiments for Biogas Production from Cassava Tubers, The Joint International Conference on "Sustainable Energy and Environment (SEE)", Hua Hin, Thailand, 2004.
- [3]. Anunputtikul, W., Rodtong, S., Conversion of Raw Cassava Roots to Biogas, Thailand, 2004.
- [4]. BPS, Produksi Bahan-bahan Pangan Indonesia, 2009.
- [5]. Malhotra, M.S., Poly Aluminium Chloride as An Alternative Coagulant, 20th WEDC Conference Colombo: Affordable Water Supply and Sanitation, Sri Lanka, 1994.
- [6]. Milono, P., Lindajati T. and Aman S., Biogas Production from Agricultural Organics Residues, In The First ASEAN Seminar Workshop on Biogas Technology, Working Group on Food Waste Material (pp. 52-65), Manila, Philippines: ASEAN Committee on Science and Technology, 1981.
- [7]. Quoted in Anunputtikul, W., Rodtong, S., Biogas Production from Cassava Tubers, Thailand, 2004.
- [8]. Sitohang, Tongam J. L. dan Ihwan U. F., Evaluasi Parameter-Parameter yang Mempengaruhi Produksi Biogas pada Bioreaktor Anaerobik, TK-470 Penelitian, Institut Teknologi Bandung, 2000.
- [9]. Vicenta, M. Pacheco G. Alamis M. L. A., Anglo P. G., tan B. V. and Silverio C. M., A Study of Some Factors Affecting Biogas Production from Pineapple Peelings, In Bidin R., Chong C. N. and Wang C. W. (eds), Proceeding of the Second ASEAN Workshop on Biogas Technology Applied in the Management and Utilization of Food Waste Materials (pp. 189-202), Kuala Terengganu, Malaysia, 1984. Quoted in Anunputtikul, W., Rodtong, S., Biogas Production from Cassava Tubers, Thailand, 2004.
- [10]. Viswanath, P., Devi S. S. and Nand K., Anaerobic Digestion of Fruit and Vegetable Processing Waste for Biogas Production, Bioresource Technology 40: 43-48, 1992. Quoted in Anunputtikul, W., Rodtong, S., Biogas Production from Cassava Tubers, Thailand, 2004.