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## Design and Build a Manual Stirred Biodigester Using a 200 Liter Capacity Double Propeller Using Cow Manure and Rumen Raw Materials

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### ABSTRACT

Processing organic waste into renewable energy is an effective solution to reduce environmental impact and meet energy needs. This research aims to design and build a manually stirred biodigester using a double propeller system with a capacity of 200 liters. This biodigester is designed to process cow manure waste and rumen as the main raw material, utilizing the abundant and not yet optimal biomass potential. A manual stirring system with two propellers is implemented to improve the mixing efficiency of the substrate, so as to maximize the production of biogas. Tests are carried out to evaluate the performance of the equipment, including the biogas production capacity, the quality of the methane gas produced, and the efficiency of the fermentation process. The results of the study show that the designed biodigester is able to produce biogas effectively with methane levels that meet energy use standards. Innovations in manual stirrers using double propellers have been proven to increase the homogeneity of the substrate, accelerate fermentation times, and increase the volume of gases produced. This biodigester has the potential to be applied on a household and community scale, supporting efforts to use sustainable renewable energy while reducing environmental pollution due to organic waste. This research is expected to be a reference in the development of biodigester technology that is efficient and easy to apply in various regions.

**Keywords:** biodigester, manual stirrer, double propeller, biogas, organic waste, renewable energy

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### INTRODUCTION

The recent energy crisis shows that humans are increasingly dependent on natural gas. If this problem cannot be overcome, then this energy crisis will get worse over time. The price of natural gas will soar over time because the reserves are getting thinner, also because natural gas is a non-renewable fuel group. An alternative that can be done to overcome this energy dependence is to look for new energy sources that are renewable, cheap and environmentally friendly.

One of the renewable energy sources that comes from biological natural resources is biogas. Biogas is a gas produced from the process of decomposing organic matter by microorganisms under the condition *Anaerobic*. Examples of these organic materials are livestock manure such as cow dung (Dewilda & Julianto, 2019). Biogas from anaerobic processes of animal waste generally contains 55-70% methane gas (CH<sub>4</sub>) and 30-45% carbon dioxide (CO<sub>2</sub>). Biogas has great potential to be produced, especially in livestock areas (Fathallah et al., 2020).

In addition, starters in biogas production are very important in improving the efficiency of biogas production, one of the biogas starters is the bovine rumen. Bovine rumen contains cellulolytic and methanogenic bacteria that are very important in the process of biogas formation through anaerobic fermentation. These bacteria can break down crude fiber and complex carbohydrates in cow manure, thereby increasing biogas production. The addition of bovine rumen fluid can increase the efficiency of biogas production by two to three times more compared to using cow manure and air alone. This is due to the higher activity of cellulose enzymes in bovine rumen fluid. (Wahyuni & MP, 2018).

Padang City itself has great potential in biogas production in residents' homes, especially from the cattle farming sector. According to data from the Central Statistics Agency of West Sumatra in 2022, the cattle population in Padang City reached 18,592 heads. However, the use of cow dung for biogas

production in Padang City is still not optimal (Fidela et al., 2024).

To utilize the cow dung, it is necessary to have a tool that will be used to produce biogas optimally. A biodigester is a reactor used to produce biogas from organic matter such as cow dung. One of the challenges in the operation of biodigesters is the slow and low rate of biogas production. This is due to several factors such as uneven distribution of substrates, accumulation of by-products that inhibit the fermentation process, and environmental conditions that are not optimal for the activity of biogas-producing microorganisms.

To improve the efficiency of biogas production from cow manure, several modifications were made to the design of the biodigester, such as the addition of a stirring system. Stirring can help mix the substrate evenly, better distribute nutrients and microorganisms, and remove by-products that inhibit the fermentation process. However, the proper design of the stirring system is essential to ensure the efficiency and sustainability of the biogas production process.

Stirring is very beneficial for the material inside biodigester *Anaerobic* Because it provides an opportunity for the material to remain mixed with bacteria and the temperature is maintained evenly throughout the body. With stirring also the potential for material to settle at the bottom biodigester The smaller it is, the more evenly concentrated it is and gives the possibility that the entire material will undergo a fermentation process *Anaerobic* Evenly. Stirring can be done before inserting biodigester or when they are already inside biodigester (Indrawati, 2017).

In the research conducted Kurniawan & Sari, (2022), that using a manual stirrer is the right choice because the presence of this tool will increase methane gas. The more often the tool is operated, the more gas is produced and vice versa, if the minimum equipment is operated, the gas produced is not optimal. This study suggests that for further research using different types of raw materials and requiring modification of the tool so that the methane gas produced can be optimal.

Double propeller stirring is a stirring method that is useful for breaking and stirring materials. By using a double propeller, the distribution of materials can be improved. This is because the axial movement of the two propellers can create a more complex and turbulent flow pattern, so that the material can be better homogenized (Aida & Silvia, 2015).

Stirring using a double propeller helps to mix the raw materials (cow manure and cow rumen) evenly. This ensures that all components are well mixed, so that bacteria can spread evenly and interact with the optimal substrate. Stirring ensures sufficient contact between the bacteria and the substrate. This is important because bacteria require optimal contact to decompose the substrate and produce methane and carbon dioxide gases.

Therefore, this study aims to design an efficient construction of a stirred biodigester by using cow dung as raw material and cow rumen as the starter. The results of this research are expected to contribute to the development of biodigester technology that is more efficient and environmentally friendly, can be used non-commercially, and facilitates the use of biogas from cow manure and rumen as a sustainable renewable energy source.

## **METHOD**

The research method uses a tool design method which is divided into several stages. The design stages can be seen in the picture below:

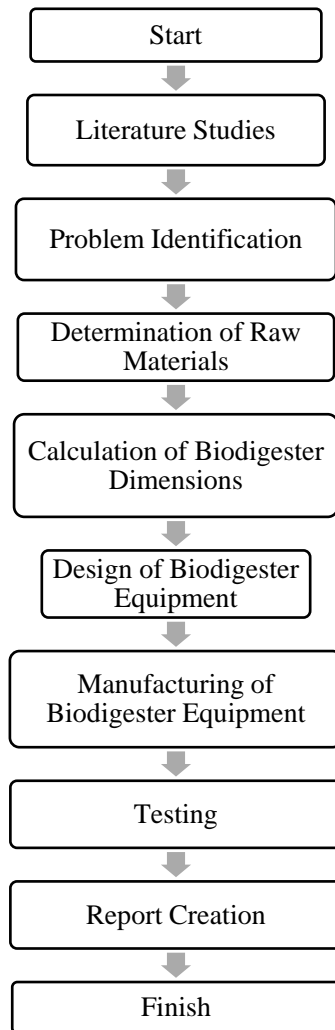


Figure 3.1 Research Methods

### Literature Studies

The first step of this research is to search for literature related to research. The purpose of conducting a literature study is to make it possible to plan and carry out research as desired. Literature was obtained from books and journals that discussed biogas production, cow manure materials, and biodigester design.

### Problem Identification

Identifying problems in the design of biogas reactors involves several important aspects that must be considered. By identifying these problems, the design of the biogas reactor can be tailored to several causes such as, increasing contact between the substrate and microorganisms.

### Determination of Raw Materials

The determination of raw materials can be determined based on their availability around the research site. The raw materials that will be used in this study are cow dung and cow rumen. Cow manure raw materials and cow rumen starters are used because of their availability and high organic content.

### Calculation of Biodigester Dimensions

In designing a biodigester, there are several stages, namely:

#### 1. Biodigester Calculation

Most reactor, separation columns, heat exchangers, and other vessels in chemical plants need to be designed as pressure vessels (Towler & Sinnott, 2013), therefore the design biodigester This time it is designed as a pressure vessel. Dimension calculation biodigester using references from the book "*Transport Processes and Unit Operations*'s 3 editions" (Geankoplis, 2003). Here are the steps to

calculate the dimensions biodigester.

a. Recording Necessary Data

The data needed in the design of the stirred biodigester are the height and diameter of the tank.

**Table 1.** Data Biodigester

It	Variable	Value
1	Biodigester Diameter (cm)	59
2	Biodigester Height (cm)	93
3	Volume (liters)	200

b. Propeller Calculation

1) Determining the Type of *Propeller*

The type of *propeller* can be determined by adjusting the characteristics of the raw materials to be used and the desired flow pattern.

2) Calculating the Diameter of the *propeller* ( $D_a$ )

$$\frac{D_a}{D_i} = 0,3$$

Information:

$D_a$  = Propeller diameter (mm)

$D_i$  = Biodigester diameter (mm)

3) Calculating the *Propeller Blade Width* ( $W$ )

$$\frac{W}{D_a} = \frac{1}{5}$$

Information:

$W$  = Propeller blade width (mm)

$D_a$  = Propeller diameter (mm)

4) Calculating the *Propeller Blade Length* ( $L$ )

$$\frac{L}{D_a} = \frac{1}{4}$$

Information:

$L$  = Propeller blade length (mm)

$D_a$  = Propeller Diameter (mm)

5) Propeller Location

The *propellers* used are 2, with the aim that the mixing of raw materials is perfectly mixed.

**Table 2.** Size Specification *Propeller*

It	Variable	Rated (mm)	Value (cm)	Symbol
1	Propeller diameter	135	13,5	$D_a$
2	Propeller Blade Width	27	2,7	$W$
3	Propeller Blade Length	33,8	3,4	$L$
4	Propeller location (1)	150	15	<i>Lower</i>
5	Propeller location (2)	564	56	<i>Upper</i>

**Design of Biodigester Equipment**

With the design completed, 3D design is carried out using *solidworks*. The first stage is to design the design part separately. After the required parts are completed, the design parts are combined (*assembly*) so that they become a complete 3D design.

**Manufacturing of Biodigester Equipment**

The manufacture of biodigesters is carried out in the Biogas Workshop owned by the TRBET Study Program which is located on the campus of the ATI Padang Polytechnic. Biodigester made based on the results of existing designs and designs along with the installation of several other supporting components.

### Testing

The research tests carried out are qualitative and quantitative. Qualitatively, namely testing the flame, fire color and gas smell produced. Meanwhile, quantitatively methane gas measurements, temperature, and pH were carried out.

### Tool

The tools used in this experiment are:

**Table 3.** Tool

It	Tool Name	Function	Sum
1	<i>Drum</i> Biogas digester	as an anaerobic <i>fermentation site for raw materials</i> to produce biogas	1
2	Pipe	as a medium for the flow of raw materials and biogas production	1
3	<i>Valve</i>	Supporting media on pipes	2
4	Mixer	for stirring raw materials to make them homogeneous	1
7	<i>Conductor</i>	as a reservoir for <i>raw material</i> overflow output	1
6	<i>Biogas storage</i>	as a biogas storage	1
8	<i>Faucets</i>	supporting media for the production of raw materials as pH and biogas measurements	1
9	<i>Pressure gauge</i>	as a gas pressure gauge in biogas digester tanks	1
10	<i>Temperature gauge</i>	as a temperature measuring device in biogas digester tanks	1
11	Hose	As a medium for the flow of biogas into <i>biogas storage</i>	1
12	<i>Fittings</i>	As a supporting medium so that the pipeline installed on the <i>drum</i> does not leak	2

### Material

The materials used in this experiment are:

**Table 3.** Experimental Variables

It	Ingredient Name	Function	Sum
1	Cow manure and Rumen	As raw materials and starters in the manufacture of biogas, it is divided into 20 kg of cow dung and 5 kg of cow rumen	25 kg
2	Water	as dilution of raw materials	125 Liters
3	Bacteria (EM4)	As a <i>starter</i> in biogas production	1 Liter

## Data Collection Techniques

This data collection technique is carried out every day by observing several parameters, namely: pressure (bar), temperature ( $^{\circ}\text{C}$ ), pH, biogas composition ( $\text{CH}_4$ ) and also COD to the flame test. The experimental variables carried out in this study are by stirring and also without stirring.

In addition, tests such as Chemical *Oxygen Demand* (COD) value testing and flame test with experiments without stirring or with stirring are also carried out.

### 1. COD Value Test

Measurement of the *Chemical Oxygen Demand* (COD) value is carried out to determine the amount of oxygen needed to decompose organic substances. The higher the COD value of an organic material, the more potential biogas will be produced. This measurement was carried out to see the COD *reduction* value produced in the use of biodigester. COD *reduction* can be determined by the following equation:

$$\text{COD reduction} = \frac{\text{COD}_{in} - \text{COD}_{out}}{\text{COD}_{in}} \times 100\%$$

### 2. Flame Test

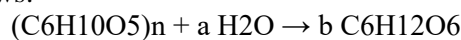
According to Muhammad Iqbal et al., (2024), a larger flame without extinguishing indicates a positive test. The specification of methane gas will show a blue flame. In the observation of the flame test, the color of the flame produced is also seen, if the gas is with a blue flame, it shows a positive research result.

## RESULTS AND DISCUSSION

In making an integrated biodigester design, calculations are first carried out to determine the specification of the biodigester to be used. The calculations carried out are the calculation of the hydrolysis mass balance, the acidogenesis mass balance, the acetogenesis mass balance and the methanogenesis mass balance in the biogas fermentation process. The raw material used in this study is cow dung. Cow manure was taken at the Slaughterhouse (RPH), Lubuk Minturun, Padang City. This cow manure is tested for *Chemical Oxygen Demand* (COD) at the beginning and end. This study was also conducted to test the results of methane gas using two experiments, namely without stirring and using stirring. From the research that has been carried out, the following results and calculations are obtained:

### Hydrolysis Mass Balance

The equation of the hydrolysis reaction of cow manure, or cellulose, becomes the simple sugar required to obtain the hydrolysis mass balance. The equation for the process of hydrolysis of cow manure into glucose is as follows:



**Table 5.** Results of Calculation of Degrees of Polymerization of Cellulose

Component	Ar (gr/mol)	Elemental Mass (g/mol)	Total Mass (g/mol)
C	12	72	13.707,1111
H	1	10	1.903,7654
O	16	80	15.230,1234
Total		162	30.841
N value			190,3765

After knowing the degree of polymerization of cellulose, we can calculate the hydrolysis mass balance as follows.

**Table 6.** Hydrolysis Mass Balance Results

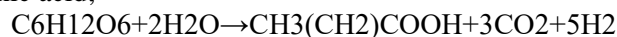
Component	Enter		Out	
	mole	g	mole	g
( $\text{C}_6\text{H}_{10}\text{O}_5$ ) <sub>n</sub>	2,3692521	73.070,1039	0	0

H <sub>2</sub> O	20.175,4676	363.158,4164	19.724,41755	355.040
C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	0	0	451,050024	81.189,00433
Total		436.228,5203		436.228,5203

In the hydrolysis reaction, cellulose is decomposed into a simpler compound, namely glucose, the mass of glucose obtained from the hydrolysis reaction is 81,189.00433 grams.

#### Acidogenesis Mass Balance

In obtaining the balance of the mass of acidogenesis, an equation of the reaction of glucose acidification into propionic acid is required. The following is the equation of the reaction of glucose acidification into propionic acid;



It is known that the mole of glucose in the hydrolysis reaction is 451.050024 mol and the remaining mole of residual water in the hydrolysis reaction is 19,724.4176 mol. Therefore, the mass balance of the acidogenesis reaction is as follows:

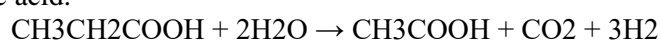
**Table 7.** Acidogenesis Mass Balance

Component	Enter		Out	
	mole	g	mole	g
C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	451,050024	81.189,00433	0	0
H <sub>2</sub> O	19.724,4176	355.039,5159	18.822,3175	338.801,7151
CH <sub>3</sub> CH <sub>2</sub> COOH	0	0	451,050024	33.377,70178
3CO <sub>2</sub>	0	0	1.353,150072	59.538,60317
5H <sub>2</sub>	0	0	2.255,25012	4.510,50024
Total		436.228,5203		436.228,5203

In the acidogenesis reaction, glucose is decomposed into propionic acid, and the mass of propionic acid formed from the acidogenesis reaction is 33,377,70178 grams

#### Asetogenesis Mass Balance

In obtaining the mass balance of asetogenesis, an equation of the acetogenesis reaction of propionic acid to acetic acid is required. The following is the equation of the acetogenesis reaction of propionic acid to acetic acid:



(Soeprijanto et al., 2015)

It is known that the mole of propionic acid in the result of the acidogenesis reaction is 451.050024 moles and the remaining mole of residual water in the acidogenesis reaction is 18,822.3175 moles. Therefore, the mass balance of the asetogenesis reaction is as follows:

**Table 8.** Asetogenesis Mass Balance

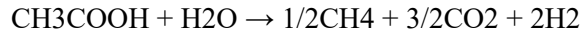
Component	Enter		Out	
	mole	g	mole	g
CH <sub>3</sub> CH <sub>2</sub> COOH	451,050024	33.377,70178	0	0
H <sub>2</sub> O	18.822,3175	338.801,7151	17.920,21746	322.563,9142
CO <sub>2</sub>	0	0	451,050024	19.846,20106
H <sub>2</sub>	0	0	1.353,150072	2.706,300144
CH <sub>3</sub> COOH	0	0	451,050024	27.063,00144
Total		372.179,4168		372.179,4168

In the acetogenesis reaction, propionic acid is decomposed into acetic acid, the mass of acetic

acid formed in the acetogenesis reaction is 27,063.00144 grams.

**Mass Balance of Metanogenesis**

In obtaining the mass balance of methanogenesis, an equation is needed for the reaction of acetic acid to methane gas. The following is the equation of the reaction of the methanogenesis reaction of acetic acid into methane gas;



It is known that the mole of acetic acid in the result of the acetogenesis reaction is 451.050024 moles and the remaining mole of residual water in the acetogenesis reaction is 17,920.21746 moles. Therefore, the mass balance of the metanogenesis reaction is as follows:

**Table 9.** Mass Balance of Metanogenesis

Component	Enter		Out	
	mole	g	mole	g
CH <sub>3</sub> COOH	451,050024	27.063,00144	0	0
H <sub>2</sub> O	17.920,2175	322.563,9142	17.469,16743	314.445,0138
CO <sub>2</sub>	0	0	676,5750361	29.769,30159
H <sub>2</sub>	0	0	902,1000481	1.804,200096
Q <sub>4</sub>	0	0	225,525012	3.608,400192
Total		349.626,9156		349.626,9156

In the metonogenesis reaction, methanogenic bacteria convert acetic acid into methane gas, the mass of methane gas formed from the methanogenesis reaction is 3,608.400192 grams.

**Reactor Volume**

After the mass balance calculation for each reaction in the biogas formation is carried out, the next step is to determine the appropriate reactor volume to be used in this study. The determination of reactor volume uses the overall mass balance of all biogas formation reaction circuits.

**Table 10.** Overall Mass Balance on Biogas Formation Reaction

Component	Density	Enter		Out		
		mole	g	mole	g	%w/w
(C <sub>6</sub> H <sub>10</sub> O <sub>5</sub> ) <sub>n</sub>	1,5	2,369252	73.070,103	0	0	0
H <sub>2</sub> O	0,99568	20.175,46	363.158,41	17.469,1	314.445,01	0,72082635
C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	1,2	0	0	0	0	0
CH <sub>3</sub> CH <sub>2</sub> COOH	0,99	0	0	0	0	0
CO <sub>2</sub>	0,00182	0	0	2.480,77	10.9154,10	0,25022230
H <sub>2</sub>	0,0008234	0	0	4.510,5	9.021,0004	0,02067952
CH <sub>3</sub> COOH	1,05	0	0	0	0	0
Q <sub>4</sub>	0,000643	0	0	225,52	3.608,4001	0,00827181
Total	5,73896		436.229		436.229	1

After obtaining the total mass of the product produced from biogas fermentation, which is 436,229 grams, then density data of the product produced from biogas fermentation is needed. The density data of biogas fermented products was obtained at 5.73896 g/ml, therefore the volume of biogas fermented products is 150,000 ml or 150 liters.

After obtaining the volume of fermented products, then to determine the volume of biodigester used, in general the volume of the reactor used is 15%-25% greater than the volume of the product produced. In this study, the volume of biodigester to be used is 25% larger than the volume of the product, therefore the volume of the biodigester for this study is 200 liters. The biodigester used in this

study is a commercial tank with a volume of 200 liters, the specifications of the biodigester are as follows

### Chemical Oxygen Demand (COD) Results

In the initial and final COD with experiments without stirring were carried out in the Sawahlunto City Environmental Laboratory with the *spectrophotometric testing method*. To test the initial and final COD using stirring was carried out in the Department of Environmental Engineering, Water Laboratory, Andalas University using the *titrimetric method*.

**Table 11.** COD Laboratory Results and COD Calculation *Reduction*

It	Experimental Variables	COD	COD	COD
		<i>Inlet</i>	<i>Outlet</i>	<i>Reduction</i>
		mg/L	mg/L	%
1	No Stirring	65.000	47.000	28
2	With Stirring	17.600	7.920	55

The measurement of COD values in the study was carried out by the spectrophotometry method for experiments without stirring and the titrimetric method for the experimental method using stirring. From the measurements that have been made, a significant difference in measurement results between the titrimetry method and the spectrophotometry method can be seen in table 11. The significant difference between these two methods is due to the difference in accuracy, according to Harahap et al., (2023) The spectrophotometry method provides more accurate results because it does not depend on reaction conditions such as titration so that, with the presence of reaction conditions such as temperature, pH and the presence of other substances that are inconsistent, the chemical reaction does not run perfectly and the measurement results with the titrimetry method become inaccurate.

### Results of Research Without Stirring

Without stirring, the fermentation is carried out without any treatment on the raw materials for 16 days during the forming process. In this study, observation data was taken on temperature, pH and also the methane values produced. This observation was carried out for 16 days with 4 data collections a day for temperature and pH, namely at 09:00 am, 13:00 pm, 17:00 pm and 21:00 pm, as well as methane gas results which were taken once a day on the 12th to 16th day

### Research Results with Stirring

The stirring in question is fermentation by stirring for 5 minutes on raw materials for 16 days during the formation process. The stirring is carried out only once a day. In this study, observation data was taken on temperature, pH and also the methane values produced. This observation was carried out for 16 days with 4 data collections a day for temperature and pH, namely at 09:00 am, 13:00 pm, 17:00 pm and 21:00 pm as well as taking methane gas results which was carried out once a day on the 12th to 16th day, following the first experiment, namely without stirring to get a comparison between these two experiments.

### Design Model of Biogas Biodigester with Stirring

In this study, the design of the tool biodigester Biogas with stirrer *double impeller* created using *drum* with a capacity of 200 liters with a manual stirring system. Disadvantages of biodigester Stirring, in fact, is susceptible to leakage. However, this research has an advantage, namely the biodigester designed so that these shortcomings can be overcome by modifying biodigester so that there is no leakage. The first modification is to obtain biogas results that have a high methane content, so manufacturing is carried out *double impeller* where the purpose of this production is to accelerate the formation of biogas (Tanjung, 2021), and manufacturing *Impeller* It is also modified so that there is no leakage in the biogas output, where the laying *Impeller* and the biogas output is at the lid biodigester. The modifications made are inserting the stirring rod with pipe, where pipe is inserted until it reaches

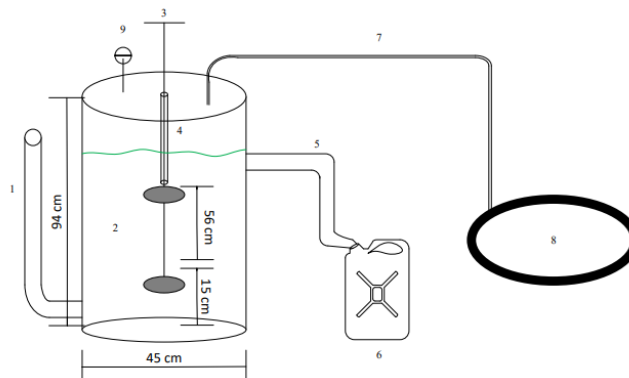
the raw material so that the formation space for biogas is minimal with leakage. This is evident during leak testing biodigester both using water and a compressor, it turns out that water and wind are inserted in biodigester did not come out. The leak testing process is carried out by inserting water, which is the first step to close all parts *Inlet* And *oulet* pipe Then pay attention to every corner biodigester which allows water to escape. Furthermore, leak testing using an air compressor using soap foam placed at each joint Biodigester Pipe, then observe each connection pipe by looking at the soap bubbles that blow when the wind is inserted into the biodigester. The following is a picture biodigester on the research.



**Picture 1.** Manual Stirred Biodigester

This biogas biodigester with stirrer is made of easy-to-get materials, namely *HDPE drums* with a capacity of 200 liters. This biodigester consists of several important components, namely fermentation containers (*drums*), storage containers as a place for *overflowing* raw materials (*dirigen*), stirring iron, temperature measurement and also pressure measurement. The construction process starts from the tool design stage, tool preparation and also tool assembly until it is completed.

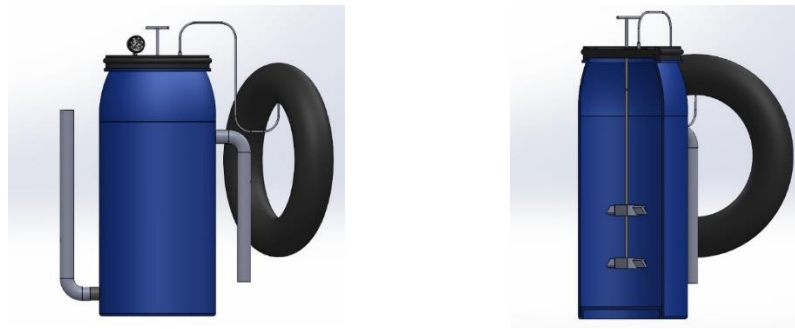
In this study, the design of the shape of the biodigester in 2 and 3 dimensions was carried out using software such as *Visio* and *Solidwork*. Before designing the biodigester, calculations are made to measure the location of the *impeller* that will be put into the *drum* that will be the place where the raw materials are fermented. Here is a design in 2 dimensions and 3 dimensions.



**Picture 2.** 2-Dimensional Design Biodigester

Figure 4.2 Description:

- 1) Raw material *inlet* pipe
- 2) Biodigester tank with a capacity of 200 liters
- 3) *Manual Impeller*
- 4) *Modified safety factor for impeller*
- 5) Raw material *overflow* pipe
- 6) Raw material *overflow* tank
- 7) Hose for discharging biogas production into *biogas storage*
- 8) *Biogas storage*, biogas production storage
- 9) *Pressure gauge*, biogas pressure gauge



**Picture 3.** 3-Dimensional Design Biogas Digester

The selection of materials to be used as biogas digesters also requires considerations such as corrosion resistance due to the raw materials used, easy maintenance and relatively cheap price considerations.

#### **Tool Preparation and Assembly**

In the preparation of the tool for the assembly of the biogas digester, it is necessary to select the material to be used to ensure that the biogas digester can be used for a long period of time. The material used for making biogas digester tanks is *high-density polyethylene* (HDPE) material. The material has the advantage of resistance to corrosion. In addition, these materials are also used in storage containers as *overflow* of raw materials, pipes as a supporting medium for the flow of raw materials and products, *valves*, and product storage containers, namely biogas.

Furthermore, the selection of the location is important to ensure that the biogas digester is not exposed to sunlight which can cause an explosion in the device because it has a high temperature. Ensuring a safe location can reduce unwanted risks, so this research was carried out in the TRBET Workshop that has been available.

In assembling this biogas digester, the following steps are taken:

##### 1) Double Impeller Manufacturing

The first step in making an *impeller* is to take measurements so that the *impeller* is in accordance with the raw materials that will be put into *the drum*. The material used in the *impeller* is US iron. The iron is then cut into 4 parts based on the measurements and calculations that have been made. After making appropriate cuts, iron joints are made on the iron stalks that have been prepared. Weld to connect several stirring leaves, welding is done carefully so that the stirrer is durable. The next step is to paint the *impeller*, this aims to prevent rust that causes corrosion on the *impeller*.

##### 2) Biogas Digester Manufacturing

Biogas digester is a tool used as a fermentation site for the production of biogas. The first step taken is to drill holes in the points that have been designed using an electric drill tool, such as *inlet* and *outlet* holes, stirring holes, *pressure gauge* holes, and *temperature gauges*. Next, which is to connect the pipe with *the elbow* and *fittings* using silicone glue. Make sure the sides are closed so that there are no air leakage gaps that will enter the biogas digester.

#### **Biogas Digester Performance in Biogas Formation**

This biogas digester has a capacity of 200 liters with a *safety factor* of 25%, where the feed of raw materials put in the biogas digester is around 150 liters. This biogas digester works by inserting filling materials in the form of cow manure, cow rumen, water and also EM 4 which has been mixed previously with a ratio of raw materials, namely 1:5. The mixture of ingredients is stirred first evenly so that the input of raw materials into the biogas digester runs well.

Some of the factors that are considered to see the performance of the equipment for making biogas digesters are the type of raw materials used and their availability, the operating temperature at the time of fermentation, the pH of the raw materials both before and after fermentation and the variables of the raw materials to be tested. The experimental variables carried out to see the performance of the Biogas Digester are:

#### **No Stirring**

In conducting this study, the raw material used is 150 ml where cow dung and cow rumen used

is 25 kg dissolved in 125 liters of water and added nutrients. Before inserting the raw material, pH measurement is carried out so that the raw material has a neutral pH and is in accordance with the microorganisms that will ferment. This measurement is carried out using pH paper by putting some of the raw materials into the container, then slipping pH paper in the solution or raw materials and then looking at the color changes seen on the pH paper, whether the solution is acidic or alkaline as discussed in the theory that to find out the acidity degree of a solution, it is necessary to test both using pH paper. In addition, testing with pH paper is carried out after the raw materials have entered the biodigester as much as once a day. This is done in order to maintain the stability of the pH in the biodigester. Low pH indicates that the condition of microbes has decreased in the production of methane, this is in accordance with the statement Setiarto, (2016) which states that the pH value is too low can stop the fermentation process, this usually happens because there is a precipitate so that the bacteria do not work thoroughly. The pH measurement carried out in this study was also carried out once a day. Based on research carried out, the pH obtained by this treatment is 6-7.

COD value testing is also carried out before putting raw materials into biodigester. A high COD value allows to produce more biogas products, this is comparable to microbes that produce methane gas will get more nutrients from cow manure that has high COD levels (Saragih et al., 2023). The COD value obtained from the test results was 65,000 mg/L. In addition, COD testing was also carried out after fermentation was completed. The final COD value obtained is 47,000 mg/L so that the COD value is obtained *Reduction* by 28%. Performance Biodigester can also be seen in the COD value which has decreased to 28%.

Fermentation is carried out for 16 days to see the methane gas produced. On the 7th day, it was seen that the pH had decreased, which means that fermentation had been carried out. The input of raw materials is also carried out on the 7th day to raise the pH back to 7 just like the pH at the beginning before entering the biodigester. This is done to stabilize the pH of the raw materials in the biodigester so that the fermentation process runs well.

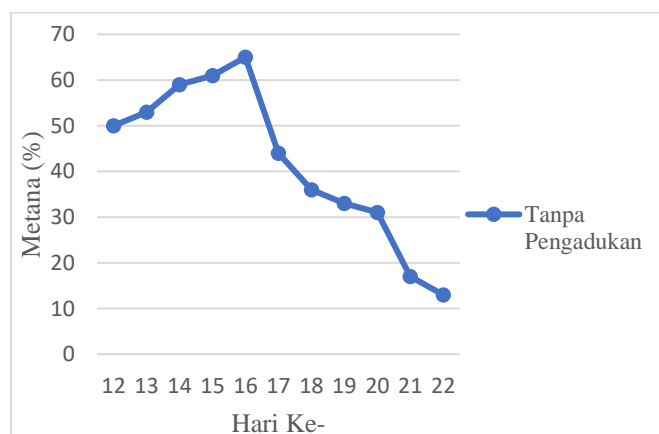
Factors looked at in addition to COD and pH values, namely temperature and methane gas values obtained. The value of the temperature can be seen from the temperature installed at the *body drum* or tank biodigester and to see the value of the methane gas produced, you can look at it using a tool *Gas Analyzer* specifically for detecting methane gas. Temperature changes in biodigester has a range of 26-32oC, where this temperature state indicates the state of the temperature range called mesophilic temperature. Where biogas installations usually use the mesophilic temperature range because it is easier to operate and methane gas production is more optimal than in the thermophilic temperature range which requires a stricter temperature control system (Cahya, 2018).

The biogas formation process has 4 stages, namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. In the hydrolysis stage, microorganisms convert long-chain organics into short-chain ones such as glucose, fatty acids and amino acids with a pH condition of 7. The next stage is acidosis where microorganisms convert short chains into alcohol with a pH condition of still 7. The three stages can be seen in this study where the 1st to 6th days. But on the 7th day there is a change in pH where this is the stage of acetogenesis in producing acetic acid and then the stage in the formation of methane gas, namely the stage of methanogenesis. Measurement of methane gas using *Gas Analyzer* carried out on the 12th to 22nd day. The measurement, which started from the 12th day, was because on the previous day there had been no methane gas formation. Based on research Salim & Kafiar, (2017) stated that the gas production obtained was quite significant, namely on the 12th day. The measurement carried out is by inserting part of the biogas through the *Output* biogas into the bottle using a supporting medium such as a gallon pump, then connect the ends *Gas Analyzer* on the top of the bottle so that the tool can measure the methane gas produced.

The increase in methane gas continues to occur day by day, this is due to the temperature being in mesophilic conditions and a stable pH. The increase in methane gas is influenced by the fermentation time carried out. The longer the fermentation time, the more methane gas is produced (Widiawati et al., 2017). The highest concentration of methane gas was obtained on the 16th day, which was 65%. The following is a graph of methane gas measurement results.

In the microbial life phase it has 4 phases i.e., The lag phase is not clearly visible on this graph, since the data starts directly at a fairly high value (about 50%) on day 12, without showing the initial adaptation period that is usually seen. An exponential phase can be observed from day 12 to day 16,

where there is a significant and rapid percentage increase from about 50% to 65%, indicating rapid growth of the microorganism population under optimal environmental conditions. The stationary phase appears to be very brief or not clearly visible on this graph, as there is no apparent plateau before the sharp decline occurs. The death phase begins after the 16th day, is characterized by a drastic drop in percentage from 65% to about 45% on the 17th day, and continues to decline until it reaches a low of around 13% on the 22nd day. This phase of death indicates a decline in the population of microorganisms that may be caused by reduced nutrients or the accumulation of toxic substances in their growing environment.



**Figure 4.** Chart of Methane Gas (CH<sub>4</sub>) Without Stirring

Observation of the flame test is also carried out to prove the presence of methane gas and determine the magnitude or size of the flame produced. Biogas produced on bioreactor can be used to meet household needs by using a gas stove (Karaman et al., 2021). In the flame test in this study, it was carried out by connecting *Output* gas on *Biogas Storage* (inner tube) with a gallon pump, where the function of this gallon pump is to attract the gas in the biogas storage, so that the gas inside can be pulled out.



**Figure 5.** Gas Flame Test Without Stirring

In the image above, it is clear that the flame produced during the flame test is blue, this is the same as the LPG flame where the gas in LPG is blue with methane gas and carbon dioxide gas content. According to Kinasih, (2020), this methane gas flame test can be marked by a blue flame.

#### Using Stirring

Stirring in the reactor will allow direct contact between the substrate and the bacteria or microorganisms that produce the gas. The more often stirring, the greater the chance for bacteria to degrade the substrate (Mohammad et al., 2016). In addition, stirring is also useful to obtain a uniform

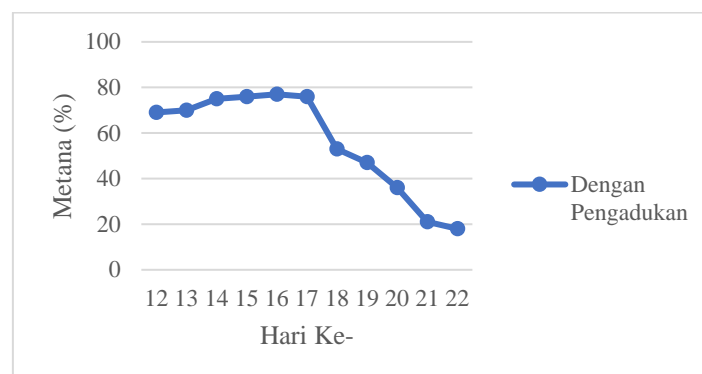
temperature in biodigester. Mohammad et al., (2016) stated that the stirring process can shift the biogas production time to one to two days earlier than if biodigester no stirring was carried out. Stirring aims to homogenize between the substrate and biogas-forming microorganisms, if stirring too fast it can interfere with microbial activity. However, for substrates that are not stirred, it can inhibit the release of biogas due to the formation of foam in the biodigester. Thus this shows the influence of anaerobic processes so that more biogas can be produced (Anggun, 2023).

In the study using this variable with stirring, it has the same raw materials and treatment as the experimental variable without stirring. This is done to see the difference in the results of biogas that will be produced either using or without stirring. The variable of the stirring experiment carried out in this study is by stirring the raw materials using a stirrer that has been installed on the biodigester for 5 minutes every day for up to 22 days. It aims to increase the methane gas produced (Kurniawan & Sari, 2022).

pH measurements are also done once a day using pH paper or litmus paper. Based on the research with this experiment, the pH results obtained are 7. These results can be said to be stable because the stirring factor has an important role in pH control. In addition, stirring also has the function of preventing the accumulation of raw materials on the base biodigester which can inhibit the formation of methanogenic bacteria (Wahyudi & Hendraningsih, 2020).

COD testing is carried out both at the beginning before the input of raw materials and at the end after the completion of fermentation of raw materials. The initial COD obtained was 17,600 mg/L with a decrease in COD or final COD of 7,920 mg/L, so that the COD *Reduction* in this trial was obtained by 55%.

Temperature measurements were also carried out in this study using a temperature device that had been installed on the *body* Biodigester Tank. The measurements were carried out 4 times a day at 09:00 am, 13:00 pm, 17:00 pm and 21:00 pm. The following is a graph of the average daily temperature chart obtained in this study. Temperature changes inside biodigester has a range of 26-30oC where the temperature state is called mesophilic temperature. Mesophilic temperature has a temperature range of 25-40oC, where this temperature is the optimal temperature for the growth of mesophilic bacteria and this temperature is included in the ideal temperature for the activity of microorganisms. (Lantang & Mawardi, 2022). Stirring increases heat exchange in biodigester. When the raw materials are mixed, the heat generated during the fermentation process can be dispersed more evenly thereby reducing the temperature fluctuations that may occur if the raw materials are not stirred.



**Picture 4.** Chart of Methane Gas (CH<sub>4</sub>) with stirring

Methane gas measurements using a *gas analyzer* were carried out on the 12th to 22nd day. The measurements carried out are the same as the measurements in experiments without stirring. The increase in methane gas continues to occur day by day, this is due to the stable temperature of the mesophilic range and pH. This is because stirring is carried out, so that the distribution of substrates and fermentation bacteria can be mixed homogeneously and the fermentation process of the substrate can occur evenly.

Effective stirring helps in the anaerobic fermentation process. By stirring the raw materials can be mixed evenly. This allows microorganisms to interact with raw materials optimally so that methane production increases.

The analysis of the phases of microbial life in this graph shows several phases of microbes. The lag phase is seen at the beginning of the chart, from day 12 to day 17, where the values fluctuate by about 70-80% without significant changes, indicating the presence of a short-term positive autocorrelation. The exponential phase is not evident in this data, as there is no growth or decline that accelerates over time. However, we can observe a stationary phase at the beginning of the chart, from day 12 to day 17, where the data moves in a relatively stable distance with no obvious trend, showing temporary stationary characteristics. Finally, the phase of death or drastic decline occurred from the 18th day, where the value dropped sharply from about 77% to 53%, and continued to decrease until it reached about 18% on the 22nd day. This phase of death marks a significant structural change in a short period of time, the end of the previous stationary phase and indicates the presence of strong external factors affecting the variables measured.

Observation of the flame test is also carried out to prove the presence of methane gas and determine the magnitude or size of the flame produced. The tests carried out were the same as in experiments without stirring. In the flame test in this study, it was carried out by connecting the gas output in the *biogas storage (inner tube)* with a gallon pump, where the function of *this gallon pump* is to attract the gas in the *biogas storage*, so that the gas inside can be pulled out.

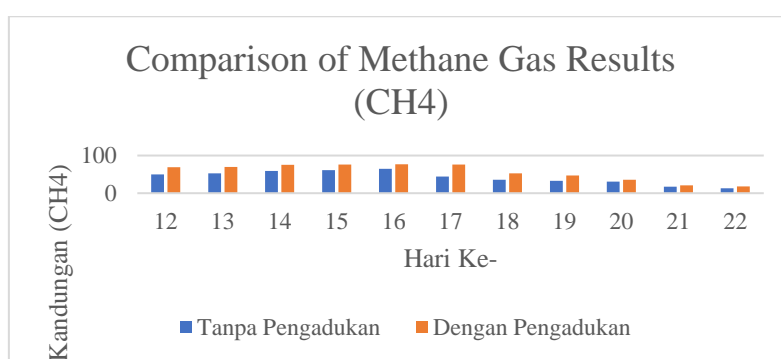


Picture 5. Gas Flame Test Without Stirring

### Analysis of Methane Gas Results Produced Using Two Different Experimental Variables

Measurement of methane gas (CH<sub>4</sub>) results was carried out using a *methane gas detection gas analyzer*. The measurement method using this tool is the first step of vacuuming the packaged bottle using a gallon pump, then the gas produced in the bioreactor is pumped through the *gas outlet* using a gallon pump into the vacuum bottle. After that, methane gas measurements were carried out using a *gas analyzer* to read what percentage of methane was produced. Methane gas measurements are carried out 1 time a day.

The experimental variables carried out in this study were experiments without stirring and using stirring. The following is a comparative graph of the results of methane gas produced using the two experiments.



Picture 6. Methane Gas Results Comparison Chart

The methane gas produced tends to increase from day to day. Based on figure 8. Therefore, a graph of the relationship between fermentation time and changes in methane gas in the biodigester with experiments without stirring and also with stirring can be obtained. From these results, methane gas testing using two experiments is very different. Where the formation of methane gas on the 12th day in the experiment without stirring was obtained by 52% and in the experiment with stirring was 69%. The low methane gas in the experiment without stirring was influenced by the substrate that was not homogenized because the nutrient intake obtained by the microbes was not complete due to sedimentation at the bottom of the biodigester, which affected the productivity of bacteria.

It is different from the results of methane gas in experiments using stirring. Where this is characterized by a stirring function inside the biodigester. Among them is to maintain that there is no sediment in the biodigester. Because this can cause obstruction of the flow of gas formed in the bottom area so that it affects the amount of methane gas produced. In addition, stirring can also increase the contact between microbes and the substrate so that bacteria get nutrients properly (Kurniawan & Sari, 2022).

#### **Analysis of Methane Gas Results Using Double Impeller**

The analysis carried out in this study was by comparing the results of methane gas that was carried out previously with the modification in the stirring of this study. The advantages of this tool can be seen from the comparison between existing journals and modified research designed. The following is a table of methane gas comparison results produced from several previous studies:

If you look at the previous research data, the range of methane gas produced is from the lowest number, which is 19.544% and at the highest number, which is 54.22%. Meanwhile, in this study, the methane gas produced was 77%. The *propeller* modification carried out in this study turned out to have a better advantage compared to some previous journal *review* data, so that the propeller modification had an effect on the methane gas yield produced. This is due to the lack of circulation and mixing of organic matter in the previous stirring so that it can slow down the fermentation process. With the modification of the *propeller* carried out in this study, it aims to make the circulation of organic matter better, so that it can increase the fermentation rate and more methane gas yield.

#### **CONCLUSION**

Based on the results and discussion, it can be concluded that the design of a manually stirred biodigester with a double propeller capacity of 200 liters has been successfully developed and functions well in producing biogas from cow manure and rumen. The results of the study prove that stirring has a significant role in increasing methane gas production. In the experiment without stirring, the methane gas produced reached 65%, while in the experiment with stirring it increased to 77%. The study also showed that impeller modification and the application of manual stirring resulted in higher efficiency than previous studies, which only reached the range of 19-54% methane gas. The comparison graph shows that stirring accelerates the exponential phase and increases the peak methane production, while the stationary phase is more stable and the death phase is more gradual.

Thus, this biodigester offers a more effective and efficient solution to increase the production of organic matter-based biogas. The results of this study make a positive contribution to the development of renewable energy technology and show great potential in managing organic waste in a more productive and environmentally friendly manner.

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