# Biogas Production From Cassava Starch Effluent Using Microalgae As Biostabilisator

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***Abstract - The rapid growing of Indonesian population is emerging several critical national issues i.e. energy, food, environmental, water, transportation, as well as law and human right. As an agricultural country, Indonesia has abundant of biomass wastes such as agricultural wastes include the cassava starch wastes. The problem is that the effluent from cassava starch factories is released directly into the river before properly treatment. It has been a great source of pollution and has caused environmental problems to the nearby rural population. The possible alternative to solve the problem is by converting waste to energy biogas in the biodigester. The main problem of the biogas production of cassava starch effluent is acid forming-bacteria quickly produced acid resulting significantly in declining pH below the neutral pH and diminishing growth of methane bacteria. Hence, the only one of the method to cover this problem is by adding microalgae as biostabilisator of pH. Microalgae can also be used as purifier agent to absorb $CO_2$.The general objective of this research project was to develop an integrated process of biogas production and purification from cassava starch effluent by using biostabilisator agent microalgae. This study has been focused 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 $Na_2CO_3$, and feeding management in the semi-continuous process of biogas production. The result can be concluded as follows: i) The biogas production increased after cassava starch effluent and yeast was added, ii) Biogas production with microalgae and cassava starch effluent, yeast, ruminant bacteria, and urea were 726.43 ml/g total solid, iii) Biogas production without microalgae was 189 ml/g total solid.***

***Keywords: microalgae, ruminant bacteria, bioga, cassava effluent, biodigester***

## I. INTRODUCTION

The rapid growing of Indonesian population is emerging several critical national issues i.e. energy, food, environmental, water, transportation, as well as law and human right. As an agricultural country, Indonesia has abundant of biomass wastes such as agricultural wastes include the cassava starch wastes. 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, 2010). Utilization of cassava is mostly for producing starch (tapioca) and flour. The concentration of cassava starch factory effluent is in the range of 12,000-20,000 ppm COD. The problem is that the effluent from cassava starch factories is released directly into the river before properly treatment. It has been a great source of pollution and has caused environmental problems to the nearby rural population. The possible alternative to solve the problem is by converting waste to energy biogas in the biodigester (Cereda, 1994).

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without oxygen) conditions. Biogas is a mixture of gases that is composed chiefly of methane ($CH_4$): 55-70 vol. %, carbon dioxide ($CO_2$): 30-45 vol. %, other gases: 1-5 vol. % (Deublein *et al*., 2008). In the producing optimum biogas, ratio of C and N is needed optimum ratio of 20-30 (Padmasiri, et.al., 2007, Simamora, 2006). Because of the effluent has ratio C and N very high 86 (Anunputtikul, et al, 2004, Budiyono and Sunarso, 2010), source of nitrogen is needed. Biogas technology of cassava wastewater was used anaerobic biodigester (Barana, 2000).

Biogas technology is not a new technology and this technology has been developed in Indonesia several years ago (Speece, 1996, Muryanto, et al, 2006). Various efforts to increase the biogas production has been proposed and developed. Some patent specifically provides methods of increasing the production of biogas using a bacterial inoculums such as U.S. Patent No. 20080124775, U.S. Patent No. 20070062866, and U.S. Patent No.7,560,026. Furthermore, implementation of biogas technology from cassava starch effluent also been made by many researchers in this decade (Manilal, et.al., 1990, Anunputtikul, et.al., 2004, Mulyanto, et.al, 2005). However, biogas production rate from cassava starch effluent is still very low.

The process of biogas production from various organic materials in anaerobic biodigester involves a number of simultaneously working through several stages of biochemical reactions that hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Speece, 1996). The main problem of the biogas production of cassava starch effluent is acid forming-bacteria quickly produced acid resulting significantly in declining pH below the neutral pH and diminishing growth of methane bacteria when the digester initially fed (Ribas, 2003, Rodtong, et.al., 2004). So far, a biogas production of cassava starch effluent has not been much investigated in Indonesia yet. The things to be considered of biogas production of cassava effluent are nitrogen source to support the growth of the methane bacteria (Manilal, 1990); microbiology as biocatalyst (Werner Kossmann, *et al*, 2008); pH control during biogas production to keep methane bacteria alive (Werner Kossmann, *et al*, 2008); and feeding management in the semi continuous process of biogas production.

Therefore, the development of biogas technology that is currently dominated by the efforts of how to can improve

concentration and residence time in the biodigester to increase the rate of biogas production (Burke, 2001, Budiyono, et.al, 2009a). The research project is expected to contribute toward enhancement of knowledge in biogas technology by finding new technology of enhancement of biogas production. From the preliminary study conducted in Energy Conversion Laboratory of Mechanical Engineering and Waste Treatment Laboratory of Chemical Engineering University of Diponegoro, specifically for cassava starch effluent, biogas production will stop immediately in 4 days due to the decrease of pH drastically in hydrolysis and acidogenesis step. The main problem of the biogas production of cassava starch effluent is acid forming-bacteria quickly produced acid resulting significantly in declining pH below the neutral pH and diminishing growth of methane bacteria (Budiyono and Sumardiono, 2010). Hence, the only one of the method to cover this problem is by adding microalgae as biostabilisator of pH. Microalgae can also be used as purifier agent to absorb $CO_2$.

Basically, biogas technology is not a new technology. This technology has been developed several years ago in the world include in Indonesia (Muryanto, et al, 2006). The process of biogas production involves a number of several stage work simultaneously of biochemical reactions i.e. hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Speece, 1996). Various efforts to increase the biogas production has been proposed and developed. Furthermore, implementation of biogas technology for cassava starch effluent also been made by many researchers in this decade (Manilal, et.al., 1990, Anunputtikul, et.al., 2004, Muryanto, et.al, 2005). Several effort to increase biogas production rate from cassava starch effluent has been conducted by several researchers i.e. by adding nitrogen source to support the growth of the methane bacteria (Manilal, 1990); using microbiology as biocatalyst (Werner Kossmann, *et al*, 2008); pH control during biogas production to keep methane bacteria alive (Werner Kossmann, *et al*, 2008); and feeding management in the semi continuous process of biogas production. However, the development of biogas technology is currently dominated by the efforts of how to improve concentration and solid residence time (SRT) of microorganism in the biodigester (Burke, 2001). In addition, biogas production rate from cassava starch effluent is also still very low. So far, the biogas production of cassava starch effluent has not been intensively investigated yet.

Several research activities will be carried to develop an integrated process of biogas production and purification from cassava starch effluent by using biostabilisator agent microalgae. The scientific merit and economic benefit of the developed system are: i) the system can produce biogas in a very short time with the production of three times compared to conventional systems for the same period, ii) the system can produce biogas with high methane content due to the absorbsion $CO_2$ by microalgae, and iii) the system can be operated continuously so that the biogas production rate increase and biodigester volume decrease significantly. Design and technological feasibility study will be conducted in order to find out a comprehensive understanding of the fundamental scientific and industrial application which influenced by several factors: (i) the concentration of slurry, (ii) mixing factor which has implications for the homogeneity of the biodigester, (iii) pH control in biodigester which has the implications for the biogas production rate, (iv) integrated operation which has implications for the ease of controlling all the operating parameters, and (v) residence time in the biodigester which reflects the level of microbial concentration to biogas production. Technical data design parameters, operating conditions, hydrodynamics processes and physical-chemical properties of the fluid is absolutely necessary in the design study, develop operating procedures and troubleshooting prepare to the next step is the diffusion of technology to industrial application.

## II. MATERIALS AND METHOD

Cassava starch effluent was made syntheticly with total solid 1% (w/v). 25 gr of cassava starch was dissolved in 2,500 ml of microalgae 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. $Na_2CO_3$ was also prepared if necessary for rising the alkalinity of pH solution.

a. Variable

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.

b. Experiment Procedures

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. 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.

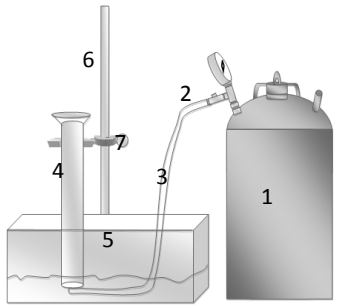


Figure 1. Water Displacement Technique; 1. Anaerobic biodigester 5L, 2. Valve, 3. Hose, 4. Measure glass, 5. Wash basin, 6. Statif, 7. Clamp

2. 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 ($Na_2CO_3$).
3. 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 DISCUSSIONS

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

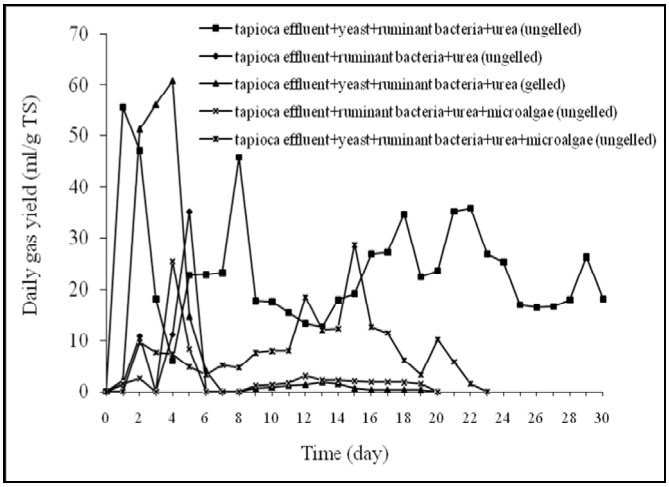


Figure 2. Daily Biogas Production per Gram Total Solid (ml/g total solid) from Various Feed Compositions Performed in Anaerob Biodigester of 5 L Digestion Volume.

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. 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.

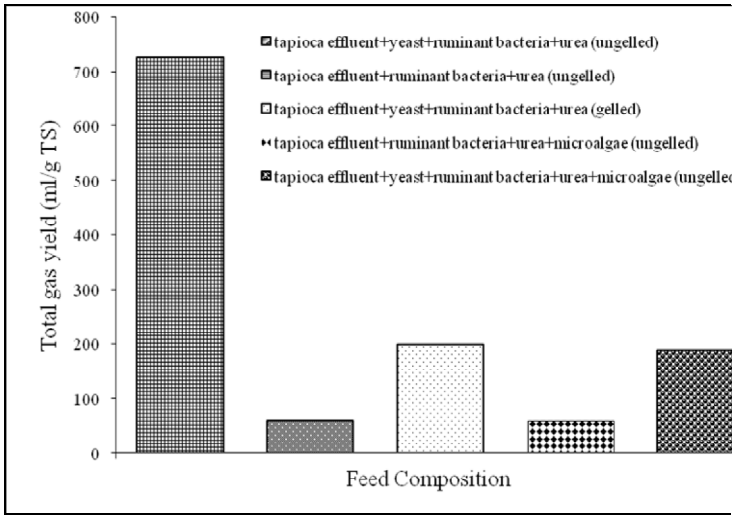


Figure 3. Total Gas Yield per Gram Total Solid (ml/g total solid) from Various Feed Compositions Performed in Anaerob Biodigester of 5 L Digestion Volume.

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 $H_2$-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., $H_2S$), and water. It was almost that 70% of methane was formed from acetate, and the rest was formed from carbon dioxide and hydrogen.

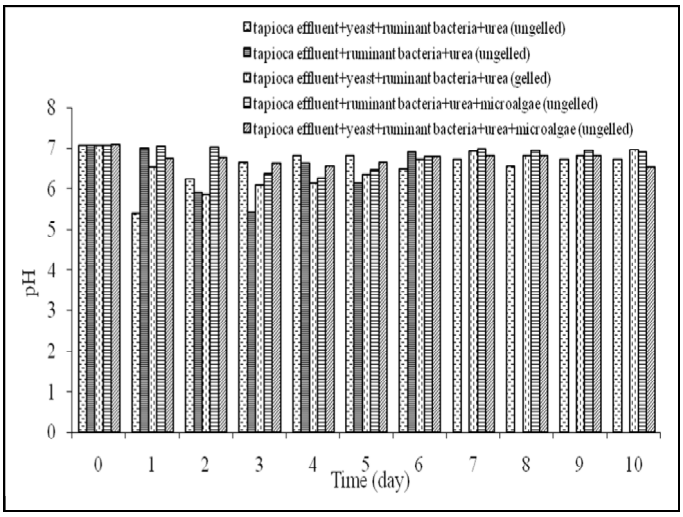


Figure 4. pH from Various Feed Composition Performed in Anaerob Biodigester of 5 L Digestion Volume.

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 $Na_2CO_3$ when the pH below 6.8. Based on previous study that the relation of percentage adding of $Na_2CO_3$ to delta pH solution was expressed by equation y = 3.914x + 0.042, so 0.39% of $Na_2CO_3$ 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 $Na_2CO_3$ 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 $Na_2CO_3$ was added, respectively. In Tank 3, 0.28%, 0.22%, 0.21%, 0.15% of $Na_2CO_3$ was added at second, third, fourth, and fifth days. In Tank 4, 0.18% of $Na_2CO_3$ was added at fourth day. In Tank 5, 0.1% of $Na_2CO_3$ 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 ($Na_2CO_3$) 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 $Na_2CO_3$ 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.

During 30 days of operation, the temperature ranges of 30.5-33$^0$C, 29.5-33$^0$C, 31-33$^0$C, 30-32.5$^0$C, and 30.5-32.5$^0$C were found in the digester 1, 2, 3, 4 and 5, respectively (Figure 5). At the initial retention time, the temperature was fluxtuative from 29.5$^0$C until 33$^0$C, but since the day thirteenth the temperature of mixtures stabilized. A slightly difference of temperature between the gelling feed and ungelling feed was occured but they still in the range of mesophilic temperature (29.5-33$^0$C).

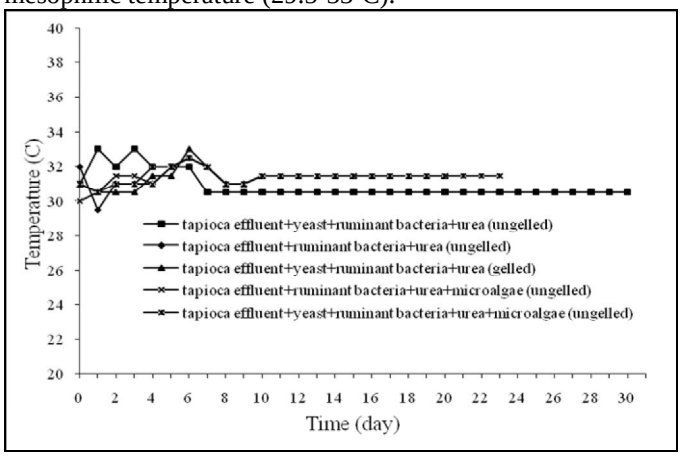


Figure 5. Temperature from Various Feed Composition Performed in Anaerob Biodigester of 5 L Digestion Volume.

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.

## IV. CONCLUSIONS

The main problem of the biogas production of cassava starch effluent is acid forming-bacteria quickly produced acid resulting significantly in declining pH below the neutral pH and diminishing growth of methane bacteria. Hence, the only one of the method to cover this problem is by adding microalgae as biostabilisator of pH. Microalgae can also be used as purifier agent to absorb $CO_2$.The general objective of this research project was to develop an integrated process of biogas production and purification from cassava starch effluent by using biostabilisator agent microalgae. This study has been focused 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 $Na_2CO_3$, and feeding management in the semi-continuous process of biogas production. The result can be concluded as follows: i) The biogas production increased after cassava starch effluent and yeast was added, ii) Biogas production with microalgae and cassava starch effluent, yeast, ruminant bacteria, and urea were 726.43 ml/g total solid, iii) Biogas production without microalgae was 189 ml/g total solid.

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