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CO Digestion for Biogas Production from Tapioca Industrial Wastewater and Septage

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In this study, a combination of substrate rich carbon with substrate rich nitrogen was carried out. The experiments were conducted in batches process by varying the C/N ratio and types of anaerobic microbial sludge of the cow rumen, anaerobic microbial sludgefrom wastewater treatment plant (WWTP) of septage and anaerobic sludge from WWTP of tapioca industry. Practically in the range of C/N ratio 20-30 didn't give a significant effect on the biogas production.The C/N 30 ratio provides the most biogas production rate, while the microbe derived from the cow rumen gives the most biogas production rate.Adaptation phase occurred up to 11th days, growth phase occurred lasted until day 24st, stationary phase occurred in the range of day 24th-31st and death phase occurred after day 31st. Biogas yield (by cow rumen) is 1,127 liters per kg of COD removed or 161 liters per kg of COD per day.

Keywords : biogas, co digestion, C/N ratio, septage, tapioca wastewater, cow rumen

INTRODUCTION

Anaerobic decomposition is the process of breakdown of complex organic substrates without oxygen, utilize anaerobic micro-organism. Decomposition of combination of organics substrates is known as co-digestion. The purpose of combiningthe two or moreorganic substratesfor control the C/N ratio so that the biogas production can be maximized. Organic substrates can be derived from organic waste, human waste, animal waste, organic waste from tapioca industry. The wasteater from tapioca industry has anCOD of about 8,840-11,800 mg/l (Fettig et al., 2013), containing carbohydrates of 25.37% (Setyana et al., 2011). Carbon is needed by microbes as an energy source while nitrogen is needed to build cell structures (Erfin et al., 2012). If nitrogen deficiency, then there is a decrease in pH. But if too much, will form a lot of NH_3 gas. When the ratio of carbon and nitrogen about 20-30 it will produce maximum biogas (Kayhanian M., et al., 1994).

Research conducted by Robby et al., (2013) states that the higher organic load rate (OLR) put into biodigester, the biogas production will be greater and obtained biogas production of 0.44 m^3/day at the OLR of 1.4 kgCOD/m^3.day. In addition, the decrease in COD will increase with increasing OLR, and the COD decrease up to 51.8% in OLR 1 kgCOD/m^3 day. In this study, biogas produced by combine of tapioca wastewater rich of C and septage rich of N.

THEORY

The basic principle of biogas production is decomposition of organic compounds by anaerobic microorganisms without oxygen. The product decomposition gas is a mixture, among which the most dominant are CH_4 and CO_2. Biogas is produced by methanogen or methanogenic bacteria. These bacteria are naturally present in anything wastes containing organic materials, such as livestock waste and organic waste. There are several factors affecting biogas production ie temperature, pH, volatile fatty acid (VFA), nutrition, toxic substance, (hydrolic residence time (HRT), C/N ratio, microbial species, food per microorganism (F/M)ratio (Al Seadi et al., 2008). Especially C/N ratio, the optimum C/N ratio for biogas production is around 20-30 (Kayhanian M., et al., 1994). In general, fluid from ruminansia (cow rumen) used as a source of methanogenic microbes. Stages in the anaerobic decomposition process are hydrolysis, acidogenesis, acetogenesis and methanogenesis. In hydrolysis of organic components such as fat, protein, cellulose is split into its monomers. In this phase, the exso-enzyme (hydrolase) of the facultative or obligatorily anaerobic bacteria breaks the bonds on the unsolved organic polymer. As a result, the covalent bond of the compound is split and dissolved in a chemical reaction with water. The breaking of these bonds aims to make the organic compounds more easily absorbed and digested by bacteria in their metabolism (Grady and Lim, 1980). The product hydrolysis will be utilizeby microorganisms as a source of carbon and energy. Hydrolytic microorganisms release the hydrolytic enzymes, convert biopolymers organic into simple organic monomerssuch of fatty acids, glycerol, monosaccharide, water-soluble amino acids (Al Seadi et al., 2008). In theacidogenesis stage, the organic monomers will be decompose by the anaerobic facultative bacteria into an organic acid with short chains such as propionic acid, butyric acid, acetic acid. These acids organic will be decrease the pH. The methane forming bacteria require optimum pH 6.5-8. The third stages is acetogenesis, the acetogenic bacteria is supported by the presence of hydrogen compounds. In this stage, acetogenic microorganisms convert VFA to acetic acid. The acetogenesis stage is important to avoid the accumulation of VFAs which inhibit the occurrence of methanogenesis stages. The last stage of anaerobic decomposition is methanogenesis that is the final phase in methane formation. Acetic acid, H_2 and CO_2 are converted into methane gas. In this phase, anaerobic conditions must be maintained because not all substrates can be broken down by methanogenic microorganisms (Gerardi 2003).

EXPERIMENT

The tapioca industrial wastewater is obtained from Sidomukti Village of Pati Regency. Septagewaste is obtained from Terboyo, Semarang City. Both wastes are stored at 4ºC, before use. When these two substrates are used, they are filtered on a 200 mesh filter, analyzed for their COD content, carbon content, total nitrogen content and total solids content. Microorganism took from cow rumen obtained from animal slaughter house of Semarang City, activated sludge from active anaerobic mud WWTP Tapioca Industry in Pati Regency, activated sludge from anaerobic mud from WWTP SeptageSemarang City. The all activated sludge is also filtered on200 mesh screen before usage. The process is carried out at batch-conditioned, and all substrate and microbial are mixed together in a 2-liter plastic container. Biogas volume is measured bywater displacement apparatus. The fermentation process is carried out at room temperature, the ratio of substrate to microbial (F/M) = 0.5. The independent variable is the incubation time,the control variable is the C/N ratio and the types of activated sludge. The observed response by incubation time is the volume of biogas and COD. Analysis of substrate parameters such as COD, Carbon, Nitrogen and Solids refer to Indonesian National Standard : COD-SNI 06-6989.15-2004 (BSNI, 2004a); Total Organic Carbon-SNI 01-3554-2006 (BSNI, 2006); Total Kjeldhal Nitrogen-SNI 19-7030-2004 (BSNI, 2004b); Total Solids and Volatile Solids SNI-06-6989.26-2005 (BSNI, 1991.).

RESULTS

The initial COD of tapioca industrial wastewater and septagewastewater were 10,997 mgO_2/l and 2,135 mgO_2/l, respectively. Carbon content in tapioca industrial wastewater is larger (12,740 mgC/l) than septagewastewater (208 mgC/l), but on the contrary the nitrogen content in tapioca industrial wastewater is much less (151 mgN/l) than septagewastewater (6,300 mgN/l). The C/N ratio in the tapioca substrate of 84.4 indicates more dominant carbon content, while in the septagewaste substrate of 0.03, indicates a more dominant nitrogen content. **Table 1** shows that cumulative biogas production up to day 60 reaches

Table 1. Biogas Cumulative Volume (ml) and Biogas Production Rate (ml/day)

Days	Biogas Cumulative Volume, ml			Phase/Stage	Days	Biogas Production Rate, ml/day		
	C/N-20	C/N-25	C/N-30			C/N-20	C/N-25	C/N-30
0	0	0	0					
11	62	99	116	Adaptation	0-11	6	9	11
24	1419	1767	2189	Growth	11-24	104	128	159
31	3284	3817	4424	Stationary	24-31	266	293	319
60	6282	7117	8434	Death	31-60	103	114	138

Table 2. Cumulative Biogas Volume (ml) and Biogas Production Rate (ml/day)

Days	Cumulative Biogas Volume, ml			Phase/Stage	Days	Biogas Production Rate, ml/day		
	CR	TIN	TAP			CR	TIN	TAP
0	0	0	0		0			
11	116	145	140	Adaptation	0-11	11	13	13
24	2189	1681	1626	Growth	11-24	159	118	114
31	4424	3366	3386	Stationary	24-31	319	241	251
60	8434	5081	5446	Death	31-60	138	59	71

6,282-8,434 ml. The highest biogas cumulative volume was achieved on C/N30, followed by C/N25 and C/N20. In the C/N30 ratio, the nitrogen content is less than in the C/N25 and C/N20 ratios, therefore, can reduce the formation of NH_3 which can inhibit the biogas production. From Table 1 it is also seen that during the fermentation process about 11 days, the biogas production rate still slowly. The adaptation or hydrolysis stage takes place.The rate of production is between 6 -11 ml/day. In the 13th - 24th days the rate of production increases 104-159 ml/day. This is of microbial growth stage. On the day of 24-31st, the rate of production between 266-319 ml/day. The ongoing phase is the stationary stages. After 31 to 60th is the phase of microbial death where there is a decrease in the biogas production rate 103-138 ml/day.

By anova statistical analysis based data in Table 1, shows that the P = 0.076 is greater than 0.05. Practically mean that in the range of C/N ratio 20-30 didn't give a significant effect on the biogas production. However the C/N-30 was produced biogas most than the C/N-20 and C/N-25at every stage of the process. The low of C/N ratio (20-25) indicate that nitrogen in the substrate is available in large quantities. The final product of decomposition process is gas and ionic forms, among them is NH_3 dan NH_4^+. Total ammonia nitrogen of 0,17- 14 g/L will be inhibited methanogenic activity to produce methane gas and reduce methane gas until 50% (Kayhanian M. 1994, Zeshan OP, Karthikeyan , 2012). The concentration of NH_3 in the range of 25-140 mg/l is toxis to methanogenic microorganism (Guerrero L et al. 1997).

The effect of the use of cow rumen (CR), anaerobic sludge from WWTP of Septage (TIN) and anaerobic sludge from WWTP of Tapioca (TAP) to biogas production can be seen in **Table 2**. where the fermentation process at room temperature, C/N-30 , F/M = 0.5. From the Table 2 shows that the highest biogas production is produced when using microbes from CR, followed by microbes from TAP and TIN. The biogas production rates also evident in the second to fourth stages. From Table 1 and Table 2 it is also show that although C/N was minimum, the most biogas production rate takes place in the stationary phase by using microbe from cow rumen.

Biogas yield is shown in **Table 3** and **Table 4**. The yield of biogas increases step by step, then decreases at the death stage. At a steady stage, the yield of biogas produced by using microbes from cow rumen, activated anaerobic sludge from septage WWTP and anaerobic sludge from tapioca WWTP were 1,127 liter/kgCOD (161 liter/kgCOD/day), 1,070 liter/kg COD (153 liter/kgCOD/day) and 827 liter/kgCOD (128 liter/kgCOD/day) respectively. Forty to sixty per cent of microbes in the cow rumen include bacteria and protozoa (Deublein D, Steinhauser 2008). They digest non structural carbohydrates of tapioca (amylopectin) respectively.

Table 3. Biogas Yield, Liter/Kg COD

Days	CR	TIN	TAP
0	0	0	0
0-11	37	48	47
11-24	774	719	955
24-31	1127	1070	827
31-60	735	948	896

Table 4. Biogas Yield, Liter/Kg COD/Day

Days	CR	TIN	TAP
0	0	0	0
0-11	3	4	4
11-24	60	55	73
24-31	161	153	118
31-60	25	33	31

CONCLUSIONS

The C/N ratio range of 20-30 didn't significance difference to biogas production. Microbes derived from cow rumen had better performance than microbes derived from anaerobic sludge WWTP of tapioca industry and ananerobic sludge of septage WWTP . In the stationary phase (by the cow rumen), the biogas yield is 1,127 liters per kg of COD removed or 161 liters per kg of COD per day.

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