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Analysis Of Biogas Pressure Based On Mass Variation Of Raw Material Using 150 L / Tank Digester Capacity

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ABSTRACT

Biogas pressure produced in a period of 10 days is 0.001 kg on the 3rd day to 0.013 kg on the 10th day or equivalent to an average of 0.0013 kg / day, which in each day experiences a different increase. The raw materials used are 8 kg cow dung and 2 kg pineapple skin waste with a raw material ratio of 4: 1 and 10 liters of water are added mixed with EM4. In this study, the authors compared the biogas pressure produced from a mixture of raw materials from cow manure and pineapple peel waste with biogas produced from a mixture of raw materials from cow dung and water hyacinth. The research method used is literature review, interviews and then the data collected will be used to calculate the ratio of biogas pressure. From the results of the biogas pressure comparison it was found that the mixture of raw materials for cow dung and water hyacinth was more effective than biogas with raw materials for cow dung and pineapple skin waste with a fermentation process within 10 days.

***Keywords**: Digester, Biogas, Pressure*

1. INTRODUCTION

Biogas is a gas produced by anaerobic activity or fermentation of organic materials. Biogas is included in the biomass energy that is obtained from livestock manure, processing a number of certain plants, manure, or human waste. Biogas is able to overcome energy problems in rural areas and also overcome the waste generated from livestock.

Using Appropriate Technology (TTG) which is a biogas digester can be one way to process livestock manure waste such as cow dung into biogas. However, many digesters found in rural areas are digesters with a capacity of 5,000 liters which take up a lot of space so that it is not easy in terms of the mobility of the device. To get effective biogas results, additional ingredients are needed which will be mixed with cow dung waste such as water hyacinth, pineapple fruit skin waste, EM4 and water.

1.1 Understanding Biogas

Biogas is a gas that is formed through the process of fermentation of organic waste materials, such as animal manure and organic waste by anaerobic bacteria (bacteria that can live without oxygen).[10]

The properties of the main gas components are explained as follows:

a. $CH4$ gas considered as a useful fuel. This gas is non-toxic, odorless, and lighter than air.

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b. $CO2$ is an inert gas that is colorless, odorless, and heavier than air. $CO2$ is a rather toxic gas. Higher concentrations $CO2$ in biogas produce biogas with a low calorific value.
c. $H2S$ a colorless gas. Because it is heavier than air $H2S$ extra dangerous at low places. At low concentrations this gas has a special odor like rotten eggs. At high concentrations, it will be more dangerous because it does not smell. In addition, $H2S$ is also corrosive which can cause problems in the combustion process of biogas.
d. Water vapor, although a harmless result, will become corrosive if combined with $NH3$, $CO2$ and especially $H2S$ from biogas. The maximum water content in biogas is developed because of the gas temperature. If the aqueous biogas is saturated leaving the digester, cooling will produce water condensation.

Table 1 Composition of gas types and quantities

Component	%
Metana (CH_4)	55 – 75
Karbondioksida (CO_2)	25 - 45
Nitrogen (N_2)	0 – 0,3
Hydrogen (H_2)	1 – 5
Hydrogen Sulfida (H_2S)	0 – 3
Oksigen (O_2)	0,1 – 0,5

(**Source :** www.herman.B.dkk.2007)

The concentration of impurities (methane, carbon dioxide, water, sulfide hydtogens, nitrogen, oxygen, ammonia, siloxanes and particles) depends on the composition of the substrate from which the gas originates. When it flows out of the digester, biogas is saturated with water vapor, and this water causes corrosion in the pipe. Water can be removed by cooling, compression, absorption, or adsorption. By increasing the pressure or decreasing the temperature, the water will be removed from the biogas condensate. Cooling can only be achieved by planting gas channels equipped with condensate traps in the soil. Water can also be removed by using molecular sieve adsorption, $SiO2$, or activated carbon. This material is usually regenerated by heating or decreasing pressure.

1.2 Biogas Composition

The composition and productivity of a biogas system is influenced by parameters such as temperature of the digester, pH (acidity), pressure, and humidity of the air. The most important component of biogas is methane ($CH4$). Table 2 is a description of the biogas composition from Horikawa in 2004 where biogas was composed of 81.1% $CH4$.

Table 2 Biogas Composition

Gas	Digester Sludge Sistem Anaerob (% volume)

CH_4	81,1 %
CO_2	14,0 %
H_2S	2,2 %
$N_2 + O_2$	2,7 %

(**Source :** Horikawa, 2004)

However, the opinions regarding the composition of biogas below are used as references by some researchers. Biogas generally consists of:
1. Methane, $CH4$ = 55 - 75%
2. Carbon dioxide, $CO2$ = 25 - 45%
3. Carbon monoxide, CO = 0 - 0.3% 4. Nitrogen, $N2$ = 1 - 5%
5. Hydrogen, $H2$ = 0 - 3%
6. Hydrogen sulfide, $H2S$ = 0.1 - 0.5%
7. Oxygen, $O2$ = the rest

Biogas is different from natural gas and city gas. Some differences in the characteristics of biogas, city gas, and natural gas can be seen in Table 2.7. Biogas has a moderate heating value and the amount is very dependent on the content of $CH4$ in biogas. Biogas density is slightly higher than air density. If burned, biogas has a low maximum speed, which is around 0.25 m / s.
High enough methane content in biogas can replace the role of LPG and petrol (gasoline). But in biogas there are other ingredients besides methane which need a purification process. The gas is gas $H2S$ which is considered as impurity and if it combines and is freed with air it can be oxidized to $SO2$ and $SO3$ which are corrosive and if oxidized further by $H2O$ can trigger acid rain. Besides $H2S$ there is also water vapor and $CO2$ which is not useful when burning. Biogas which contains an amount of $H2O$ can reduce the heating value. Gas $H2O$ as gas $H2S$ also needs to be cleaned from biogas.

1.3 Cow dung

Cow dung is an organic material that specifically has a role in increasing the availability of phosphorus and micro elements, reducing the adverse effects of aluminum, providing carbon dioxide in plant canopies, especially in plants with dense canopies where air circulation is limited. Cow dung contains many nutrients needed by plants such as nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and boron (Brady, 1974, in Sudarkoco, 1992). Cow dung has a low C / N ratio of 11, this means that in cow dung contains nitrogen (N). The chemical composition of cow dung can be seen in Table 3.

***Table 3** Chemical Composition of Cow Manure*

Type of Analysis	***Content (%)***

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Water content	*80*
Organic Ingredients	*16*
N	*0,3*
P_2O_5	*0,2*
K_2O	*0,15*
CaO	*0,2*
Nisbah C/N	*20 – 25*

*(**Source :** Lingga, 1991)*

1.4 Pineapple

Pineapple, pineapple, or ananas (Ananas comosus (L.) Merr.) Is a type of tropical plant originating from Brazil, Bolivia, and Paraguay. This plant belongs to the pineapple-nanasan family (Bromeliaceae family). The stature (habitus) of plants is low, herbaceous (chronic) with 30 or more long, sharp-tipped leaves arranged in a rosette around a thick stem. The fruit in English is called pineapple because of its shape like a pine tree. The name 'pineapple' comes from the name of the Tupi for this fruit Anana, which means "very good fruit". Hummingbird is a natural pollinator of this fruit, although various insects also have the same role.

Table 4 *Nutritional Content of Pineapple*

NUTRITION ELEMENTS	**AMOUNT**
Calori (cal)	50,00
Protein (g)	0,40
Fat (g)	0,20
Carbohydrates (g)	16,00
Calsium (mg)	19,00
Phosphorus (mg)	9,00
Fiber (g)	0,40
Iron (g)	0,20
Vitamin A (IU)	20,00
Vitamin B1 (mg)	0,20
Vitamin B2 (mg)	0,04
Vitamin C (mg)	20,00
Niacin (g)	0,20

*(**Source:** Direktorat Gizi Depkes RI ta, 1998)*

1.3 Biodigester (Biodigester)

Biodigester is a major component in biogas production. Biodigester is a place where organic material is decomposed by bacteria anaerobically (without air) into $CH4$ and $CO2$ gases. Biodigester must be designed so that the anaerobic fermentation process can work well. In general, biogas can form 4 - 5 days after the digester is filled. Biodigester production generally occurs in 20-25 days and then the production drops if the biodigester is not replenished.

During the anaerobic decomposition process, the nitrogen component changes to ammonia, the sulfur component changes to $H2S$, and the phosphorus component changes to orthophospates. Some other components such as calcium, magnesium, or sodium turn into a type of salt. More complete, the following list are some of the purposes of making biodigester.

1. Reducing the amount of solids.

Because solids break down into gas and not all solids can decompose, the purpose of the process
digestion is reducing the amount of solids.

2. Generating energy.

As is known, the main target of the digestion process is to produce $CH4$ gas containing 50 MJ / kg of energy. The greater the content $CH4$ in biogas, the greater the energy in biogas.

3. Reduces odor from dirt.

Biogas can be intended to reduce odors and not eliminate odors from dirt. At least by making the odor digester produced during the digestion process can be directed so as not to disturb the comfort of human life.

4. Produces clean wastewater.

Some water after digestion must be removed. Clean wastewater becomes very important if it will be used for irrigation. Some waste water can also be returned again to the digester.

5. Produce solids that contain nutrients for fertilizer.

Solids that do not decompose into gas can be used as fertilizer as long as they still contain good nutrition. The resulting solid must also be protected from hazardous substances.

1.4 Biogas Manufacturing Parameters

The rate of biogas formation process is highly determined by factors that affect microorganisms, including temperature, pH, nutrition, solid concentration, volatile solid, substrate concentration, digestion time, mixing of organic matter and the influence of pressure.

2 METHODS

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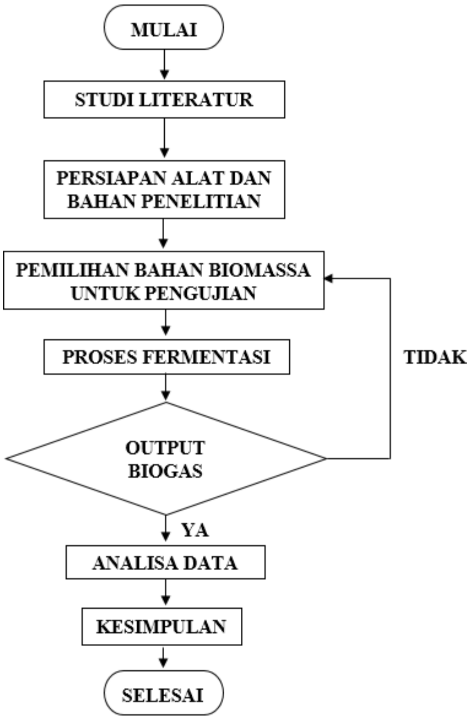
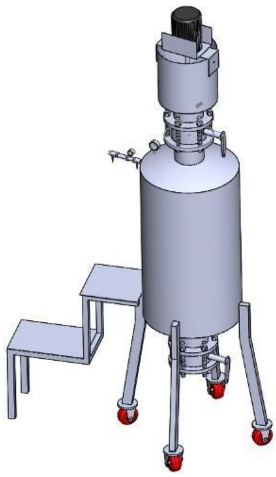
In this study there are several steps that must be carried out in stages and sequentially as in Figure 1. This is very necessary to be done in order to facilitate the work steps and also the analysis of research to be carried out.



The tools that will be used during the research process are:

1. Biogas Digester
Digester is designed in a vertical form with the aim of facilitating continuity in the input and output of biomass material.



***(Source :** Abdurra'uf Ibnu Sabiq, 2019)*

Picture 2 Digester Biogas

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The specifications of the biodigester to be used are:

Tabel 5 Spesifikasi Biodigester

NAME COMPONENT	DIMENSION	INGREDIENTS/INFORMATION
Digester Tube	- Thick 2 mm - Diameter 500 cm - High 1000 cm - Volume 150 l	- Alumunium Plate
Mixer Tubes	- Thick 2 mm - High 300 cm - Diameter 300 cm	- Alumunium Plate - 1 unit mixer

2. Pressure Gauge

Pressure gauge is a measuring tool that serves to measure a fluid pressure that can be either gas or liquid in a closed tube.

*(**Source:** http://www.rossbrownsales.com.au/page/pressure.html)*

Picture 3 *Pressure Gauge*

Pressure gauge is also capable for use in monitoring any air pressure and gas that is in an air compressor, various vacuum equipment, to medical gas cylinders and fire extinguishers.

3. Control Valve

Control valve is a material that is also needed in research.

*(**Source :** http://www.flowcontrolequip.com/portfolio/fisher-et-sliding-stem-control-valve/)*

Picture 4 *Control Valve*

Control valve is an instrument or mechanical equipment to regulate fluid flow by regulating the valve opening and closing.

4. Gas Stove

Gas stoves are cooking utensils that generate high heat from gas energy sources.

*(**Source:** http://ujimutu.lipi.go.id/index.php/pengujian/detil/20/sni-kompor-biogas-1-tungku)*

Pictute 5 Gas Stove

The stove has a closed / insulated space from the outside as a place where fuel is processed to provide heating for items placed on it.

5. Stove Hose

The tool needed to flow through the gas to the stove is a hose.

(**Source:** https://bacaterus.com/merk-regulator-gas-terbaik/)

Picture 6 Stove hose

The tools needed to drain something, the substance that is flowed will affect the base material of the hose.

The materials that will be used to conduct this research are:

1. Cow dung

Cow dung needed in this study is cow dung in the form of liquid or solid.

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*(**Source:** Henry Siringoringo, 2017)*

Picture 7 *Cow dung*

2.Pineapple Skin Waste

Another ingredient needed to get biogas is pineapple skin waste. Here is an example of pineapple skin waste.

*(**Source:** Eko Sunardiyanto)*

Picture 8 Pineapple skin waste

Several studies were conducted and reported that there are many benefits of pineapple, especially for parts that are rarely used, such as the skin, stems and leaves. Pineapple skin waste contains tannins, saponins, steroids, flavonoids, phenols and other compounds.

3. EM 4

EM4 stands for Effective Microorganism. The following are examples of EM4 that will be used in research.

*(**Source:** https://www.olx.co.id/iklan/em4-pertanian-untuk-tanaman-1l-1-liter-IDxrzSf.html)*

Picture 9 EM4

Used to accelerate the fermentation process of organic matter in the formation of biogas. The EM4 used is 1 liter and can be obtained at farm shops in traditional markets or online markets.

3 RESULT AND DISCUSSION

The raw materials used in this study are cow dung and pineapple fruit skin waste.

The ratio between cow dung and pineapple fruit skin.

Table 6. Research Materials Components

MATERIAL NAME	MASS MATERIAL
Cow dung Pineapple Skin Waste Water	8 kg x 6,3 = 50,4 kg 2 kg x 6,3 = 12,6 kg 10 L x 6,3 = 63 L

*(**Source:** Abdurra'uf Ibnu Sabiq, 2019)*

This, the total conversion of 10 kg of biomass raw material plus 10 liters of water used in biogas production is 23.8 liters. The following is some documentation in the preparation of raw materials carried out during the study.

*(**Source:** Abdurra'uf Ibnu Sabiq, 2019)*

Picture 10 Biogas Raw Materials

Prior to mixing, enumeration is carried out on pineapple peel waste to facilitate the fermentation process. Then, after that carried out mixing cow dung along with pineapple fruit skin waste using water and EM4. After everything is mixed and stirred so that the mixing is more evenly distributed, then all the raw material that has been mixed is put into the biogas digester for the fermentation process.

*(**Source:** Abdurra'uf Ibnu Sabiq, 2019)*

Picture 11 The Process of Inserting Raw Materials in Digester

After all the raw materials are put into the digester, the fermentation process will occur in a biogas digester reservoir. Then wait for 10 working days to find out the biogas pressure that results from the mixture of raw materials.

3.1 Pressure That Is Generated From A Mix Of Raw Material For Cow Manure With Water Hyacinth

The process begins with mixing cow dung with water hyacinth that has been chopped and blended. A mixture of cow dung and water hyacinth is added to the water. In this research, biogas pressure of 0.016 kg was produced during the fermentation period of 10 days, equivalent to 0.0016 kg / day on average. The following is a biogas pressure table.

Table 7. Biogas Pressure for Cow and Water Hyacinth Manure Raw Materials

Time (Day)	1	2	3	4	5	6	7	8	9	10
Preasure **Biogas (g/cm^2)**	0	0	1	2	4	6	8	11	13	16

*(**Source:** Akhmad Suwito, 2018)*

In table 7 it is known that biogas starts producing on the 3rd day and biogas pressure is getting higher every day. The biogas pressure value on the 3rd day is 0.001 and is increasing up on the 10th day with a pressure value of 0.016.

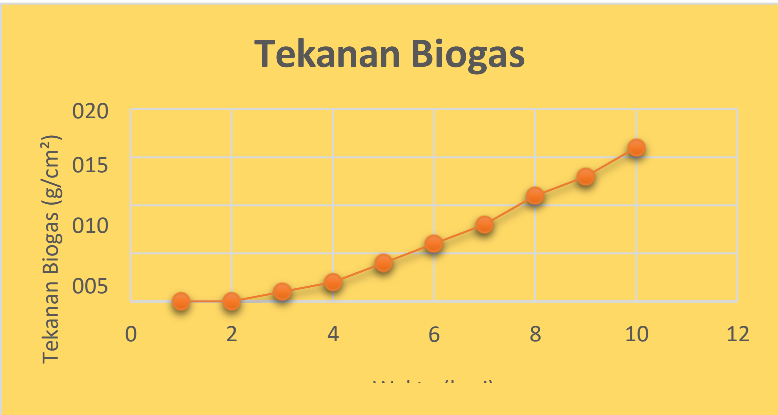
To find out the biogas pressure that will be produced from the raw material of cow dung and pineapple fruit skin waste, using biodigester which has a capacity of 150 liters with a mixer. The biodigester is then filled with 8 kg of cow dung and pineapple skin waste of 2 kg with 10 liters of water added which has been mixed with EM4. So, from the experimental results it was found that before the formation of biogas in the tube, the biodigester only contained air. Thus the biogas pressure measurement carried out, the following results were obtained:

Table 8. Biogas Pressure Inside The Digester

Time (Day)	1	2	3	4	5	6	7	8	9	10
Preasure Biogas (g/cm^2)	0	0	1	3	5	6	7	9	11	13

*(**Source:** Abdurra'uf Ibnu Sabiq, 2019)*

Based on table 8 it can be seen that the pressure generated by biogas with a fermentation time of 10 days. From day 1 to day 2 biogas pressure production was not seen. At the pressure gauge contained in the biogas digester began to show the production of biogas pressure on the 3rd day of 0.001 kg, on the 4th day the biogas pressure increased by 0.003 kg and on the 5th day the biogas continued to produce and continued to increase to 0.005 kg The longer and more days, the greater the pressure of biogas and the faster movement. In the research on the 10th day the biogas production produced was 0.013 kg or equivalent to an average of 0.0013 kg / day.



*(**Source:** Akhmad Suwito, 2018)*

Picture 12. Biogas Pressure for Cow and Water Hyacinth Manure Raw Materials

Based on graph 1 it is known that the pressure of biogas produced from the raw material of a mixture of biomass cow manure with water hyacinth is increasingly increasing.

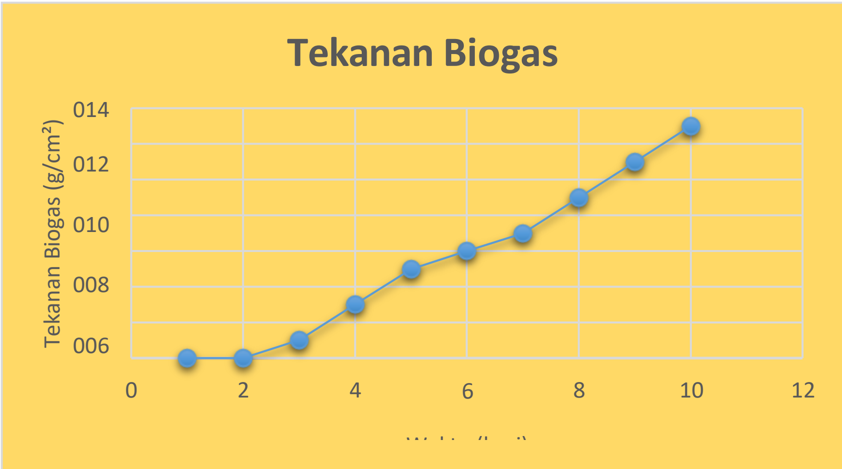
To find out the biogas pressure that will be produced from the raw material of cow dung and pineapple fruit skin waste, using biodigester which has a capacity of 150 liters with a mixer. The biodigester is then filled with 8 kg of cow dung and pineapple skin waste of 2 kg with 10 liters of water added which has been mixed with EM4. So, from the experimental results it was found that before the formation of biogas in the tube, the biodigester only contained air. Thus the biogas pressure measurement carried out, the following results were obtained:

Table 9. Biogas Pressure Inside The Digester

Time (Day)	1	2	3	4	5	6	7	8	9	10
Preasure Biogas (g/cm^2)	0	0	1	3	5	6	7	9	11	13

(**Source:** Abdurra'uf Ibnu Sabiq, 2019)

Based on table 9 it can be seen that the pressure generated by biogas with a fermentation time of 10 days. From day 1 to day 2 biogas pressure production was not seen. At the pressure gauge contained in the biogas digester began to show the production of biogas pressure on the 3rd day of 0.001 kg, on the 4th day the biogas pressure increased by 0.003 kg and on the 5th day the biogas continued to produce and continued to increase to 0.005 kg The longer and more days, the greater the pressure of biogas and the faster movement. In the research on the 10th day the biogas production produced was 0.013 kg or equivalent to an average of 0.0013 kg / day.



Picture 13. Biogas Pressure Inside The Digester

*(**Sumber:** Abdurra'uf Ibnu Sabiq, 2019)*

In graph 13 it can be seen that the production that is occurring more and more biogas pressure is experiencing a significant increase starting from day 3 to day 10.

Table 10. Comparison of Biogas, Natural Gas and City Gas

Parameter	**Biogas (60% CH_4)**	**Natural Gas**	**City Gas**
Lower calorific value (MJ/m^3)	21,48	36,14	16,1
Density (kg/m^3)	1,21	0,82	0,51
Wobbe index down (MJ/m^3)	19,5	39,9	22,5

Maximum ignition speed (m/s)	0,25	0,39	0,70
Theoretical air requirements (m^3 udara/m^3 gas)	5,71	9,53	3,83
Maximum concentration $CO2$ in the chimney	17,8	11,9	13,1
Dew point (ºC)	60 – 160	59	60

*(**Source:** Wellinger, 2001)*

Based on table 10, biogas density is 1.2 kg / $m3$, assuming biogas is produced in kilograms (kg), it can be converted to $m3$, namely:

$$V = \frac{M}{\rho}$$

V = 0,0013 kg : 1,2 kg/m^3

V = 0,00108 m^3

Based on the above calculation the volume of biogas produced on average per day in this study is 0.00108 $m3$. Based on these references, the researchers estimated that within 30 days, the biogas that could be produced was around 0.0324 $m3$. This estimation is the result of the average volume of biogas per day multiplied by 10 days.

Average biogas volume per day x 30 days = estimated monthly biogas volume 0.00108 $m3$ / day x 30 days = 0.0324 $m3$.

Biogas from the results of this study was then applied to the biogas stove. From the results of the application, it has been obtained data for biogas size with a volume of 0.00108 $m3$ and a pressure of 0.013 kg can be used to turn on a biogas stove with a fire load on a medium scale with a duration of 60 minutes.

*(**Source :** Abdurra'uf Ibnu Sabiq, 2019)*

Picture 14. Application of Biogas on Biogas Stoves

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The flame duration is obtained from testing the fire on a biogas stove. The test is carried out when the gas storage tank volume reaches a maximum. The flame in this study was tested using a medium flame. Where the medium flame is used to heat 2 liters of water, it takes 9 minutes, until the water as much as 2 liters boils with a temperature of 100 ºC.

From the results of the medium flame test, the time used to heat the water to boiling is 9 minutes with a final temperature of 100 ºC. Besides the flame color is still a mixture of blue and yellow, this is because at the beginning of combustion there is still a lot of gas content in the digester tube.

Biogas pressure analysis in this case is a comparison between biogas production using raw materials from cow dung and pineapple fruit husk waste with biogas production that has been done previously by using a 150 liter biogas capacity using raw materials from cow dung and water hyacinth by comparison between the raw material is 4: 1 and mixed with 10 liters of water.

From the results of research conducted then compared with previous studies with different raw material starters, the following results were obtained:

Table 11. Comparison of Biogas Pressure in 10 Days

Time (Day)	Preassure Biogas (g/cm^2)	
	Cow Dung + Water hyacinth	Cow Dung + Pineapple Skin
1	0	0
2	0	0
3	0,001	0,001
4	0,002	0,003
5	0,004	0,005
6	0,006	0,006
7	0,008	0,007
8	0,011	0,009
9	0,013	0,011
10	0,016	0,013

*(**Source:** Abdurra'uf Ibnu Sabiq, 2019)*

From table 11 it can be analyzed that, for biomass raw material from cow dung and pineapple peel waste under study has a smaller pressure results when compared to a mixture of biomass raw material from cow dung with water hyacinth with a comparison of raw materials 4: 1 and the length of time for the fermentation process for 10 days. Both raw materials start producing biogas pressure on the 3rd day where the biogas pressure value of the two biomass feedstocks is 0.001 kg. The value of biogas pressure with a mixture of cow manure and pineapple peel waste is 0.013 kg or equivalent to 0.0013 kg / day, whereas for cow manure mixture with water hyacinth within 10 days is 0.016 kg or equivalent to average - an average of 0.0016 kg / day.

4. KESIMPULAN

From the results of the discussion it can be concluded as follows:

1. Using a 150 liter capacity biogas digester and 10 kg of biomass as raw material used plus 10 liters of water, the total raw material put into the tube is 23.8 liters.
2. Raw materials for cow dung and pineapple peel waste with a ratio of 4: 1 produce biogas pressure of 0.013 kg or equivalent to an average of 0.0013 kg / day with the total time of combustion that can be used to heat 2 liters of water is 18 minutes with a temperature of 100 ºC. Whereas in previous studies with the same comparison using raw materials for cow dung and water hyacinth produced biogas pressure of 0.016 kg or equivalent to an average of 0.0016 kg / day within 10 days.
3. The composition of raw materials used is very influential on the results of biogas production, from the comparison between raw materials of cow dung and pineapple fruit skin waste with raw materials of cow dung and water hyacinth that produce biogas well is raw material of cow dung with water hyacinth.

REFERENCES

[1] Suyitno, A. Sujono dan Dharmanto (2010) *"Teknologi Biogas"* Yogyakarta: Graha Ilmu halaman 4-7

[2] Nasution, A. Y. (2018) 'Nasution, AY. Development Of Knife Eyes On The Making Process Of Organic Burning process Of 7 Liters For UMKM DEVELOPMENT OF KNIFE EYES ON THE MAKING PROCESS OF ORGANIC BURNING PROCESS OF 7 LITERS FOR UMKM'. Jurnal ABDIMAS TALENTA Vol.3 No.2

[3] Anggy, R. Sulistya, R. (2016) *"Pemanfaatan Ekstrak Kulit Buah Nanas (Ananas comous L. Merr.) Untuk Sediaan Gel Hand Sanitizer Sebagai Antibakteri Staphylococcus aureus Dan Escherichia coli",* Jurnal Universitas Negeri Semarang

[4] Diyanti, R. R. Puspita, A. (2012) dkk, *"Pembuatan Biogas Dari Eceng Gondok (Eichornia crassipes) Melalui Proses Pretreatment Dengan Jamur Phanerochaete chrysosporium Dan Trichoderma harzianum",* Jurnal Teknik POMITS Vol. 1, No. 1

[5] Fajar, Y. (2016) *"Pembuatan Energi Biogas Dari Fermentasi Kulit Buah Nanas Dengan Biodigester Berkapasitas 200 liter",* Jurnal, Universitas Nusantara PGRI Kediri

[6] Guyup, M.D.P. Sirajuddin H.A. dkk (Maret 2017) *"Rancang Bangun Reaktor Biogas Tipe Portable Dari Limbah Kotoran Ternak Sapi",* Jurnal Ilmiah Rekayasa Pertanian dan Biosistem, Vol. 5, No.1

[7] Hariyanto, K. Benedictus, M. (November 2016) *"Performa Pembakaran Kompor Biogas Menuju Desa Mandiri Energi Di Yogyakarta",* Jurnal Nasional Teknologi Informasi dan Kedirgantaraan (SENATIK) Vol. II

[8] Made, I.M. Ida, B.A (Juli 2012), *"Analisa Kualitas Dan Kuantitas Biogas Dari Kotoran Ternak",* Jurnal Volume 1, Nomor 2

[9] Ramaiyulis, Riva, H. (September 2016) *"Kinerja Digester Biogas Pengolah Limbah Peternakan Sapi Skala Rumah Tangga",* Jurnal Politeknik Pertanian Negeri Payakumbuh.

[10] Ridhuan, Kms. Norvedo, H. (September 2012), *"Pengaruh Perbandingan Eceng Gondok Dan Kotoran Sapi Terhadap Proses Fermentasi Untuk Mendapatkan Energi Biogas",* Jurnal Mechanical, Volume 3, Nomor 2
[11] Sulistiyanto, Y. Sustiyah, dkk. (Mei 2016) *"Pemanfaatan Kotoran Sapi Sebagai Sumber Biogas Rumah Tangga Di Kabupaten Pulang Pisau Provinsi Kalimantan Tengah",* Jurnal Udayana, Vol. 15, Nomor 2
[12] Tri, R.D.L. (2010) "Pemanfaatan Bagase Tebu Dan Limbah Nanas Sebagai Bahan Baku Penghasil Biogas",
[13] Jurnal Sekolah Pascasarjana Institut Pertanian Bogor,
[14] Yudi, S. Eka, S. W. "Campuran Limbah Air Karet (Lateks) Eceng Gondok Dan Kulit Nanas Sebagai Bahan Baku Biogas", Jurnal Jurusan Teknik Mesin Universitas Bangka Belitung
[15] "Pengertian Definisi Energi Biomassa Beserta Contoh", Sumber: https://benergi.com/pengertian-definisi- energi-biomassa-beserta-contohnya
[16] Novi, A. (Desember 2015)"Biogas: Sumber Energi Terbarukan Untuk Indonesia Mandiri Dan Mendunia", Sumber:https://www.kompasiana.com/novi.ardiani/5683bbe0c2afbd2209f/biogassum berenergiterbarukanuntuki ndonesiamandiridanmendunia?page=all
[17] Sumber: http://digilib.unila.ac.id/10335/15/BAB%20II.pdf
[18] Sumber: http://digilib.unila.ac.id/10335/15/BAB%20II.pdf
[19] Sumber: http://eprints.polsri.ac.id/1007/3/Bab%20II.pdf
[20] Sumber: http://eprints.polsri.ac.id/3288/3/bab%202.pdf
[21] Sumber:https://sinta.unud.ac.id/uploads/wisuda/11043050313BAB%20II.f
[22] Wikipedia Bahasa Indonesia, Ensiklopedia Bebas, "Biogas" Sumber: https://id.wikipedia.org/wiki/Biogas
[23] Wikipedia Bahasa Indonesia, Ensiklopedia Bebas, "Energi Terbarukan", Sumber:
[24] https://id.wikipedia.org/wiki/Energi_terbarukan