THE EFFECT OF C/N RATIOS OF A MIXTURE OF BEEF CATTLE FECES AND WATER HYACINTH (*Eichornia crassipes*) ON THE QUALITY OF BIOGAS AND SLUDGE

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Abstract

The objective of this study was to know the effect of C/N ratios of fermentation substrate composed of beef cattle feces and water hyacinth (Eichornia crassipes) mix on the quality of produced biogas and sludge. Experiment was performed based on completely randomized design with three treatments of C/N ratio: i.e., 20, 25, 30, and replicated six times. The result showed that C/N ratios significantly increase the CH_4 content. Highest CH_4 content was provided by C/N ratio of 30. Ratios of C/N has no significant effect on CO_2 content, and results in very low H_2 content. The result also indicated that C/N ratios significantly decrease N, P, and K contents of the sludge. Although, C/N ratio of 20 provides the highest concentration of N, P, and K contents, all produced sludge may be used as single source of fertilizer.

Key words: beef cattle feces, water hyacinth, biogas, sludge

INTRODUCTION

Livestock development in Indonesia is increasing continuously particularly in beef cattle production. This has been lead to high amount of animal farm wastes at beef cattle production region, either feces or urine or farm wastes. Therefore, environmental pollution including land, water and air pollution also increased. This condition may also retard the acceleration of local sustainable development. On the other hand, the government nowadays is implementing cleaner production in all development sectors including animal production. Recycling is one of cleaner production activities that may conducted in beef cattle production. This activity may converts wastes into more valuable product. Since, energy become insecure, beef cattle feces will be more beneficial if recycled to produce biogas as source of energy. However, this activity may face difficulty, since cattle feces has low C/N ratio, i.e., 19 [5]. This is far below the ideal C/N ratio for biogas production. A C/N ratio of 30 will allow digestion and gas production to proceed at the best possible rate. If there is too much carbon (C/N of 60) in the slurry, the production of biogas slows down. If there is too much nitrogen (C/N of 10), the digestion will slow down. In addition to a lower biogas production rate, nitrogen loss will decrease the quality the fertilizer [1].

Environmental pollution caused by organic waste is indicated by algal and weeds' bloom in water bodies. In Indonesia, *Eichornia crassipes* bloom is the most widespread pollution indicator which very difficult to be removed due to its fast growth. So that, removing *E. crassipes* requires continuous daily base activity, such as recycling. Using *E.crassipes* in recycling beef cattle feces will improve C/N ratio of recycling feedstock. *E. crassipes* has high C/N ratio, due to high content of cellulose 20.4 – 42.23% [6]. This may be useful to increase the C/N ratio of biogas production feedstock made of beef cattle feces.

Using beef cattle feces and E.crassipes as feedstock of biogas production may provide some benefits, i.e., overcome environmental pollution, weeds abundance, produce source of energy alternative and organic fertilizer. However, information of the benefits in not available yet particularly in term of biogas production and organic fertilizer quality which representing the successful of this production. Therefore, the objective of this study was to know the effect of C/N ratios of biogas production feedstock composed of beef cattle feces and water hyacinth (*Eichornia crassipes*) mix on the quality of produced biogas and sludge.

MATERIAL AND METHOD

Beef cattle feces used in this study was obtained from Beef Cattle Teaching Farm at Faculty of Animal Husbandry Universitas Padjadjaran, while E. crassipes was obtained from Rancaekek District, Sumedang Regency West Java. The beef cattle is *Brahman sp.* imported from Australia.

In order to formulate biogas production feedstocks, chemical analysis of beef cattle feces and *E. crassipess* was done in duplex. The result of the analysis is presented in Table 1. C/N ratio of the feedstock was then calculated using the following formula [3].

$$\text{C/N ratio} = \frac{(F \times Cf) + (S \times Cs)}{(F \times Nf) + (S \times Ns)}$$

Where, F = beef cattle feces (kg), S = *E. crassipes* (kg), Nf = nitrogen content of cow dung (%). Ns = nitrogen content of *E.crassipes* (%), Cf= carbon content of beef cattle feces (%), Cs = carbon content of *E. Crassipes.* This study was done based on Completely Randomized Design with three treatments, i.e., C/N ratio of 20 (CN_{20}), 25 (CN_{25}), and 30 (CN_{30}) with six replication. Based on the formula, for example we can mix one kg cattle feces with 0.96 kg *E. Crassipes* to compose feedstock C/N of 25. The laboratory scale digester of 1500 ml was filled with 10% feedstock and water of 90%. Hence, 10% feedstock having C/N ratio of 25, there was 355.95 gr cattle feces and 713.20 gr *E. Crassipes* wet basis. The experiment was conducted in the period of 30 days. At the end of experiment, some variables were measured : (1) quality of biogas as well as CH4, H2, and CO2 using Gas Chromatography Mass Selective Detector (GCMSD), (2) quality of sludge as organic fertilizer as well as total-N, P_2O_5 and K_2O. Total-N was analyzed using Kiejldahl method, while P and K were analyzed according to [12]. The obtained data were analyzed using ANOVA followed by Tukey-test to know the differences among the treatments.

RESULTS AND DISCUSSIONS

The C/N ratios of the feedstock give various CH_4 contents of the produced biogas. The result of ANOVA indicated that the treatments significantly affecting CH_4 content, moreover the result of Tukey-test had shown the higher the C/N ratio, the higher the CH_4 content of the biogas. The effect of C/N ratio of 30 on CH_4 content is significantly ($P<0.05$) higher than that of C/N ratio of 25 and 20 respectively (Table 2). Based on Table 2, the highest percentage of CH_4 is resulted from C/N ratio of 30, viz. 17.27%. Previous studies indicate that CH_4 content in biogas from various waste materials are vary, from undetected to 69% [8] and as high as 70% [9]. Therefore, the content of CH_4 categorized low, although it is resulted from the ideal C/N ratio. There some other factors that influencing the production of CH_4 during fermentation process such as digester temperature. During the fermentation process, temperature digester was in the range of 25 – 29^{o}C, which is lower than the optimum temperature. Most anaerobic digestions operate at a hemophilic temperature range of 30-38^{o}C [2], with the average of 35^{o}C [4]. It means that the growths of microorganisms in the digester were slower than it should be. The CO_2 content of produced biogas is in the range of 63.48 – 69, 96%. Carbon dioxide used as electron receptor to form CH_4 [7]. So this high concentration of CO_2 content indicates that methanogenesis phase of fermentation were just began due to the slow growth of microorganism, and only small amount of CO_2 were used by microorganism to produce CH_4.

This study indicated that H_2 content of the produced biogas was very small so that undetected by gas chromatography. Usually, during the fermentation, microorganisms using H_2 as electron donor to produce CH_4 [10]. Since the quantity of H2 is very small, the quantities of produced biogas were also small.

The chemical analysis result of CO_2 from the resulted biogas presented on Table 2. It is found that the CN_{30} (C/N ratio of 30) provides the highest nitrogen content (69.965%), followed by CN_{25} (C/N ratio of 25) provides nitrogen content of 66.98 %, and finally CN_{20} (C/N ratio of 25) provides nitrogen content of 63.48 %. The result of ANOVA indicated that the treatmens are significantly influence the CO_2 content of biogas, then continued with the Tukey-test. The result of the test showed that the CN_{20} provide higher CO_2 content of produced biogas (P<0.05) than CN_{25} and CN_{30}. This finding proved that the methanogenesis is just beginning. During the process of methanogenesis, hydrogen producing eubacteria produced H_2 that used by methanogenesis archaeobacteria together with CO_2 to form CH_4 [11]. However, since H_2 was limited, the high CO_2 content did not provide high CH_4 content of the biogas. In contrary, although provides the lowest CO_2 content, CN_{30} result in the highest CH_4 content. The carbon content of the CN_{30} feedstock was higher than CN_{20} and CN_{25}. This may support microorganisms to grow faster and produce more H_2 than those in CN_{20} and CN_{25}.

The results of chemical analysis of N-Total, P_2O5 and K_2O contents presents on Table 3. The N-Total content of the resulted sludge are vary in the range of 0.82 - 1.06%. The result of ANOVA shows that C/N ratio significantly influences the N-total content of the resulted sludge. The result of Turkey-test indicate CN_{20} result in higher N-total content (P<0.05) compared to that resulted from CN_{25} and CN_{30}. The higher C/N ratio, the higher C content and the lower N content in the feedstock. In an airtight biogas digester, there a lot of organic acid produced during anaerobic fermentation of organic substance, which helps to absorb and fix ammonia and minimize the loss of nitrogen, thus conserving the fertility of the resulted sludge or manure [7]. Hence, the N content of the feedstock treated with CN_{20} were higher than other treatment that also occurred in the sludge.

Moreover, the results of this study also reveal that resulted sludge contains P_2O_5 in the range of 0.20 – 0.77%. Again, the treatments were affecting P2O5 content of the resulted sludge, and Tukey-test result showed that CN_{20} provide higher P_2O_5 content (P<0.05) than CN_{25} and CN_{30}. This P_2O_5 content of sludge allegedly related to the growth of microorganism. With high nitrogen content compared to carbon content, CN_{20} supported microorganism's growth. In this condition, certain heterotrophic bacteria are able to take up simple organic molecules produced by hydrolysis and fermentation. Since there is no electron acceptors are available, the microorganisms sequester the electrons and carbon in intracellular solids, such as polyhydroxybutyrate. With the help of acetyl coenzyme A (HSCoA), hydrolysis of intracellular polyphosphate performed, which in turn release phosphate to the environment during anaerobic condition [10].

Furthermore, the study indicated that the treatment of C/N ratio also produced varying K_2O content of the sludge, namely 0.28 – 1.04%. The variation was significantly cause by the C/N ratios. The results of Tukey-test were more specifying the difference of every treatment. CN_{20} provided higher K2O content of the sludge (P<0.05) than what CN_{25} and CN_{30} did. It can be see that increasing C/N ratio decreased the K_2O content of the sludge. It is predicted that the number of microorganisms in CN_{20} are mostly came from beef cattle feces, the portion of cattle feces in this treatment were higher than in the others treatments, consequently the concentration of nitrogen also higher. At the beginning, microorganism growth faster and increased the mineralization of potassium. As the result, the K_2O content of the sludge were also increased. The K2O contents of the sludge were beyond the compost quality standard.

Finally, although the highest contents of nitrogen, phosphorous and potassium were provided by CN_{20}, all those major nutrients content are fulfilling the standard quality of compost, i.e., 0.4 % N, 0.1% P_2O_5, and 0.1% K_2O [10]. Therefore, all resulted sludge can be use as organic fertilizer.

Table 1. Carbon and nitrogen content of beef cattle feces and *E. crassipes*

Organic matter	Carbon content (%)	Nitrogen content (%)	Water content (%)	C/N ratio
Beef cattle feces	49.87	2.69	78.50	19
E. crassipes	48.81	1,23	89.70	39.68

Table 2 The result of Tukey-test the effect of C/N ratio on CH4 content of biogas (α 0.05)

Treatment C/N ratio	Average CH_4 content (%)	Average CO_2 content (%)
CN_{30}	17.27 a	63.48 c
CN_{25}	9.07 b	66.98 b
CN_{20}	2.72 c	69.96 a

Table 3 The result of Tukey-test the effect of C/N ratio on Total-N, P2O5 and K2O content of Sludge (α 0.05)

Treatment C/N ratio	Average Total-N content (%)	Average P_2O_5 content (%)	Average K_2O_5 content (%)
CN_{20}	1.06 a	0.77 a	1.04 a
CN_{25}	0.88 b	0.88 b	0.53 b
CN_{30}	0.82 b	0.82 c	0.28 c

CONCLUSIONS

The result of study showed that C/N ratios significantly increased the CH_4 content. The highest CH_4 content provided by C/N ratio of 30. The ratios of C/N had no significant effect on CO_2 content, and resulted very low H_2 content. The result of study also indicated that C/N ratios significantly decreased N, P, and K contents of the sludge. Although, C/N ratio of 20 provided the highest concentration of N, P, and K contents, all produced sludge can be used as single source of fertilizer.

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REFERENCES

[1] Amott. 1998. The Biogas/Fertilizer Handbook. Appropriate Technologies for Development. IEC/Peace Corps. Washington DC. 1998

[2] Chu, L. M. and P.K. Wong, 2006.Municipal wastewater treatment. In Microbial Biotechnology, 2nd edition. in. Kun L.Y. (Eds), World Scientific Publishing Co. Ltd. Singapore. 2006; 625-666.

[3] CSIRO. Composting: Making Soil Improver from Rubbish. Discovering Soil No.3. 1997.

[4] Davis, M.L. and S.J. Masten. Principles of Environmental Engineering and Science. McGraw-Hill Co.Inc. New York 2004.

[5] Gaur A C, A Manual of Rural Composting FAO/UNDP, Regional Project RAS/75/004. Field Document No.15. FAO, Rome, 1982, 102

[6] Gopal, B. and K.P. Sharma. Water-Hyacyinth (Eichornia crassipes): most troublesome weed of the world. Hindasia Publisher. New Delhi. 1981.

[7] Institue of Soil and Fertilizer-AASR. Research Work on the Utilization of Digester Sludge and Effluent As Fertilizer. In :Biogas Fertilizer System. Technical Raport on Training Seminar in Cina. UNEP Report and Proceeding Series.2. UNEP. Nairobi 1981:49-56

[8] Panel on Methane Generation. Methane Generation from Human, Animal and Agricultural Waste. National Acadeimc of Science. Washington DC. 1977.

[9] National Standardization Agency of Indonesia.. Specification of compost made from domestic organic waste..SNI No. 19-7030- 2004.

[10]Rittman,B.E. and P.L.McCarty. Environmental Biotechnology: Principles and Applications. McGraw-Hill Book Co. Singapore. 2001

[11] Submali, G and R.S. Mehrotra. Principles of Microbiology. Tata McGraw-Hill Education Private Limited. New Delhi. 2009.

[12] Sudjadi, M., I.M. Widjik and M. Sholeh. Soil analysis guidelines. Soil Research Agency, Bogor. 1971.Publ.No.10:51-61