

# The Development of Mini Portable Digester Designs for Domestic and Restaurant Solid Waste Processing to be Clean Biogas as Energy's Alternative to Replace LPG

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**Abstract.** Biofuel is developed as an alternative source of second generation energy that could be attained from organic waste. This research is purposed to create applicative and cheap Portable digester unit for society. The design concepts' screening that was made under considerations of the experts is finally resumed. Design 1 with final weight score of 1, design 2 with final weight score of -1, design 3 with final weight score of 2, design 4 with final weight score 3, design 5 with final weight score of -1, design 6 with final weight score of 0. Accepted designs for further concept assessment are design 1, 2 and 6. The result of concept assessment applies weighting for the scoring. Design 1 resulting 2.67, design 2 results 2.15 while design 3 results 2.52. Design 1 is concluded as the design with biggest result, which is 2.67. Its specification is explained as follows: tank capacity of 60 liters, manual rotating crank pivot, tank's material is plastic with symbol 1, material of axle swivel arm is grey cast iron, 2 mm rotary blades with hole. The experiment 1 contained 23.78% methane and 13.65 carbon dioxide that resulted from content test.

## 1. Introduction

It is revealed from the data from Ministry of Energy and Mineral Resource that Indonesian crude oil reserve is decreasing over years. In 2012, as much as 3.742 million stock tank barrels (MMSTB) are recorded as oil reserve. In 2013, the number is decreased to 3.692, while in 2014 the reserve is calculated as 3.642 MMSTB. Overall from 2012 to 2014, it experienced 118 MMSTB declining [1]. The head of Geology Office, Ministry of Energy and Mineral Resource affirmed that fossil energy dependency is dominated by oil needs that reach 41.8%, 29% of charcoal and 23% of gas. This requirement is addressed to fulfil industrial sector that dominates approximately 37% from total fossil energy utilization in Indonesia [2]. Excessive oil exploitation will cause global warming phenomenon. It elevates within 1% raise every year and continues raising [3]. For the last decades, biogas that is derived from sustainable organic material employed as alternative energy source, which is provided as the replacement of petroleum fuel. Biogas could be defined as energy source that produces microbiologically from anaerobic organic waste [4] by using liquefaction, acidogenesis, acetogenesis, and methanogenesis process. Biogas consists of methane CH<sub>4</sub> (55-70%), CO<sub>2</sub> (25-50%), H<sub>2</sub>O (1-5%), H<sub>2</sub>S (0-0.5%), N<sub>2</sub> (0-5%) and NH<sub>3</sub> (0-0.05%) [5].

The process of anaerobic digestion that subjected to form organic matters is influenced by certain factors, as follows: (1) fermented substrate that classified as better substrate [6]; (2) temperature change that becomes a sensitive issue to anaerobe fermentation process [18], therefore the raise of temperature could improve number of biogas production [7, 8, 9, 10]; (3) Neutral pH ranged between 6.6 – 7.6 is the best pH to be used in anaerobe decomposition process [11, 12, 13]; (4) Volatile Solids (VS) are the food for hydrolysis process as well as acid formation anaerobically; (5) Total Solid is the solids that measured based on its remaining quantity (mg/l) on heating temperature between 103-105 °C [14]; (6) Hydraulic retention time (HRT) is defined as duration of substrate when being processed in reactor before flowing out as effluent [15].



Recently, biogas of organic material is made by selecting large numbers of waste. It takes spacious location and significant funding. Hence, a unit of digester that requires only small scale of SOP material by considering limited area and low budget is urgently needed. Therefore, a digester unit called Portable digester is constructed. To build a portable digester of 220 liters, several specifications are required as follows; (1) the frame uses elbow plate of 40 mm x 40 mm x 4 mm; (2) prime system uses electric motor OEM; (3) rotating drum table uses oval that supported by UCF; (4) the table pedestal applies UCF 1/50; (5) drum capacity is 220 liters; (6) drum plate pedestal is 5 mm; (7) Whole construction applies knock down system [16]. Optimum composition for biogas with 220 liters capacity is explained as follows; (1) composition of 20 gram cow dung; (2) 12 ml inkoulumus; (3) 12 gram wet waste; (4) 5 ml distilled water; (5) 82% N<sub>2</sub> gas; (6) 20% CO<sub>2</sub> gas; (7) and stirring round of 25 Rpm [17]. The research is conducted manufacture GFRP fibre that indicates higher temperature condition on biogas fermentation of GFRP than traditional biogas, which is 0.85°C [18]. Other research about digester stove illustrates injector outlet with outlet diameter of 1.46 mm and 1,9 mm. Burning energy is yielded as 4.4% and 31.7% [19]. Based on explained background, the objective of the research is designated to apply biogas technology in the form of applicative Portable Digester with 60 liters capacity under good quality, reasonably price, and easy-use device.

## **2. Research Methodology**

### *2.1 Research Object*

The object of the research is to develop portable digester that was constructed from previous research. Design development and recent design cover the reduction of Portable Digester to smaller capacity, rotary mechanism that is no longer applies electric motor, process of biogas forming that employs taguchi experiment table and performs the test of biogas specimen toward methane gas.

### *2.2 Data Collection*

Questionnaire, interview, and literature study are used as data collection methods. Questionnaire distribution is addressed to obtain results from several alternatives of design. Interview is conducted by proposing general questions to users about portable digester while study literature is conducted by comprehend and study several references as literatures, research report and other scientific writings that support research.

### *2.3 Improvement Process for Portable Digester with capacity of 220 liters*

The improvement process is performed as follows: (1) structure frame re-establishment. It is restored due to the frame instability because of quivering; (2) the imperfect rotary of the stir so the solution could not well blended; (3) insufficient capacity of biogas production; (4) the improvement of Portable Digester capacity to 60 liters

### *2.4 Process of Portable Digester Design Development*

Design development process is performed by involving experts on biogas, mechanical engineering, user and workshop where the tools are assembled to consider the appropriate design. The design covers several steps: (1) The participatory members are selected from mechanical engineering background (1 person), biogas expert (1 person), user (1 person) and representative from the workshop (1 person); (2) Designing Portable Digester by conducting Focus Group Discussion (FGD). A discussion is held to design Portable Digester, appropriate tools and to compare it with the previous one; (3) Creating several design alternatives based on classification tree that has already prepared by participatory team; (4) conducting evaluations toward several design alternatives that have already prepared by the team; (5) Performing the improvement on designs based on evaluation and later approved by the whole team member; (6) Creating the questionnaire page to select the preferable

portable digester design; (7) Directing the team member on questionnaire completion; (8) Fulfilling the questionnaire; (9) Processing the questionnaire to assess the prepared alternative designs.

### 2.5 Experiment Process on Portable Digester based on Taguchi Method

Design of experiment on Portable Digester is a process to provide the information related with the experiment. The stages for conducting experiment are defined as follows: (1) The selection of product quality characteristics that will be examined; (2) Identification and selection on factors that affected to quality characteristics; (3) Determination of controlling factors and noise factor as well as factor level; (4) The selection of orthogonal matrix for control factor (Inner Array) and uncontrollable factor (Outer Array); (5) Determination of combination matrix (Product Array).


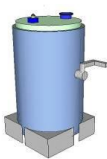
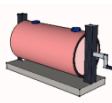
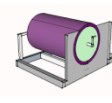


## 3. RESULT AND DISCUSSION

### 3.1 The Process of Designing Digester 60 liters

The design is made by applying modular part concept, where each part of digester has its own function. 2D design modeling supported by specific software, inventor fusion, 2D layout sketching using Software Proengineer and 3D model finishing by using Google Sketch-Up software. Design concept selection uses SS method. The concept design of digester by using SS method involves several stages, as follows:

1. Making some Portable Digester concept designs based on the point 2.4
2. Filtering the Portable Digester concept designs based on the analysis and recommendation from the FGD team, in which the team gives (+) sign for the designs that have positive contribution to the criteria, and vice versa, if the designs give negative contribution to the criteria then they are given (-) sign, and the sign will be 0 if the designs are neutral toward the criteria. Result of these analysis can be used for decision making, i.e.: (1) Accept the designs if the final score given by the FGD team is on the top three on the whole concept designs scoring; (2) Reject the designs if the final score is not on the top three; (3) The decision will be merged if there are same score on the designs. Concept designs filtering is shown on the table 1.

Table 1. The Screening of Portable Digester Design Concept

Selection Criteria	Design Concept Alternatives					
	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
						
Easy to use	+	+	+	-	0	+
Long Durability	0	-	0	0	-	-
Easy to Produce	+	-	-	-	+	0
Easy Maintenance	-	+	+	-	-	+
High Productivity of Gas	+	0	0	+	0	0
Low Price	0	-	+	-	+	-
Total +	2	2	3	1	1	2
Total 0	2	1	2	1	3	2
Total -	1	3	1	4	2	2
Final Score	1	-1	2	-3	-1	0
Leveling	2	3	1	4	3	2
Decision	Y	Y	T	T	Y	T

Description:

T = Tidak/No (Design is rejected)

Y = Ya/Yes (Design is accepted)

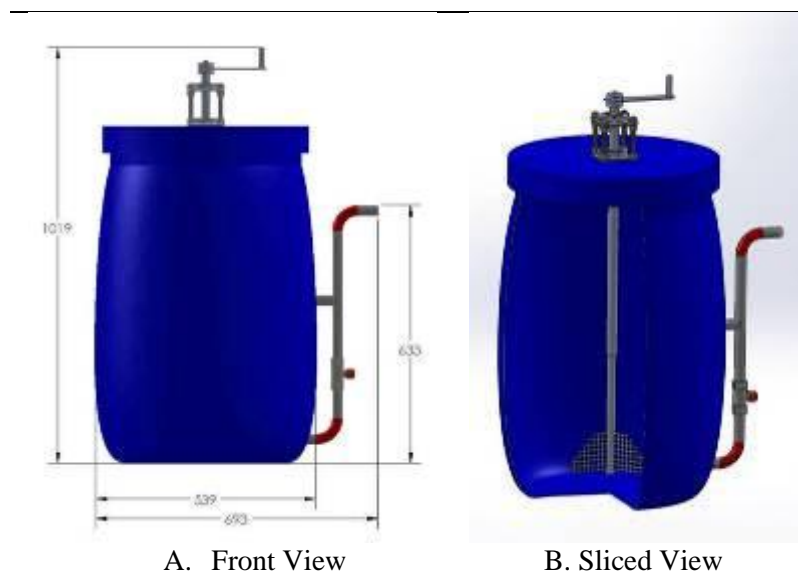
From screening concept on table 1, it can be concluded that: (1) concept design 1 is accepted, hence design 1 is titled as design A to be assessed with scoring concept; (2) concept design 2 is accepted, hence design 2 is titled as design B to be assessed with scoring concept; (3) concept design 5 is accepted, hence design 5 is titled as design C to be assessed with scoring concept; design concept of 3, 4, 6 are rejected and excluded from assessment of scoring concept.

- From the five selection criteria given by the expert, we did scoring for the chosen designs of the previous stage. The scoring result is shown on the following table.

Table 2. The result of Design Scoring of 1,2 and 5

No	Selection Criteria	Concept A		Concept B		Concept C	
		Weight	Rating	Score Weight	Rating	Score Weight	Rating
1	Easy to Use	0,2	2,83	0,57	2,01	0,40	1,67
2	Long durability	0,3	2,57	0,77	2,03	0,61	2,33
3	Easy to Produce	0,3	2,63	0,79	2,21	0,66	3
4	Easy Maintenance	0,1	2,67	0,27	2,03	0,20	2,93
5	High Productivity of Gas	0,1	2,77	0,28	2,7	0,27	2,97
<b>Total</b>		<b>1</b>		<b>2,67</b>		<b>2,15</b>	<b>2,52</b>

- From concept assessment, the greatest score that is derived from design 1 with 2.64, design 1 is selected as Portable Digester design that will be used as experiment device. Selected design 1 is shown by figure 3.



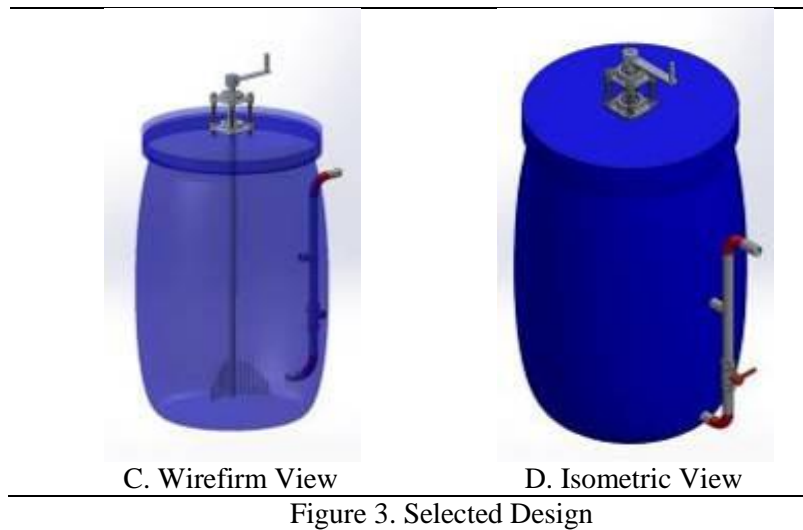


Figure 3. Selected Design

5. Portable Digester has technical specification as follows; (1) rotary device of digester is swivel crank as the rotary power, which has rotary capacity as 60 Rpm; (2) Connection system of swivel crank uses screw knob as anti vacuum; (3) Pedestal point of swivel crank is placed on center of digester center; (4) rotary blade uses plate with hole of 2 mm; (5) Portable digester has 3 holes, 1 hole is functioned as the component's entry duct for biogas former, 1 hole is functioned as output duct of methane and the other hole is functioned as waste canal; (6) Material of portable digester is HDPE plastic.

### 3.2 Biogas Experiment by Using Taguchi Method

The experiment is subjected for optimum composition identification in order to manufacture methane gas by using Taguchi method. The method is executed as follows:

1. The selection of the characteristics of gas product will be examined. The selection of product quality is the determination of result quality from experiment. Product quality in this case is the amount of methane gas percentage that will be yielded.
2. Identification and influenced factors selection toward quality characteristics. Identification and factor selection is the composition of methane gas.
3. Determination of controlling factor and noise factor as well as factor level determination. Controlling factor is a factor that can be converted in methane gas formation. Controlling factor is shown in table 3.

Table 3 Controlling Factor

No	Controlling Factor	Level 1	Level 2
1	Cow Dung	2,5 Liter	3 Liter
2	Inoculum	15 Liter	17 Liter
3	Vegetable Waste	300 gr	360 gr
4	Water	7,5 Liter	9 Liter
5	Type of stirring	Manual	Electric
6	Stage of Stirring	twice/day	3 times/day
7	Duration of Stirring	2 Minutes	4 Minutes

4. The selection of Orthogonal matrix for Inner Array and uncontrolled factor (Outer Array). Selection of controlling factor matrix is the determination of the amount of experiment table composition that will be performed. Standard Orthogonal Matrix L8 is illustrated by table 4

Table 4. Orthogonal Matrix of L8

Trial	Column Number						
	1	2	3	4	5	6	7
<b>1</b>	1	1	1	1	1	1	1
<b>2</b>	1	1	1	2	2	2	2
<b>3</b>	1	2	2	1	1	2	2
<b>4</b>	1	2	2	2	2	1	1
<b>5</b>	2	1	2	1	2	1	2
<b>6</b>	2	1	2	2	1	2	1
<b>7</b>	2	2	1	1	2	2	1
<b>8</b>	2	2	1	2	1	1	2

5. After the determination of table L8 is performed, experiment process will be carried out. The testing result on biogas content for experiment 1 is 23.78% methane and 13.65 carbon dioxide.

#### 4. Conclusion

From the concept of screening, it can be concluded that: (1) concept design 1 is accepted, hence design 1 is titled as design A to be assessed with scoring concept; (2) concept design 2 is accepted, hence design 2 is titled as design B to be assessed with scoring concept; (3) concept design 5 is accepted, hence design 5 is titled as design C to be assessed with scoring concept; design concept of 3, 4, 6 are rejected and excluded from assessment of scoring concept.

Design 1 is concluded as the design with biggest result, which is 2.67. It is confirmed as a valid portable digester design that will be used as experiment's model. Portable Digester has technical specification as follows; (1) rotary device of digester is swivel crank as the rotary power, which has rotary capacity as 60 Rpm; (2) Connection system of swivel crank uses screw knob as anti vacuum; (3) Pedestal point of swivel crank is placed on center of digester center; (4) rotary blade uses plate with hole of 2 mm; (5) Portable digester has 3 holes, 1 hole is functioned as the component's entry duct for biogas former, 1 hole is functioned as output duct of methane and the other hole is functioned as waste canal; (6) Material of portable digester is HDPE plastic. The testing result on biogas content for experiment 1 is 23.78% methane and 13.65 carbon dioxide.

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