Waste Technology (WasTech)
Journal homepage: http://ejournal.undip.ac.id/index.php/wastech
An International Journal

Study of Biogas Production Rate from Water Hyacinth by Hydrothermal Pretreatment with Buffalo Dung as a Starter

Yuhelsa Putra[1], Dewi Murni[2], Teguh Kurniawan[3]

[1]AgricultureDepartment, Universitas Sultan AgengTirtayasa, Serang, Indonesia
[2] Biological Department, Universitas Sultan AgengTirtayasa, Serang, Indonesia
[3]Chemical Engineering Department, Universitas Sultan AgengTirtayasa, Serang, Indonesia
e-mail: teguh@ft-untirta.ac.id

Abstract- *In this paper, the effects of hydrothermal pretreatment on biogas enhancement production rates from water hyacinth mixed with buffalo dung was investigated.The focus of the experiment was on thetime of hydrothermal pretreatment and the ratio of water hyacinth with buffalo dung. The hydrothermal pretreatedsubstrates were characterized by TDS, BOD and pH.The hydrothermal pretreatment of 60 minutes with the ratio of water hyacinth to buffalo dung 1:2 showed the highest biogas production rateat 7889 ml/day. However, the highest methane composition was 52.82% which resulted on the hydrothermal treatment of 30 minutes with equal ratio of water hyacinth and buffalo dung. Thus, the optimum of methane yield obtained at hydrothermal pretreatment for 30 minutes with equal ratio of water hyacinth to buffalo dung is 2856 ml/day.The hydrothermal pretreatment increases the rate production of biogas 102% and the methane yield51% relative to untreated water hyacinth.The ratio of water hyacinth and buffalo dung has a great impact on biogas productionrateand compositions for hydrothermal pretreated substrates.*

Keywords – *Biogas;Hydrothermal pretreatment;Water hyacinth; Buffalo dung.*

Submission: July 25, 2014 Correction: August 24, 2014 Accepted: August 30, 2014

Doi: 10.12777/wastech.2.2.26-30

[How to cite this article: Kurniawan, T., Putra, Y., &Murni, D. (2014).Study of Biogas Production Rate from Water Hyacinth by Hydrothermal Pretreatment with Buffalo Dung as a Starter.*Waste Technology, 2*(2), 26-30. doi:10.12777/wastech.2.2.26-30]

1. Introduction

In the last few decades research on biomasshas become the trending topic due to the depletion of fossil fuel and its environmental issues. As a tropical country, Indonesia has a big opportunity to develop the biomass based fuel originate from waste agricultural cellulose as well as nonagricultural cellulose. Twocommon routes to exploit biomass for energy purpose are thermal and fermentation processes.The anaerobic digestion for producing biogas is one of the promise and simple way to harvest the renewable energy. The first generation process generates biogas from livestock dung. Next, second generation of biogas generated from cellulose plant also attracted since its abundant availability and low-cost raw materials.

One of water plant that becomes a problem on river is water hyacinth due to its fasted growing which implicate to theeutrophication. On the other hand, the major component of water hyacinth is cellulose which is the basic substrate for fermentation. Thus, water hyacinth has a high potency as a raw material for biogas fermentation due to its cellulose high content[1]. However, water hyacinth containslignin which is a disadvantage of using water hyacinth in the biogas production.Pretreatment throughphysical and chemical routes are reported effectively breakdown the lignin [2,3,4].

According to Mosier et al. [5] pretreatment by steaming, the addition of lime and hydrothermal are some of the methods that can improve significantly the action of hydrolysis enzyme.The main effect is to dissolve hemicellulose and lignin structural which increases the probability of accessing the cellulose by hydrolysis enzyme.Walch et al. [6] showed that hydrothermal treatment can be applied to remove hemicellulose from lignocellulose material through combination of dissolution and auto hydrolysis effects on the temperature of 120 ^{o}C to 200^{o}C.The hydrothermal pretreatmentmake the differences in the size of the raw materials used in the fermentation process become homogeneous[7]. This led to the exposed of the surface area and causes the cellulose more accessible to enzymes.

According to Ferrer[8] hydrothermal pretreatment at a temperature of 80^{o}C for 30 minutes rises the water hyacinth hydrolysis process by triggering dissolution of water hyacinth from 4 to 10-12%. It hasshown that the pretreatment by boiling and steaming make the higheraccess for bacteria through enzymatic hydrolysis process of lignocellulosic biomass. As the result,the glucose as the hydrolysis product increased considerably. Thisglucose will then be used by bacteria and transformed into anacetic acid which has an important stepas a reactant for the production of biogas by methanogenic bacteria. Thus, an increase in the hydrolysis process will increase the activity of methanogenic bacteria and in turn will increase biogas production and methane.

Qiao[9] reported thatafter hydrothermal pretreatment 170^{o}C/h, biogas production from lignocellulosic biomass increased from 210 ml/g to 238 ml/g of raw material.Hydrothermal pretreated substrate had resulted into an increase of 9.2% in biogas production and 20 % in methane production compared to that of untreated wheat straw substrate [10].Another study suggested that the hydrothermal pretreated substrate had resulted into an increase of 225.6% in biogas production and 222% in methane production relative to untreated rice straw substrate[3].

Shankar et al. [1] stated that water hyacinth has no microbes essential to initiate the process of biogas production. Kalle&Menon[11] reported that buffalo dung mixture can be used as a substrate for biogas production. Each 1 g of fresh buffalo dung containing 104 bacteria from rumen fluid. El-AzeemHadi[12] showed that the production of biogas from buffalo dung ranged from 104.7 to 468.1 L/kg of total organic solids.

Hartono and Kurniawan[13] states that the maximum biogas production rate occurred in the digester with ratio composition of 75% rice straw and 25% buffalo dung with production rate 6.5 ml/h and methane concentration 59.6%.Putra [14] reported that the highest biogas production of buffalo dung occurs at of agitation 50 rpm with a volume of 120.8 ml cumulative biogas and methane 20.19 ml. The average flow rate is 0.31 cm^3/h of biogas and 0.053 cm^3/h of methane gas. Quantitative variation associated with biogas production ratio C/N, the concentration of organic solids, as well as the content of nitrogen and carbon compounds. The increase in C/N ratio led to a decrease in the anaerobic decomposition process. Increased maximum biogas production correlated with a decrease in the OTS and C/N ratio. Moorhead and Nordstedt) [15] have used a batch-type anaerobic digestion to produce biogas from water hyacinth on incubation temperature of 35 ^{o}C.

To the best of our knowledge the study of effects of hydrothermal pretreatment on the biogas production and methane from water hyacinth with a combination of buffalo dung has never been conducted.

2. Materials and Methods

The raw material of water hyacinth was taken from Ciujungwhile buffalo dung obtained from buffalo ranch in Gempol, Serang. All chemicals,$K_2Cr_2O_7$, H_2SO_4, $MnSO_4$, $Na_2S_2O_3$, using here were pure analytically grade. The hydrothermal pretreatments were examined by using autoclave.This study of fermentationwere using anaerobic batch reactor 20 liter in size.During the fermentation process, the biochemical parameters total solid (TS), COD, BODwere analyzedby standard method (ASTM D6238 – 98).

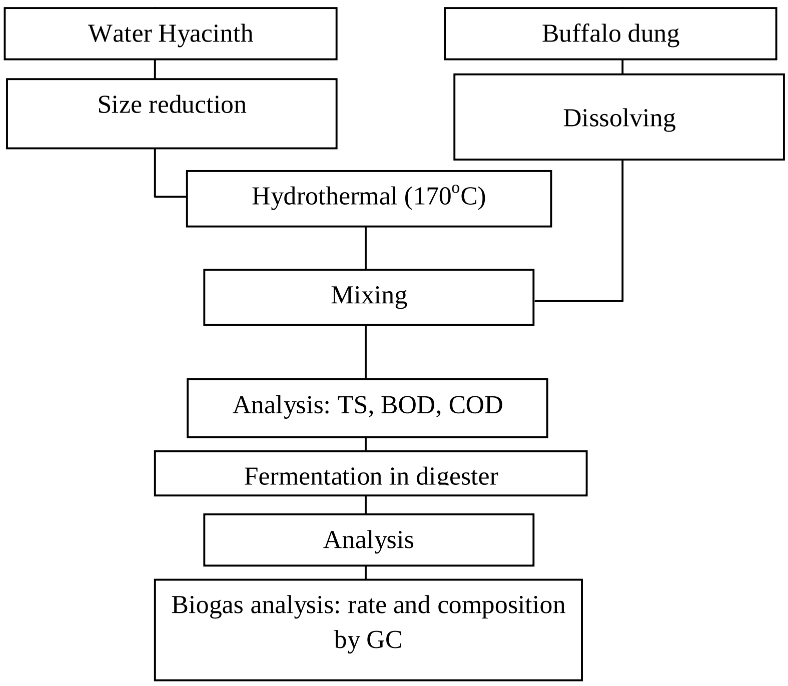

Figure 1. Experimental steps for biogas production with hydrothermal treatment

Water hyacinth reduced by 6 mm size using slicer. Buffalo dung mixed with water with ratio 1:1. The reduced water hyacinth heated in an autoclave and boiled at selected temperature of 170°C with variations of 30 minutes, 60 minutes and 90 minutes of hydrothermal pretreatment. Then, water hyacinth removed from the autoclave and left open until it reaches room temperature. After reaching room temperature, water hyacinth mixed with buffalo dung with ratio 1:2, 2:2 and 2:1. The slurry of water hyacinth and buffalo dung was then inserted into the digester. This mixture was incubated in ambient temperature for the fermentation process. The measurement of the biogas production ratewas conducted by using salt solution technique. The biogas compositions were analyzedby using gas chromatography(GCShimadzu type-8A).

3. Results and discussion

3.1 The Effects of hydrothermal treatment on biogas rates

The hydrothermal pretreatment has changed the water hyacinth colorfromgreen to brown due to the disappearance ofchlorophyll during boiling in autoclave.The BOD has surged dramatically for hydrothermal treatment of 30 minutes from 953.7 to 1549.8 (Table 1).However,further hydrothermal treated showed only a slightly difference. The increasing of BOD revealed that the microbe have a larger access to the cellulose which the substrate for biogas production.Substrates acidity of hydrothermal treated ranged within 7.9 – 8.25. As the fermentation arose the acidity was declining which indicatedacetic acid produced by acidogenic bacteria. The biogas produced is affected by the acidity [16].

The results of the measurement of biogas production without hydrothermal treatment showed low production as in Figure 2. The structure of lignin remains intact thus the microbe has no access to cellulosic materials. This low production biogas for water hyacinth without hydrothermal pretreatment confirms the study obtained by Ferrer et al (2010). The biogas rate was started to increase while the water hyacinth pretreated for 30 minutes. In addition, it achieved the peak on 60 minutes hydrothermal pretreated. However, the biogas production rates slightly decreased after 60 minutes. It is shown that hydrothermal increase significantly the biogas production rates. This probably because of the bacteria activity to produce hydrolysis enzyme increases by the greater access to the cellulosic material after removing the lignin structure during the hydrothermal process [10,11].

Table 1.Biochemical parameters before the fermentation process.

Hydrothermal treatment time (minutes)	TDS	BOD	pH
0	19.9	953.7	7.7
30	13.1	1549.8	7.9
60	19.7	1520.1	8.78
90	18.9	1549.5	8.25

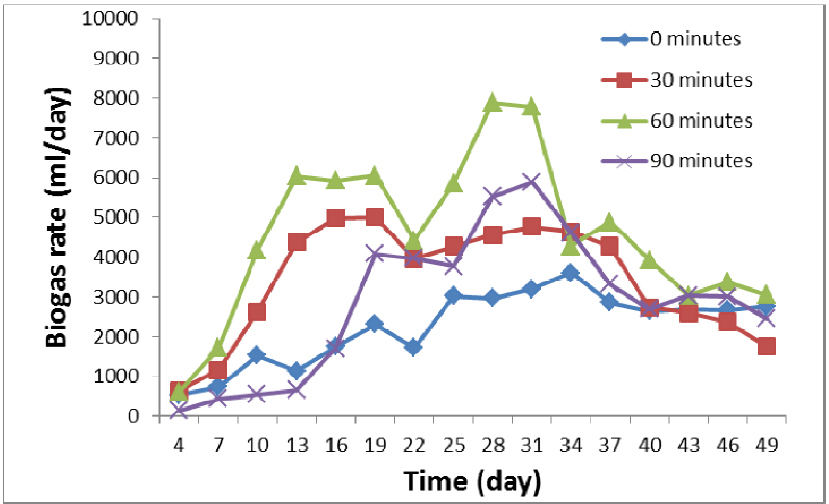

Figure 2. The Effects of hydrothermal treatment time on the biogas rate for ratio 1:2

3.2 The Effects of substrates composition on biogas rate

It can be seen from Figure 2a that the ratio of water hyacinth and buffalo dung has no significant effects on the biogas production ratefor the water hyacinth with no hydrothermal pretreated. It means that the buffalo dung as a starter for the fermentation taken place was not effectively used by the anaerobic system due to the lack of access to the cellulosic material. The ratio of water hyacinth and buffalo dung become important for the hydrothermal pretreated (figure b,c, and d). In fact, the ratio 1:2 shows the highest biogas production rates especially for 60 minutes and 90 minutes hydrothermal pretreated.This is probably due to the number of bacteria for fermentation process which was increasing with the amount of buffalo dung in the digester.

3.3 The effects of hydrothermal on methane yield

Table 2 shows that hydrothermal pretreatment by 30 minutes increase the methane content from 29.6% up to 44.9%. However, the longer the hydrothermal pretreatment have a tendency to decrease the percentage of methane. As we can see from Table 2 that the methane percentage of maximum biogas rate achieved at 60 minutes and ratio 1:2 is only 23.85%. Thus, the methane yield for the maximum biogas peak at 7889 ml/day is only 1881.8 ml/day. The high biogas production rate did not correspond with the methane yield.

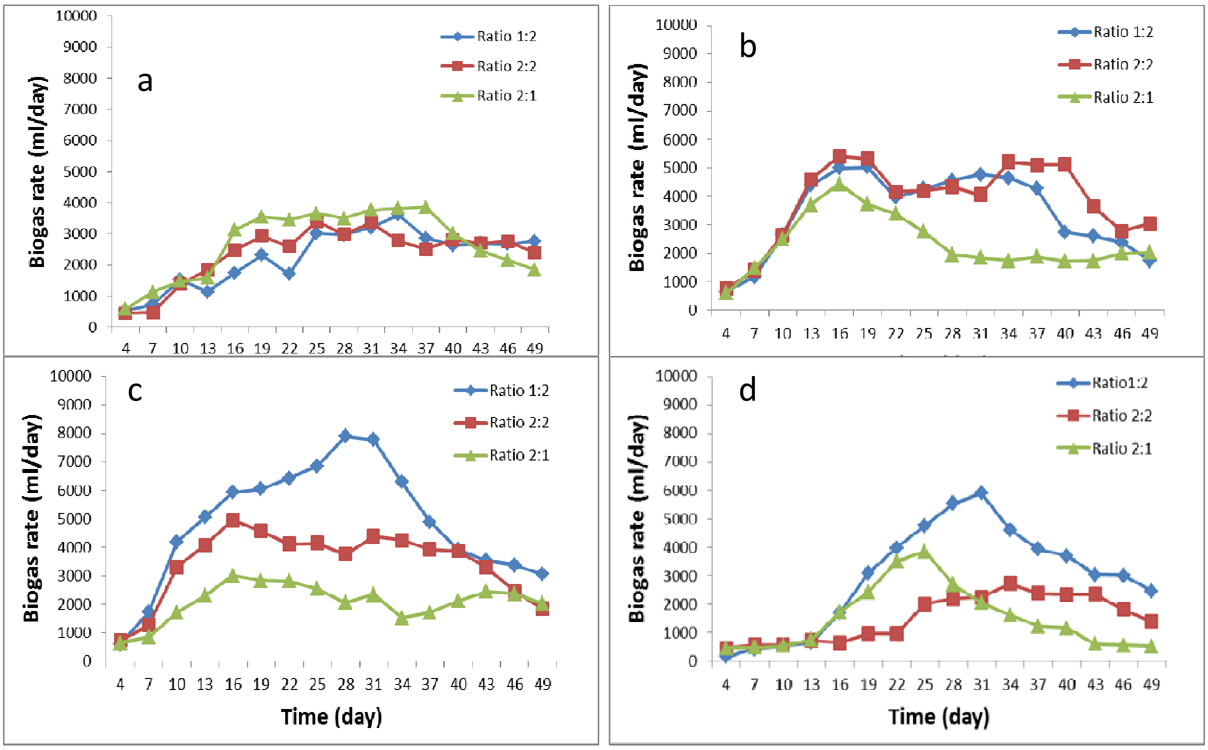

Figure 2.Biogas production with hydrothermal pretreatment a). 0 minutes, b). 30 minutes, c). 60 minutes, d). 90 minutes.

Table 2.The effects of hydrothermal time on biogas compositions

Hydrothermal pretreatment time (minutes)	Ratio water hyacinth to buffalo dung	Compositions (%)		
		CH_4	CO_2	N_2O
0	1:2	29.6308	70.36830	0.000900
30	1:2	44.9012	55.09828	0.000520
60	1:2	23.8532	76.14642	0.000380
90	1:2	31.5504	68.44931	0.000290

3.4 The effects of water hyacinth and buffalo dung ratio on methane yield

As we can see from table 3, the composition of substrates affected significantly to the composition of biogas. The analysis showed that the highest percentage of methane gas found in hydrothermal treatment 30 minutes with a ratio of 2:2, namely 52.82% (Table 2). This percentage indicates that the quality biogas produced is high which can be used as a source of electrical. The lowest percentage as 21.37 % of methane was occurred in hydrothermal treatment 90 minutes with a ratio of 2:1. The biogas rate for maximum composition reached at 52.89% is 5400 ml/day. Thus, the methane yield is 2856 ml/day. It can be concluded that the optimum of methane yield obtained at hydrothermal pretreatment for 30 minutes and equal ratio of water hyacinth to buffalo dung.

Table 3.The effects of ratio of substrate on biogas compositions

Hydrothermal pretreatment time (minutes)	Ratio water hyacinth to buffalo dung	Compositions (%)		
		CH_4	CO_2	N_2O
30	1:2	44.9012	55.09828	0.000520
30	2:2	52.8912	47.10860	0.000200
30	2:1	44.6740	55.32587	0.000134

4. Conclusions

The biogas production from hydrothermal pretreated water hyacinth mixed with buffalo dung was examined by a series of batch laboratory testing. The experiments revealed that the highest biogas production was 7889 ml which occurred on hydrothermal treatment of 60 minutes at a ratio of water hyacinth and buffalo dung 1:2. However, the highest methane percentage was 52.82% when the hydrothermal treatment of 30 minutes with the ratio of water hyacinth and buffalo dung 2:2. Thus, the optimum of methane yield obtained at hydrothermal pretreatment for 30 minutes and equal ratio of water hyacinth to buffalo dung is 2856 ml/day. The present study suggested that the hydrothermal pretreatment enhances the production of biogas from water hyacinth significantly. The ratio of water hyacinth and buffalo dung has a significant improvement on biogas production for hydrothermal pretreated substrates.

Acknowledgments

The authors would like to acknowledge the support provided by Directorate of Higher Education, Indonesia forfunding this work through scheme project of HibahBersaing: DIPA UNTIRTA no. 023.04.2.663101/2014.

References

[1] Shankar, J.H., Patil, P.L., Muralidhara, Ramya M., and Ramya 2013. Effect of substrate concentration on biomethanation of water hyacinth. *International Journal of Chemical, Environmental & Biological Sciences*, 1: 2320–4087.

[2] Rahmayetty, Kurniawan, T., Gumelar, A.J., danDewi, S.K. 2012. Pengaruhpenambahanbasaterhadpproduksi biogas daricampuranjeramipadidankotorankerbau. Prosiding Seminar NasionalTeknik Kimia Indonesia. Jakarta.

[3] Chandra, R., Takeuchi, H. and Hasegawa, T. 2012a. Hydrothermal pretreatment of rice straw biomass: A potential and promising method for enhanced methane production. *Applied Energy*, 94:129-140.

[4] Sari, F.P. and Budiyono 2014. Enhanced biogas production from rice straw with various pretreatment : a review. *Waste Technology*, 2(1):17-25.

[5] Mosier N., Wyman, B.C., Dale, and Elander,Y.Y.R,. Lee, M., Holtzapple, M. and Ladisch 2005. Features of promising technologies for pretreatmentoflignocellulosic biomass. *Bioresource Technology*, 96:673–686.

[6] Walch E., Zemann, A., Schinner, F., Bonn, G., Bobleter, O. 1992. Enzymatic saccharification of hemicellulose obtained from hydrothermally pretreated sugar cane bagasse and beech bark. *Bioresource Technology*,39:173-177.

[7] Zeng. M.S., Mosier, N., Huang, C.P., Sherman, D.M., and Ladisch, M.R. 2007. Microscopic examination of changes of plant cell structure in corn stover due to hot water pretreatment and enzymatic hydrolysis. *Biotechnology and Bioengineering*, 97 (2):265-278.

[8] Ferrer I., Palatsi J., Campos, E. and Flotats, X. 2010. Mesophilic and thermophilic anaerobic biodegradability of water hyacinth pre-treated at 80 °C.*Waste Management,* 30:1763–1767.

[9] Qiao, W. X., Yan, J.Y., Sun, W.Y., Wang, Z., Zhang 2011. Evaluation of biogas production from different biomass wastes with/without hydrothermal pretreatment. *Renewable Energy*, 36:3313-3318.

[10] Chandra, R., Takeuchi, H., Hasegawa, T. and Kumar, R. 2012b. Improving biodegradability and biogas production of wheat straw substrates using sodium hydroxide and hydrothermal pretreatments. *Energy,* 43:273-282.

[11] Kalle, G.P. and Menon, K.K.G. 1984. Inhibition of methanogenesis and its reversal during biogas formationfrom cattle manure. *J.Biosci*., 6(3):315–324.

[12] Hadi, A.M.A. and El-Azeem, S. A. M. 2008. Effect of heating, mixing and digester type on biogas production from buffalo dung. *Misr J. Ag. Eng*., 25(4):1454-1477.

[13] Hartono, R. danKurniawan, T. 2009. Produksi biogas darijeramipadidenganpenambahankotorankerbau. Prosiding Seminar NasionalTeknik Kimia Indonesia. Bandung.

[14] Putra, Y. 2011. Pengaruhpengontrolanprofilkecepatanagitasiterhadappembentukan biogas reaktordenganbahankotorankerbau. Tesis Program Magister TeknikFisika. InstitutTeknologi Bandung.

[15] Moorhead, K.K. and Nordstedt R.A. 1993. Batch anaerobic digestion of water hyacinth: effects of particle size, plant nitrogen content and inoculum volume. *Bioresource Technology*, 44:71-76.

[16] Astuti, N., Soeprobowati, T.R. and Budiyono 2013. Observation of temperature and pH during biogasproduction from water hyacinth and cow manure. *Waste Technology*, 1(1):22-25.