Applicative Biogas Plant For Processing Cow Dung In The Small Scale Livestock Farming

Ramaiyulis, Ulva Mohtar Lutfi, Riva Hendriani, John Nefri

Abstract: This study aims to evaluate the performance of the biogas plant to process cow dung in small-scale farms in rural areas. This biogas plant uses a digester from a 3,000-liter polyethylene tank equipped with a concrete inlet and outlet tub. The tank is planted into the ground upside down and connected to the inlet and outlet tub using 4 " PVC pipes, as well as the gas line to the stove with a plastic hose, while the stove uses a modified LPG stove. The results of the digester performance test showed that the biogas production rate ranged from 96-104 liters/hour so that 1,244 liters of biogas were accumulated in the morning, 576 liters in the afternoon, and 589 liters in the afternoon. The total gas accumulated in the digester provides pressure between 150-220 mmH_2O and is enough to push biogas from the digester to the stove. The use of biogas can turn on 2 ignition stoves at once in the morning for 230 minutes, afternoon for 112 minutes, and evening for 116 minutes. Environmental conditions in the digester with a pH of 7.5 and a constant temperature of 25 ºC can support the anaerobic fermentation process in the digester to produce an optimal and constant rate of biogas production. The residual fermentation slurry from the digester produced a total of 183 liters/day and contained 1.76% nitrogen, 0.81% P_2O_5, and 0.49% K_2O. This biogas processing unit is suitable for developing small scale farmers in rural areas to run environmentally friendly livestock businesses.

Index Terms: biogas production, biogas composition, green energy, slurry composition.

1 INTRODUCTION

The increase in energy demand caused by population growth and depletion of world oil reserves and the problem of emissions from fossil fuels put pressure on every country to immediately produce and use renewable energy. Indonesia targets the realization of an optimal mix of energy in 2025 by reducing the role of kerosene and increasing the role of gas and encouraging the use of renewable energy [1]. Households in Indonesia use energy sources for cooking consisting of LPG (72.38%), firewood (21.57%), kerosene (3.78%), charcoal / briquettes (0.19%), electricity (0 , 85%) and others (1.24%) [2]. The use of biogas as a renewable energy source is still very low and has not been calculated.

Indonesia has the potential to develop biogas energy sources because it is in line with the Republic of Indonesia's government program to increase the cattle population towards beef self-sufficiency [3]. Beef cattle farming is generally carried out as a family business by small scale farmers with 2-3 cattle. The development of biogas energy sources for farming families will be able to meet the energy needs of farming families independently. Biogas raw material, namely cow dung, is produced around 8,952 kg/household/year and if processed can produce 1,253 m3 biogas/ household/year so that it can meet the needs of energy for cooking of one family [4]. Cow dung is an organic material that is suitable as a biogas-forming fermentation substrate because it contains a C/N ratio of 23.5 which is in the optimum C/N ratio range (20-25) for an anaerobic fermentation process [5]. The residual slurry of biogas fermentation can be used by farmers as organic fertilizer or processed commercially in the organic fertilizer processing unit (UPPO) [6].

- *Ramaiyulis, Animal Husbandry Study Program of Agricultural Polytechnic of Payakumbuh, Indonesia, PH+6285263053550. E-mail: ramaiyulis@gmail.com*
- *Ulva Mohtar Lutfi, Veterinary Paramedic Study Program of Agricultural Polytechnic of Payakumbuh, Indonesia, PH+628126631177. E-mail: ulvamohtar@gmail.com*
- *Riva Hendriani, Agribusiness Study Program of Agricultural Polytechnic of Payakumbuh, Indonesia, PH+6285263022927. E-mail: riva_hendriani@yahoo.com*
- *John Nefri, Agribusiness Management Study Program of Agricultural Polytechnic of Payakumbuh, Indonesia, PH+628126707885. E-mail: johnnefri@gmail.com*

The biogas produced is suitable used to meet the energy needs of households in rural areas, technically, socially, and economically. Biogas can replace the role of firewood, kerosene, and LPG as energy sources for cooking. Biogas development for the community that has been carried out is limited to a grant project. Some of the obstacles in the development of biogas are the lack of technical capabilities, the biogas reactor does not function due to leakage or construction errors, the design of the reactor is not user-friendly, manual handling, and expensive construction costs [7]. Development of household-scale biogas digester with 2-3 cattle or ± 25 kg of cow dung/day, can use a 2,500-5,000 liter capacity digester tank. This digester can produce biogas equivalent to 2 liters of kerosene/day to meet the energy for cooking of one household with 6 family members. In this study, the biogas plant uses a 3,000-liter polyethylene tank that was planted into the ground and equipped with an inlet and outlet tub. This biogas plant is claimed as an applicative biogas digester for processing cow dung in small-scale livestock farming because simple, permanent, and easy to build at low cost. This study aims to determine the performance of the biogas digester for the development of small-scale farming biogas technology.

2 MATERI AND METHOD

2.1 Biogas Digester

Biogas digester uses a polyethylene tank which is commonly used as a tank for household water stock with a 3,000-liter capacity. The digester tank is prepared by installing the inlet and outlet pipes using a 4-inch PVC. The pipe is installed by punching the tank wall on the top side to insert the pipe into the tank and then locked with the pipe glue. The pipe that enters the tank for the inlet and outlet is 30 cm long respectively and the elbow is mounted on the outside of the tank so that it forms a U with the ends on the outside of the tank attached to the inlet and outlet tub. Digester tanks are planted in a ground hole in an upside-down position, ie the bottom of the tank to the top of the hole. The planting of the tank is strengthened with concrete castings on the top side of the tank to resist the surge in the tank due to gas pressure. The Inlet and outlet are made of concrete tubs with a size of

120 x 60 x 50 cm inlet, and 150 x 100 x 120 cm outlet tubs (l.w.h dimension). The position of the inlet tub is set with the position of the floor of the tub in balance with the top side of the digester tank while the outlet tub is positioned with the top of the tub is parallel to the top of the tank digester.

TABLE 1.
SPECIFICATIONS OF DIGESTER DEVICES AND BIOGAS STOVES

Specification	Information
Digester	
Type	Fixed dome
Feeding system	Batch
Capacity	3,000 liters
Tank diameter	144 cm
Tank High	211 cm
Tank material	Polyethylene
Material thickness	3 mm
Dimensions of inlet tub (l.w.h)	60x100x50 cm
Dimensions of outlet tub (l.w.h)	143x100x110 cm
inlet and outlet pipe	PVC Ø 4 inch
Biogas channel to the stove	Plastic thread hose Ø 1/2 inch
Biogas Stove	Modification of LPG 2 gas stove ignition

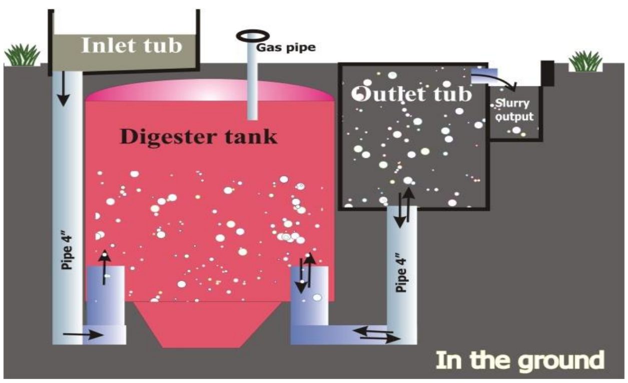

***Fig. 1**. Design of biogas digester for processing cow dung in the small scale livestock farming*

2.2 Operational biogas digester

The first filling, the digester tank is filled with slurry until full (3,000 liters). The slurry is a mixture of cow dung + water with a ratio of 1: 1 with stirring in the inlet tub to form a suspension. After the first filling, wait for 21 days, then continue with routine filling for maintenance at a frequency of 1 x 3 days with a 100-liter slurry. The biogas produced along 21 days first is discharged because methane percentage is still low and after that biogas is used routinely every day for consumption of biogas stoves.

***Fig. 2**. Installation of biogas digester for processing cow dung in the small scale livestock farming*

***Fig. 3**. Construction of biogas digester for processing cow dung in the small scale livestock farming*

2.3 Biogas stove

The biogas stove used is the LPG stove of Rinai™ type RI-522 C by modifying the gas sprayer. The working principle of LPG gas stoves is the same as biogas stoves, but the need for gas consumption for biogas stoves is higher due to the lower methane concentration in biogas compared to LPG (liquified petroleum gas). Modifications are made by dismantling the burner holder so that the gas sprayer is visible on the yellow base with a small hole. The original sprayer pit has 0.5 mm in diameter, must be enlarged 3-4 times to 1.5-2 mm using a drill so that the rate of biogas to the burner can be increased.

2.4 Parameters measurement

The measurements of the research parameters are conducted after the normal use in the household for 7 days. Daily gas production rate is measured by capturing biogas from digester with a large plastic bag at 3 observations time namely at 06.00, 12.00, and 18.00 hours, for 3 consecutive days in 4 weeks.

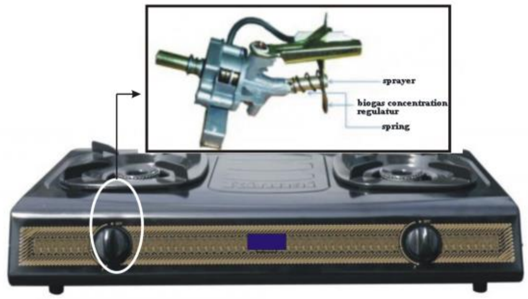

Fig. 3. Modification of stove for biogas

The captured biogas is then measured its volume using a vacuum tube filled with water and connected to a biogas storage plastic with a hose. The water in the tube flows out causing a vacuum in the tube and siphoning biogas that is accommodated in a plastic bag to fill the tube space left by the water. The volume of biogas is calculated as liters of water flows out of the vacuum tube assuming the volume of water coming out is equal to the volume of gas being siphoned into the tube. Measurement of methane (CH_4) in biogas is done by capturing CO_2 with a solution of 10 N NaOH. In one syringe of 100 ml scale filled with 50 ml of NaOH 10 N and removed all air cavities and covered with a rubber cap. Through this rubber cap, 50 ml of biogas is injected and a 5-minute wait for the NaOH reaction process with CO2, and then the scale reading on the syringe.

$$\text{Methane } (CH_4) = \frac{B-A}{C} \times 100\%$$

A: the initial scale of the syringe contains NaOH
B: the scale of the syringe after biogas injection
C: Biogas volume injected

Biogas pressure is measured by a liquid manometer in the form of a U pipe filled with water. one end of the U pipe is connected to a biogas tube and the gas pressure is determined by the difference in the surface of the water in the section which is pressured with which it is not.
The degree of acidity and the temperature of the slurry coming out into the outlet is measured with a pH meter and thermometer. Slurry nutrient content was analyzed for nitrogen using the Kjeldahl, P_2O_5, and K_2O with UV-Vis spectrophotometry methods.

3 Result and Discussion

The results of the performance measurement of small-scale farming of biogas digesters using polyethylene tanks that are planted in the soil and equipped with inlet and outlet tubs are shown in Table 2.

Table 2
Results of Performance Measurement of Biogas Digester

Digester performance	Observation time		
	06:00 hour	12:00 hour	18:00 hour
Biogas production	104	96	98
Biogas production rate (liters / hour)	104	96	98
Total biogas accumulation (liters)	1,244	576	589
Biogas pressure (mm H_2O)	220	160	150
Chemical composition of biogas			
CH_4 (%)	78.20	67.82	69.21
CO_2 (%)	21.80	32.18	30.79
Use of biogas stoves			
Stove life time (minutes)	230	112	116
Biogas consumption (liters/minute)	5.41	5.14	5.08
Slurry Output			
Outlet output (liters)	88	45	50
Slurry pH	7.6	7.5	7.5
Slurry temperature	25 °C	25 °C	25 °C
Slurry nutrient content (%)			
Nitrogen		1.76	
P_2O_5		0.81	
K_2O		0.49	

Table 2 shows the rate of biogas production produced from the slurry fermentation process in the digester by methanogen bacteria ranging from 96-104 liters/hour. The obtained biogas production is higher than reported by [8] using Fixed dome type digesters made of concrete and 7,000 liters capacity which results in a biogas production rate of 80 liters per day. Likewise, the report with the same type of digester only produces 53.3 liters/day of biogas [5]. The rate of biogas production obtained was relatively constant at three times of observation morning, noon, and afternoon. Observations were made on the 42nd day after the first filling, at which time biogas production was constant according to the report of [9] that biogas production starts on the 10th day and peaks on the 30th day then produces constant from the 40th day. At the time of observation, it is suspected that the growth of methanogenic bacteria has been constant because the rate of biogas production is influenced by the growth of methanogenic bacteria that convert volatile acids into methane and CO_2 with other end products [10]. The total accumulation of biogas in the digester is 1,244 liters in the morning at 06:00 clock, then 576 liters at 12.00 clock and 589 liters in the afternoon. Different accumulation results in the morning observations are due to the observation time interval from 18.00 clock to morning 06.00 clock is 12 hours, whereas at noon the observation time interval is 6 hours. This observation time interval is related to the time of using biogas for cooking in the household which usually starts at 6:00 in the morning, continues in the afternoon, and evening. Based on these observations it appears that sufficient biogas accumulation is available for cooking purposes to ensure the supply of energy for cooking needs in the family independently. This can be seen by a long life stove that morning for 230 minutes, during 112 minutes and 116 minutes for the first-afternoon ignition. In practice the use of biogas stoves for cooking purposes usually turns on the stove two ignitions at a time, then the stove can be lit in the morning for 1 hour 55 minutes, afternoon for 52 minutes, and evening for 56 minutes. This condition occurs continuously and constantly based on observations that have been made for 3 days a week for 4 weeks. Biogas pressure measured using a water manometer under SNI 7826: 2012 [11] obtained pressure 424, 362, and 358 mmH2O at 06:00, 12:00, and 18:00 clock. This pressure is enough to be able to constantly push biogas from the tank to the stove for optimal stove flame [12]. The recommended minimum pressure for the use of the stove so that it can burn properly is 150 mmH2O [13], meaning that if the pressure is below that number then the flame will weak which indicates the efficiency of the stove is very low. Biogas pressure in the tank is caused by the difference in slurry surface height between the tank and the outlet tubs. In this study, the construction of the outlet tub is carried out with the lip height of the outlet tub equal to the height of the top surface of the digester tank, but lower than the height of the bottom of the inlet tub. This aims to keep the biogas pressure in the tank optimal while the slurry overflow in the tank can only come out to the outlet tub and not turn back into the inlet tub. The accumulation of gas formed in the digester at a rate of 96-104 liters/hour will force the slurry from the digester to come out to the outlet tub. In this observation, the total volume of the output of the slurry in the outlet tub at 06.00 hours was 88 liters, at 12.00 hours it was 45 liters and at 18.00 hours it was 50 liters. Part of the slurry that is accommodated at this outlet will flow into the output slurry tub and some will remain in the outlet as a filler for the digester when the biogas comes out of the digester during use. The volume of the slurry going out to the outlet is proportional to the volume of space available in the digester to accommodate the accumulation of biogas formed in the digester. Based on SNI 7826: 2012 on small scale biogas digesters, a minimum gas space of 1-3 m3 should be available [11]. In this study, the maximum available gas space has reached 1.24 m^3, so that it has met SNI standards. The amount of slurry pushed out is slightly lower than the biogas that has accumulated to occupy the digester space, this is due to the compaction of biogas that is reflected by the formation of biogas pressure. The degree of acidity (pH) has a considerable influence on the process of methane gas formation. Measuring the acidity of the slurry that has just come out of the digester to the outlet tubs is found to be between 7.5 - 7.6. The acidity of this slurry is in the optimum range of the anaerobic process in the range of pH 6.0 to 8.0 [14]. This is reinforced by the results of the study of [12] who reported that neutral pH will spur the development of methanogenic bacteria so that the acetic acid remover bacteria can grow optimally and this will have an impact on the production of biogas produced. Besides pH, suitable temperature conditions support the productivity of the biogas digester in producing methane gas. In ideal temperature conditions, bacteria can grow more easily so that the formation of methane gas will take place quickly. The results of the measurement of the slurry temperature both coming out of the digester into the outlet tub and in the inlet pipe both show temperatures of 25 °C, and are relatively constant both morning, afternoon and evening. Slurry temperature is not affected by ambient temperature changes in the morning, afternoon, and evening obtained in the temperature range of 21-29 °C. The optimal temperature for the digester is 25-30 °C, this temperature range is the best environmental conditions for bacterial growth and methane production in the digester with a short processing time. The mass of the same material will be digested twice as fast at 25 °C than at 15 °C and produce almost 15 times more biogas with the same processing time [15].

4 CONCLUSIONS

The observations of the performance of the biogas digester using a 3,000-liter capacity polyethylene tank indicate that the production rate of biogas produced ranges 96-104 liters/hour so that the total volume of biogas that accumulates in the digester in the morning is 1,244, afternoon and evening as many as 576 and 489 liters. Biogas that accumulates in this digester can turn on the ignition biogas stove 2 at a time in the morning for 1 hour 55 minutes, afternoon for 52 minutes, and evening for 56 minutes. Environmental conditions in the digester with a pH of 7.5 and a constant temperature of 25 ºC can support the anaerobic fermentation process in the digester to produce an optimal and constant gas production rate. This biogas digester technology provides fairly effective performance at a relatively low cost and difficulty. The development of this technology more broadly to the community is very potential to be carried out in the use of renewable energy sources and the development of environmentally friendly farms and sustainable agriculture.

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REFERENCES

[1] D. Migas, Konversi Mitan ke Gas, Jakarta: Dirjen Migas, pp. 40-49, 2013.

[2] BPS, Indonesian Balance Energy, Jakarta: BPS-Statistic Indonesia, pp. 27-42, 2018.

[3] A. A. Sulaiman, I. Inounu, S. Torang, and Maidaswar, SIWAB Solusi Cerdas Swasembada Daging Sapi dan Kerbau. Jakarta: Sekjen Kementan RI, 2017.

[4] A. U. Farahdiba, A. Ramdhaniati, and S. S. Soedjono, "Teknologi Dan Manajemen Program Biogas Sebagai Kabupaten Malang," J. Inov. dan Kewirausahaan, vol. 3, no. 2, pp. 145–159, 2014.

[5] M. Garfí, J. Martí-Herrero, A. Garwood, and I. Ferrer, "Household anaerobic digesters for biogas production in Latin America: a review," Renew. Sustain. Energy Rev., vol. 60, pp. 599–614, 2016.

[6] Ramaiyulis, Nilawati, E. Yulia, and R. Novia, "Empowering of communities receiving the aid of organic fertilizer processing units ('UPPO') with quality and packaging improvement in Indonesia," Int. J. Sci. Technol. Res., vol. 9, no. 1, pp. 2817–2821, Jan. 2020

[7] T. W. Widodo, A. Asari, A. Nurhasanah, and E. Rahmarestia, "Design and Development of Biogas Reactor for Farmer Group Scale," Indonesian. J. Agric., vol. 2, no. 2, pp. 121–128, 2009.

[8] N. Sawyerr, C. Trois, T. S. Workneh, and O. Oyebode, "Design of a household biogas digester using co-digested cassava, vegetable and fruit waste," Energy Reports, vol. 6, pp. 1476–1482, 2020.

[9] K. Hagos, J. Zong, D. Li, C. Liu, and X. Lu, "Anaerobic co-digestion process for biogas production: Progress, challenges, and perspectives," Renew. Sustain. Energy Rev., vol. 76, pp. 1485–1496, 2017.

[10] P. G. Adinurani, H. S. Roy, W. Satriyo, N. Anggi, M. Mel and S. Andi, "The Performance of Jatropha Curcas Linn. Capsule Husk as Feedstocks Biogas in One Phase Anaerobic Digestion," Procedia Chem., vol. 14, pp. 316–325, 2015.

[11] BSN, Unit penghasil biogas dengan tangki pencerna (digester) tipe kubah tetap dari beton. Jakarta: Badan Standardisasi Nasional, pp. 16-32, 2012.

[12] E. Kusrini, M. Lukita, M. Gozan, B.H. Susanto, T. W. Widodo, "Characterization and Removal of CO2 Using Modified Clinoptilolite Zeolites in A Fixed-Bed Column," J. Chem. Inf. Model., vol. 53, no. 9, pp. 1689–1699, 2019.

[13] H. Clemens, R. Bailis, A. Nyambane, and V. Ndung, "Energy for Sustainable Development Africa Biogas

Partnership Program: A review of clean cooking implementation through market development in East Africa," Energy Sustain. Dev., vol. 46, pp. 23–31, 2018.

[14] A. J. Ward, B. Emiliano, L. Morten, F. Anders, and A. Anders, "Real-time monitoring of a biogas digester with gas chromatography, near-infrared spectroscopy, and membrane-inlet mass spectrometry," Bioresour. Technol., vol. 102, no. 5, pp. 4098–4103, 2011.

[15] S. Im, S. O. Petersen, D. Lee, and D. H. Kim, "Effects of storage temperature on CH4 emissions from cattle manure and subsequent biogas production potential," Waste Manag., vol. 101, pp. 35–43, 2020.