THE POTENTIAL OF PALM OIL MILL EFFLUENT FOR UPGRADE OF BIOGAS PRODUCTION

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Abstract - ***The increased consumption of energy all over the world has led to a drastic increase to the rates of all carbon based fuels. In addition to this, carbon based fuels has a finite source that will not be able to meet the increasing fuel needs in the world. And with fossil fuels emitting excessive carbon dioxide and other gases, they prove to increase the incidence of global warming in the world. So to meet the energy needs of the world and to control global warming, scientists and researchers all over the world are working at creating new fuels. The aims of the research were to (i) characterize palm oil mill effluent which will be used as source of upgrade biogas production, (ii) know the biotic and abiotic factor which effect POME substrate for biogas production by anaerobic digestion in bulk system. The results show that POME sludge generated from PT. Swastisiddhi Amarga Bioenergi mill is viscous, brown or grey and has an average total solid (TS) content of 36,5-55,4, COD is 50,5-73,6, BOD is 33,5-39,6 and suspended solid (SS) is 27,1-45,9 g/L, respectively. This substrate is a potential source of environmental pollutants. The biotic factors were kind and concentration of the inoculums, i.e. seed sludge of anaerobic lagoon II and 20%(w/v) respectively. Both physical and chemical factors such as pre-treated POME pH, pH neutralizer matter $Ca(OH)_2$, temperature >40^{o}C, agitation effect to increase upgrade biogas production.***

Key Words: *Upgrade of biogas production, characteristic of POME, biotic and abiotic factors, batch system.*

Introduction

Palm oil mill effluent (POME) in processing each ton of fresh fruit bunches (FFB) will produce an average of 120-200 kg of crude palm oil (CPO), 230-250 kg of oil palm empty fruit bunches (EFB), 130-150 kg fiber, shell 60-65 kg, 55-60 kg of kernels, and 0.7 m^3 of wastewater. If Indonesia managed to become a major producer of CPO world, by producing 18 million tons of CPO per year as targeted, it will produce liquid waste palm oil mill *(LCPMKS*) of >50 million tonnes per year (Ditjenbibprodbun, 2004*). LCPMKS* is a source of potential contaminants that could seriously impact on the environment, so the plant is required to handle this waste through increased processing technology (end of pipe).

Organic material in the process of anaerobic fermentation (technological overhaul of anaerobic) overhauled by the activity of microorganisms into biogas. Biogas production with *LCPMKS* materials provide various advantages among which the reduction of the amount of organic solids, the amount of unwanted microbial spoilage, and toxicity in the effluent (Judoamidjojo,et.al.,1989).

In addition, biogas residues can be used as organic fertilizer non fitotoksin (Sudradjat,et.al., 2003). Stated that the production of biogas gained attention as the end product of biogas is a mixture of CH_4 and CO_2 which is a flammable gas, its almost the same as natural gas and can be used as a source of renewable energy.

Anaerobic fermentation of organic material is the reform process undertaken by a group of facultative and obligate anaerobic microbes in a closed reactor (fixed dome) at a temperature of 35-55^{o}C. Overhaul of organic materials are classified into four stages of the process, the first fermentative bacteria hydrolyze polymer compounds into simpler compounds that are dissolved. Second, monomers and oligomers converted into acetic acid, H_2, CO_2, short-chain fatty acids and alcohols; This stage is also called asidogenesis stage. Third, the so-called non-methanogenic phase which produces acetic acid, CO_2 and H_2. Fourth, the conversion of these compounds into methane by methanogenic bacteria (Reith, et.al., 2002 ; Metcalf and Eddy Inc., 2003).

Methanogenic bioconversion process is a biological process that is strongly influenced by environmental factors, especially temperature, pH, and toxic compounds. Overall factors influencing the reform process of anaerobic organic matter in the formation of biogas, including biotic and abiotic factors.

Biotic factors such as microbial and active bodies, are abiotic factors include agitation, temperature, pH, substrate concentration, water content, the ratio of C / N and P in the substrate, and the presence of toxic materials. The fermentation process can be done by several methods, one of which is the bulk fermentation system, which is carried out in a tank (digestor), and can be tested in a laboratory scale. The aim of this study were: (i) determine the characteristics of liquid waste palm oil mill *PT. Swastisiddhi Amarga Bioenergi, Binabaru, Pekanbaru, Riau* and determine the combination of the type and concentration of inoculum best, and (ii) the influence of abiotic factors on the total production of biogas per treatment in a bulk system.

Materials and Methods

Materials needed include: the type and concentration of inoculum in the form of cow manure 10% (*KTS*-10%); *LCPKMS* mud pool I, 10 and 20% (*LKLM* I-10%, I-20%); pool II, 10 and 20% (10% *LKLM* II, II-20%), and control. Medium material abiotic treatments such as NaOH, Ca(OH)2, pH 4.4, 5.5, and 7, without agitation and increased temperature ≥40oC, with *LCPMKS* as raw material substrate. The tools needed include plastic drum 50 L, 2.5 L *PET* bottles, hoses (φ 0.5 cm), the wire.

The experiment was divided into two sub-experiments, namely waste characterization and influence of abiotic and biotic factors on the production of biogas. Drum 50 L (bioreactors), given various treatments inoculum, and *LCPMKS* as a raw material in the reactor bulk substrate anaerobic conditions. Biotic factors treatment type and concentration of inoculum, are abiotic factors such as pH, temperature, agitation, time, and a neutralizing agent. The fermentation process was measured at intervals of two weeks, lasted for 12 weeks. The production of biogas is collected in 2.5 L PET bottles and hoses (φ 0.5 cm). The end result is measured and the concentration of methane production (Jawad, M. and V. Tare., 1999). Parameters measured include pH, temperature, total production of biogas, and the rate of COD, BOD, TS, SS, oil and crude fat and total nitrogen (Suzuki, at.al., 2003; Greenberg, at.al., 1992).

Results and Discussion

The results of the study are presented in several sub-experiments of which the characteristics *LCPMKS PT. Swastisiddhi Amarga Bioenergi,* as well as the influence of biotic and abiotic factors of the total production of biogas each *LCPMKS* treatment of a bulk system.

Characteristics LCPMKS

The results of the analysis of the chemical characteristics *LCPMKS PT. Swastisiddhi Amarga Bioenergi* shows that the waste is colloidal, thick, brown or grayish, pH 4.4 to 5.4 and has an average COD content of 50.5 to 73.6; BOD 33.5 to 39.6; TS 36.5 to 55.4 and from 27.1 to 45.9 g SS / L (Table 1). Overall parameters measured above the threshold quality standards that have been set *MENKLH* designation (1995), so *LCPMKS* potential as environmental contaminants. Without efforts to prevent or manage them effectively will be a negative impact on the environment, such as odor, water pollution and public waters around the plant, and the greenhouse gas impact of global climate change (Ahmad, at.al., 2003).

Table -1: Characteristics *LCPMKS PT. Swastisiddhi Amarga Bioenergi*

Parameter	Value range	Average	Quality standards*)
pH (International Unit)	4,4-4,5	4,4	6-9
Temperature (^{O}C)	50-65	57	-
BOD (g/L)	33,50-39,60	36,55	0,11
COD (g/L)	50,50-73,60	62,05	0,25
Total Solids (g/L)	36,50-55,40	93,9	0,25
Suspended Solids (g/L)	27,10-45,9	36,50	0,10
Oil and crude fat (g/L)	29,00-29,50	29,30	0,03
Nitrogen Total (g/L)	27,00-28,70	27,70	0,02

Information: *) Based decision-51/MENLH/10/1995.

The results of the study parameters of COD, BOD and other parameters show that the quality *LCPMKS PT. Swastisiddhi Amarga Bioenergi, Binabaru, Pekanbaru, Riau,* far above the quality standards allowed, so it could potentially be a pollutant if discharged directly into the environment. Range *LCPMKS* characteristics fluctuate due to the influence of the production process plant, season, and post-harvest (Yacob, S, at.al.2006). Stated that *LCPMKS* with anaerobic reshuffle has more than 1.5 kg COD / m^3 (Battacharya et al. 2003). Production of 1 m^3 *LCPMKS* can produce 20-28 m^3 of biogas. Paepatung (2006) suggest the potential for biogas production can reach >35 times the number of 1 m^3 *LCPMKS. LCPMKS* or can be converted to 38.69 m^3 of biogas. The measurement results of previous studies showed that COD *LCPMKS* of 35-95 g / L and BOD 10-60 g / L. Other measurement results obtained 90.4 g COD / BOD L and 54.56 g / L (Prasertsan and Sajjakulnukit,2006), and 44.3 g COD / BOD L and 22.7 g / L (Zinatizadeh et al., 2006). *LCPMKS PT. Swastisiddhi Amarga Bioenergi* potential pollutants that have a negative impact on the environment and waters, on the other side of this waste is biochemically potentially economically so needed to boost the management to be more efficient.

Effect of biotic factors on the production of biogas

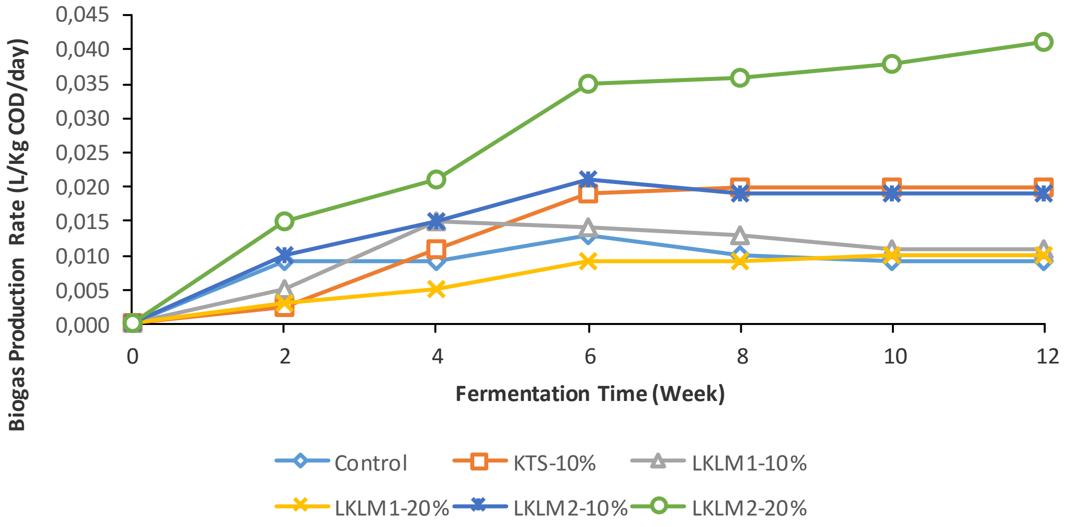

Figure -1: Interactions types, inoculum concentration and fermentation time on the rate of biogas production.

The results obtained show the influence of biotic factors and the type of inoculum concentration on the production of biogas (Figure 1), namely: (i) *KTS*-10%, (ii) *LKLM* I-10%, (iii) *LKLM* II-10%, (iv) *LKLM* I-20%, (v). *LKLM* II-20%, and (vi) control (without inoculum) is presented in Figure 1A. Biotic factors that affect the well is inoculum *LCPMKS PT. Swastisiddhi Amarga Bioenergi* pool II, with a concentration of 20% (*LKLM* II-20%) with a volume of 15 L. type substrate and inoculum concentration is very important for the reduction of organic matter and biogas production rate, because the process bio fermentasi *LCPMKS*, microbial bodies whose role is life growing up in the substrate. Sahirman (1994) stated that the inoculum is more than 12.5% (w / v) with a volume of 2 L substrate in laboratory scale did not show an increase in biogas production. While the results of this study reveal inoculum *LKLM* II-20% (w / v) with the substrate 15 L, obtained biogas production are best compared to other concentrations.

Factors type and concentration of inoculum was instrumental in the reform process and the production of biogas. Anaerobic decomposition is the process of microbial growth and energy use by overhauling the organic matter in anaerobic environments and produce methane. According Reith et al. (2003) there are four stages of anaerobic decomposition in which a process of hydrolysis of proteins into amino acids, carbohydrates are converted into sugar, and lipid converted into long-chain fatty acids and glycerol. This can be done by various types of microbes, so many factors that influence it, both abiotic and biotic factors.

The influence of abiotic factors on the production of biogas

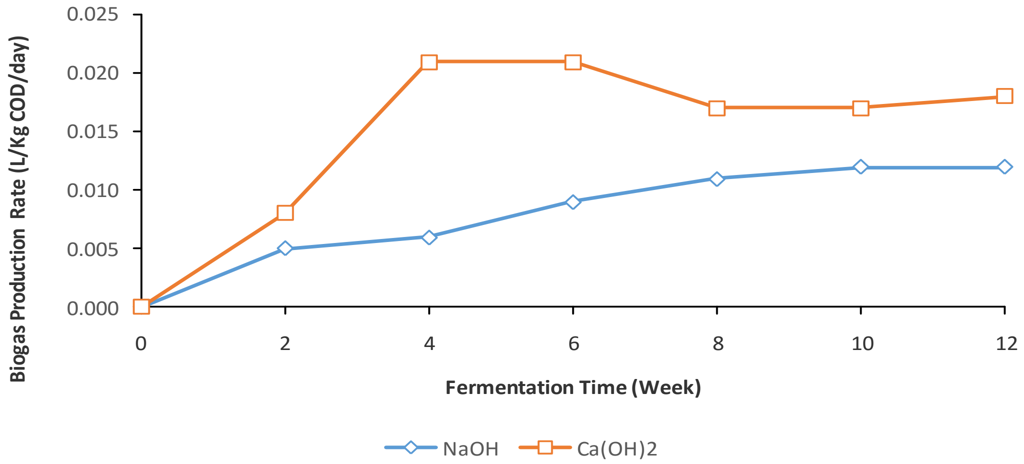

Figure -2: Interaction provision negutralizin agent and fermentation time on the production of biogas.

The influence of abiotic factors of each of the biogas productio is described in Figure 2. NaOH and $Ca(OH)_2$ nis the material used to stimulate an increase in the pH of acidic *LCPMKS* substrate. The results obtained showed that the addition of neutralizing the pH can increase biogas production, and $Ca(OH)_2$ is better than the effect of NaOH (Figure 2). This is understandable because of NaOH are met with oil will undergo saponification process produces glycerol and fatty acids (Ahmad et al., 2003).

LCPMKS rich in organic materials including fat, so the addition of NaOH likely to interfere with the process of reform of the substrate and indirectly interfere with the rate of biogas production. $Ca(OH)_2$ is often used to an increase in the pH of the solution. The optimum pH increase will accelerate the decay process, thus improving the effectiveness of microbial and can increase the production of biogas.

The results obtained indicate that the initial substrate pH 7 provides enhanced biogas production rate is better than the other pH treatment (Figure 3).

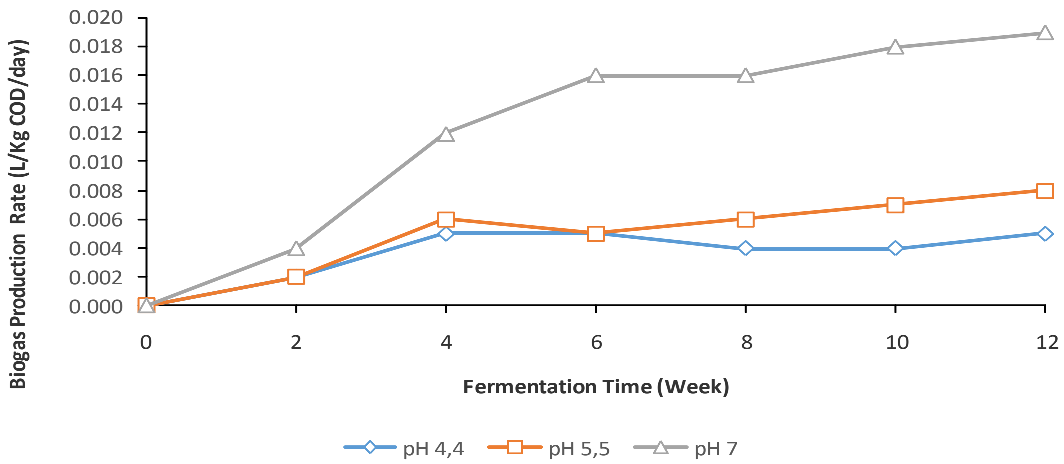

Figure -3: Interaction initial pH and fermentation time on the production of biogas

The increase in pH can accelerate the decomposition, thus speeding up reforms and indirectly accelerate the production of biogas (Metcalf and Eddy, 2003). The results obtained indicate that neutral pH spur the development of methane bacteria (methanogens), so that the pH of the acetic acid decomposer bacteria grow and develop optimally, it does increase the production of biogas. Overhaul of an anaerobic biological process that is strongly influenced by environmental factors. The main controlling factors include: temperature, pH, and toxic compounds (de Mez et al., 2003). Neutral pH degree spur the development of methane bacteria, so that the neutral pH of acetic acid decomposer bacteria grow and develop optimally, it does increase the production of biogas.

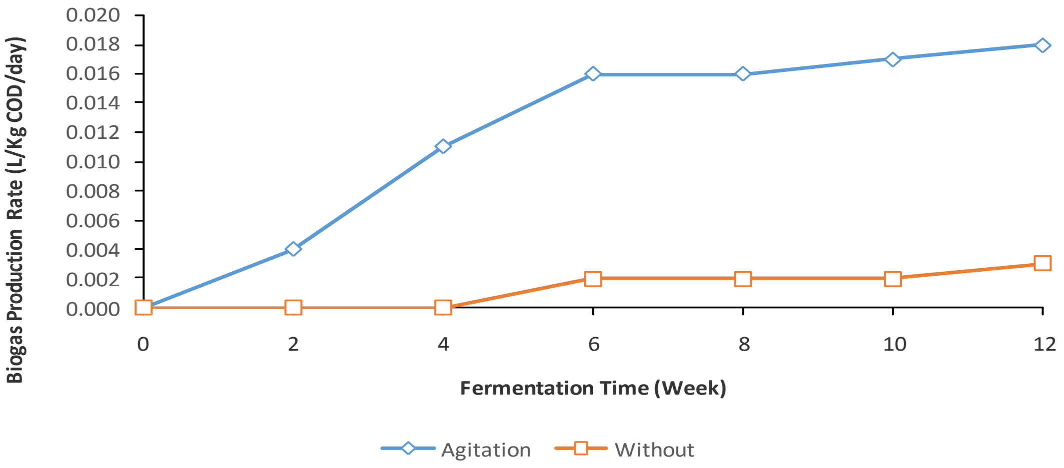

Figure -4: Interaction giving agitation and fermentation time on the rate of biogas production

Other abiotic factors, agitation also affect the production of biogas (Figure 4), where the agitation giving a better effect on the increase in the rate of biogas production than without agitation. This happens because the substrate to be homogeneous agitation, inoculum direct contact with the substrate and evenly, so that the reform process more effective. Barford (1983) stated that the agitation may increase the intensity of the contact between the organism and the substrate, compared with no agitation. Stirring is so that the contact between fresh and waste decomposer bacteria better, and avoid flying or precipitated solids, which would reduce the effectiveness of the digester and cause 'plugging' of gas and mud. Stirring or agitation of 100 rpm can increase biogas production.

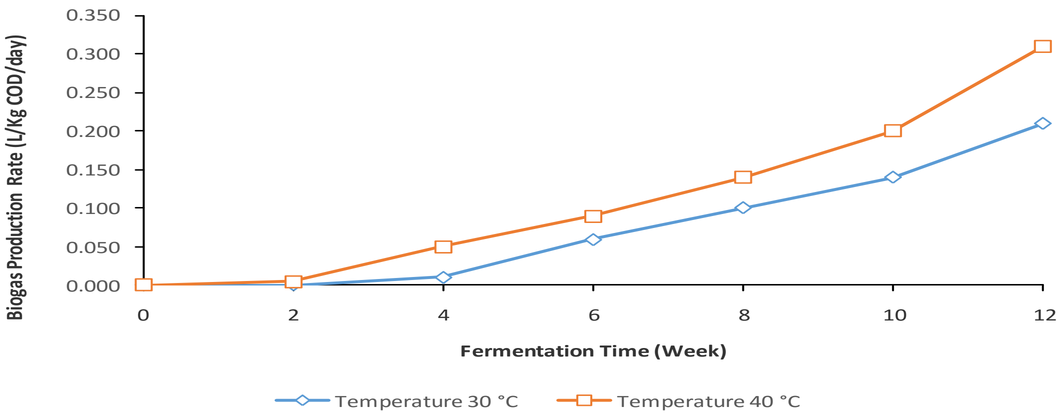

Figure -5: Interaction increase in temperature and fermentation time on the production of biogas

The results obtained showed that the increase in the substrate temperature can increase biogas production rate (Figure 5). This is understandable because of the high temperatures can accelerate chemical overhaul, rapid overhaul will be used by methanogenic bacteria to produce methane gas, thereby increasing the production of biogas. The temperature of the warm waste water can improve biochemical reactions in the anaerobic pond, where organic matter converted into biogas at a warm temperature range (mesophilic) between 30-38^{o}C. In detail, the abiotic factors that produce the highest biogas is neutral pH is 6.9 to 7.3, and the temperature of 30-38^{o}C (Metcalf and Eddy, 2003).

The results showed that the fermentation time factor with a two-week intervals affect the rate of biogas production. This is understandable because the reform process of anaerobic running four stages by the respective groups of organisms consortium (Werner et al., 1989). Each stage of the reform process takes considerable time, so that the effect of the time factor to the substrate fermentation under anaerobic conditions give different results in the production of biogas, the longer the fermentation process the higher production of biogas.

Influence of biotic and abiotic factors of the total production of biogas

The influence of abiotic and biotic factors of the total biogas production together with the factors that affect the rate of biogas production, the type and concentration of inoculum (Table 2). In this case the best condition resulting from an II with inoculum concentration of 20% (LKLM II-20%), where the total production of biogas for 12 weeks at 121 L. abiotic factors of $Ca(OH)_2$ can increase the total production of biogas, as well as a neutral pH (7), agitation and increased temperature. The treatment increased the total production of biogas, for 12 weeks each of 55 L, while the increase in temperature of 68.5 L. This can be understood as the process of formation of biogas from LCPMKS overhaul performed by microbes. So kind and inoculum concentration affects the production of biogas (Reith et al., 2003). Substrates with a neutral pH can accelerate the decay, so that methanogenic bacteria is easy to revamp the substrate to form biogas, thus increasing the production of biogas (Metcalf and Eddy, 2003). Agitation can increase the total production of biogas, since the agitation conditions become homogeneous substrate and inoculum contact the substrate becomes more intensive, so it with works more optimum inoculum. Inoculum homogeneous and uniform contact with the substrate can cause microbes to work with optimum (Barford and Cail 1985).

Table -2: Total production of biogas from anaerobic system *LCPMKS* bulk fermentation time of 12 weeks.

Treatment	Substrate *LCPMKS*	Biogas Production (L)
Biotic	Type of substrate + inoculum	
	Cow dung 10%	64,5
	LCPMKS pool I-10%	36,5
	LCPMKS pool II-10%	55.0
	LCPMKS pool I-20%	28.0
	LCPMKS pool II-20%	121.0
	Control	22.0
Abiotic 1	Addition of neutralizing agent pH	
	NaOH	34.0
	Ca(OH)2	55.0
Abiotic 2	pH substrate (early)	
	pH 4,4	15,0
	pH 5,5	20,5
	pH 7	55,0
Abiotic 3	Agitation	55.0
	Without agitation	6.0
Abiotic 4	Substrate temperature 30 C	55.0
	Increase temperature 40°C	68.5

Temperature can speed up the reform process, so as to increase the production of biogas. At a substrate temperature of 40°C produced biogas is relatively higher than 30°C. This is possible because the temperature can increase chemical reaction, thus spurring an increase overhaul of complex compounds into simpler compounds, which can be used more quickly and facilitate the activity of methanogenic bacteria form biogas (NAS, 1981; Bitton, 1999; Wellinger 1999).

Conclusion

*PLCMKS PT. Swastisiddhi Amarga Bioenerg*i is colloidal, thick, brown or grayish and have an average content of COD, 50.5 to 73.6, BOD 33.5 to 39.6, TS 36.5 to 55.4 and SS 27, 1 to 45.9 g / L, so the potential to pollute the environment. The combination of the type and concentration of inoculum best for the production of biogas from *LCPMKS*, the substrate volume of 15 L, laboratory scale cluster system is a kind of mud *LCPMKS* pool II with a concentration of 20% (*LKLM* II-20%), where the highest total biogas production amounted to 121 L. Abiotic factors that can increase the production of biogas is the addition of neutralizing the pH of $Ca(OH)_2$, the initial substrate pH = 7, and the provision of agitation, where the total production of biogas obtained respectively by 55 L. Increasing the substrate temperature of 40°C produce biogas 68.5 L.

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