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Biogas Stove Design and Test for Household Scale

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ABSTRACT

This research is an increase in the performance of biogas stoves from cow dung, for household needs. This type of research is experimental, with the independent variables being a blower with a power of 2.5 watts, two variations of burner holes 4.1 mm and 4.5 mm, and 10 times replication. The dependent variables are stove power, stove efficiency, length of time required for testing and heat and efficiency level. The specifications of the biogas stove are made of zinc (height: 9 cm, width: 38 cm and length: 70 cm), with two stoves, the gas distribution line is made of brass pipe with a diameter of 5 mm, the fire pit size (burner) is 4.1 mm and 4.5 mm, blower: 2.5 watts, factory valve opening max 5 mm, refill gas lighter system shaped like a gun that is separated from the stove, biogas fuel is cow dung. The results of the Water boilling test are that the power of the stove with a diameter of 4.1 mm and a blower of 2.5 watts is 0.904352 KW and the efficiency is 55.748%; while for a fire pit with a diameter of 4.5 mm and a blower of 2.5 watts it is 1.185 KW and the efficiency is 51.838%. Furthermore, it is concluded that smaller burner holes are more efficient. Larger burners will be more wasteful, but can save time.

Keywords: biogas stove; digesters; blowers; burner

INTRODUCTION

Biogas is a renewable energy that is environmentally friendly, cheap, easy to obtain and can be renewed. The technology is simple and the energy produced is feasible to use technically, socially, and economically, especially to overcome energy problems in rural areas [(1)].

In the results of previous studies, it is recommended to improve the performance of the stove, including blower power, variations in burner diameter, replacement of lighters from matches with magnetic lighters that are assembled with the stove, blower arrangement, power supply [(2)].

This study aims to develop the performance of biogas stoves with appropriate technology that can be utilized by the community, with details:

1) Making a biogas stove as a result of development which consists of a body, gas distribution line, blower, power supply, valve and a magnetic lighter system with biogas fuel.
2) Testing the development of the biogas stove with the Water boilling test, namely testing the power and efficiency of the stove.
3) Analyzing the performance of the biogas stove as a result of the development related to the stove power and stove efficiency testing.

METHODS

The design of this experimental research is a one-shot case study [(3)], where the researchers design a biogas stove and test the performance of the stove. The location of this research is Janggan Village, Poncol District, Magetan Regency, Indonesia and the Magetan Environmental Health Study Program Campus, Health Poltekkes, Surabaya. The research was conducted from March to October 2018.

The independent variable in this study was a blower with a power of 2.5 watts, with two variations of burner holes, namely 4.1 mm and 4.5 mm. The replication of the paired blower variation test with the burner hole variation is 10 times. The dependent variables are stove power, stove efficiency, length of time required for testing and heat and efficiency level.

The research stages include: biogas stove design, stove fabrication carried out with the help of other parties, preparation of tools and materials, preparation of biogas as fuel, filter testing, data collection of test results and data analysis. Data obtained from observations, interviews and test results, include:

1) Dimensions of biogas stove: stove body, distribution line, valve, blower, burner and flame system.
2) The capacity of biogas in the reservoir at the experimental site.
3) The process of testing the water boiling test.
4) Test results: stove power, stove efficiency, length of time and heat.

The data were analyzed descriptively, namely stove power, stove efficiency, length of time for testing and heat/heat. The data from the test results are calculated and processed manually and presented in tabular form.

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RESULTS

Table 1. Results of minimalist biogas volume measurement for households for 7, 14 and 21 days

No	Spesifikasi	Kompor inovasi akan diuji dengan type	
		1	2
1	Stove body	Manufacturing & modification	Manufacturing & modification
2	Gas distribution	Steel pipe Ø 5 mm	Steel pipe Ø 5 mm
3	Burner diameter	4.1 mm to be tested	4.5 mm to be tested
4	Pemantik	Battery and/or gas magnetic lighters will be tested	
5	Gas pressure	None	None
6	Gas suction blower	Available 2.5 watts DC, will be tested	
7	Power regulator	Digital DC power setting that can be used for electrical power that requires a maximum power of 10 watts	

Table 2. The results of calculating the power of a biogas stove with a burner diameter of 4.1 mm and a blower of 2.5 watts

No	Time (dt)	E (Kj/Kg)	Mf (kg)	cxd/b
1	420	18939	0.019372	0.873539
2	444	18939	0.018704	0.797827
3	432	18939	0.021376	0.937130
4	420	18939	0.020040	0.903661
5	444	18939	0.021376	0.911802
6	432	18939	0.021376	0.937130
7	438	18939	0.022044	0.953177
8	444	18939	0.022044	0.940296
9	441	18939	0.020708	0.889317
10	450	18939	0.021376	0.899645
Mean	437	18939	0.020842	0.904352

Table 3. The results of calculating the power of a biogas stove with a burner diameter specification of 4.5 mm with a 2.5 watt blower

No	Time (dt)	E (Kj/Kg)	Mf (kg)	P (KW)
1	375	18939	0.024716	1.248257
2	360	18939	0.022712	1.194840
3	372	18939	0.022712	1.156297
4	366	18939	0.023380	1.209819
5	372	18939	0.023380	1.190306
6	375	18939	0.024048	1.214520
7	372	18939	0.023380	1.190306
8	378	18939	0.022712	1.137943
9	384	18939	0.024048	1.186055
10	384	18939	0.022712	1.120163
Mean	373.8	18939	0.02338	1.184851

Table 4. Results of calculating the efficiency of a biogas stove with a burner diameter specification of 4.1 mm and a blower of 2.5 watts

No	Mw (kg)	Cp (kj/kg)	Mpa (kg)	cpc	ΔT (°c)	ms (kg)	Hfa (KJ/kg)	mf (kg)	E (KJ/kg)	ŋ overall (%)
1	0.5	4.186	0.145	0.840	70	0.025	2526.53	0.019372	18.939	59.47326
2	0.5	4.186	0.145	0.840	70	0.025	2526.53	0.018704	18.939	61.59731
3	0.5	4.186	0.145	0.840	70	0.026	2526.53	0.021376	18.939	54.52172
4	0.5	4.186	0.145	0.840	70	0.026	2526.53	0.020040	18.939	58.15650
5	0.5	4.186	0.145	0.840	70	0.026	2526.53	0.021376	18.939	54.52172
6	0.5	4.186	0.145	0.840	70	0.025	2526.53	0.021376	18.939	53.89764
7	0.5	4.186	0.145	0.840	70	0.025	2526.53	0.022044	18.939	52.26438
8	0.5	4.186	0.145	0.840	70	0.026	2526.53	0.022044	18.939	52.86955
9	0.5	4.186	0.145	0.840	70	0.026	2526.53	0.020708	18.939	56.28049
10	0.5	4.186	0.145	0.840	70	0.025	2526.53	0.021376	18.939	53.89764
Mean	0.5	4.186	0.145	0.840	70	0.025	2526.53	0.0208416	18.939	55.7480222

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Table 5. Results of calculating the efficiency of a biogas stove with a burner diameter specification of 4.5 mm and a blower of 2.5 watts

No	Mw (kg)	Cp (kj/kg)	Mpa (kg)	cpc	ΔT (°c)	ms (kg)	Hfa (KJ/kg)	mf (kg)	E (KJ/kg)	ŋ overall (%)
1	0.5	4.186	0.145	0.840	70	0.028	2526.53	0.0247	18.939	48.23341
2	0.5	4.186	0.145	0.840	70	0.030	2526.53	0.0227	18.939	53.66404
3	0.5	4.186	0.145	0.840	70	0.029	2526.53	0.0227	18.939	53.07667
4	0.5	4.186	0.145	0.840	70	0.028	2526.53	0.0234	18.939	50.98961
5	0.5	4.186	0.145	0.840	70	0.030	2526.53	0.0234	18.939	52.13079
6	0.5	4.186	0.145	0.840	70	0.030	2526.53	0.0240	18.939	50.68271
7	0.5	4.186	0.145	0.840	70	0.031	2526.53	0.0234	18.939	52.70137
8	0.5	4.186	0.145	0.840	70	0.031	2526.53	0.0227	18.939	54.25142
9	0.5	4.186	0.145	0.840	70	0.028	2526.53	0.0240	18.939	49.57323
10	0.5	4.186	0.145	0.840	70	0.029	2526.53	0.0227	18.939	53.07667
Mean	0.5	4.186	0.145	0.840	70	0.0294	2526.53	0.0234	18.939	51.83799

DISCUSSION

The Results of Testing the Power of a Biogas Stove with a Burner of 4.1 mm and 4.5 and a Blower of 2.5 Watts

The results showed that on a blower (2.5 watts), the use of a burner with a diameter of 4.1 mm produced a biogas stove power of 0.9043 KW; while the burner with a diameter of 4.5 mm produces a stove power of 1.185 KW. This shows that the larger the diameter of the burner, the greater the power generated. Based on the results of previous studies [(2)], the use of a 6 watt blower produces a power of 1.231190 KW. When compared to current and previous biogas stoves, there is a difference in stove power, namely 1.185 KW with 2.5 watts of power and 1.231190 KW with 6 watts of blower. However, if the blower power as a result of this research is used 6 watts of power (as before) then the power of the stove will increase to 2.844 KW which means 2 times the capacity of the previous stove.

To increase the power of the stove in the study, a blower equipped with a blower power regulator switch was used up to 10 watts. Thus the user can easily use the stove according to the needs of the large and small fire on the biogas stove. This blower component is an advantage and improvement from previous research which is not equipped with an on and off switch to increase and decrease the blower power.

From the data above, the amount of power is also followed by the use of increasing fuel consumption, namely for the burner with a diameter of 4.1 mm, it produces an average fuel consumption of 31.2 liters or mf = 0.0208 kg, while the burner has a diameter of 4.5 mm. produces an average fuel consumption of 35 liters or mf = 0.0233 kg

With (mf) getting bigger, the time needed to boil 0.5 liter of water is getting smaller. This shows that there is a relationship between the use of a larger burner diameter, which will increase the power of the stove (KW) and the consumption of biogas fuel will also increase.

There is a time difference in boiling water as much as 0.5 liters, namely a 4.1 mm diameter burner takes an average of 437 seconds (7.28 minutes), while a 4.5 mm diameter burner takes an average of 373 seconds (6.23 minutes).

Thus, it can be concluded that the greater the power of the stove, the less time or time used in boiling water, followed by the greater use of biogas fuel. The larger the diameter of the flame hole, the greater the heating will be, the greater the temperature rise and the shorter the time needed

The diameter of the fire pit on the burner of the biogas stove is very influential on the power value, this is evidenced by the greater value of the power of the pot using a burner for the diameter of the fire pit of 4 mm than the diameter of 2 mm and 3 mm. This is because for a larger diameter, the required fuel consumption is also large so that if the fuel consumption value (mf) is large, the power value (P) is also large [(4)].

The resulting blue flame indicates that it contains more than 45% methane gas [(5)]. The amount of methane gas in biogas will have a greater combustion power and the flame is not easily extinguished. Blue flames coming out of the burner in this study indicate that the greater the power of the blower, the larger the flame and wasteful of fuel.

The Results of Testing the Efficiency of a Biogas Stove with a Burner of 4.1 mm and 4.5 mm and a Blower of 2.5 Watts

Testing the efficiency of the biogas stove was carried out to obtain the efficiency of the stove by measuring the heat when cooking water to a boil using a 4.1 mm burner and 4.5 mm fire holes on a 2.5 watt blower. With the use of the same blower, the 4.1 mm burner produces an efficiency of 55.748% more efficient than the 4.5

mm burner (efficiency = 51.838%). If the value of mf (biogas fuel used) is smaller then the value of efficiency will be large.

The value of ms (mass of water that evaporates kg) on the use of a 4.5 mm burner on average is greater (0.0294 kg) than that of a 4.1 mm burner (0.0255 kg). but the efficiency value of using 4.1 mm burner is still smaller. While the time used to reach the boiling point of water is faster if the use of a blower is getting bigger.

Thus it can be concluded that the use of a large burner will shorten the boiling time of water and the more biogas fuel is used, followed by a lower efficiency value.

The smaller the power of the blower, the less fuel consumption, but the longer it takes to boil the water. The higher the methane content, the greater the energy content (calorific value) in biogas and conversely the smaller the methane content, the smaller the calorific value. This is in line with this study that the greater the use of fuel, the greater the methane content in the combustion process and the greater the energy (calorific value) generated [(6)].

The efficiency of biogas when cooking reaches 45% and this is lower than the results of the above test. It can be predicted that the important role of the flame is influenced by the volume of methane gas from the biogas used [(7)]. The volume of methane gas is 55-70% biogas. The greater the content of methane gas in the biogas, the greater the combustion power (heat produced) and the shorter the time used for cooking [(8)].

The longer the time, the water temperature will also increase. This is because the heating carried out by the stove is getting bigger [(4)]. There is an interesting thing here, namely the increase in temperature at the diameter of the fire pit of 4 mm is larger and faster than the diameter of the fire pit of 2 mm and 3 mm. This is because the heat transfer area is larger for a diameter of 4 mm than for 2 mm and 3 mm. Besides, the fuel consumption for the diameter of the fire pit is 4 mm larger than the others. This is in accordance with the theory of continuity (V1.A1=V2.A2) with the same speed, i.e., if the diameter of the hole is larger, the discharge will also be greater, meaning that the heat generated will be greater.

In addition to this, the use of a blower has a positive value, namely biogas that is accommodated in polyethylene plastic (0.15 mm thick) with a small density but can still be used because the blower as a biogas sucker does not require pressure and the flame is released through a stable flame hole. It is very different from the flame that is released without using a blower which is very dependent on the pressure on the biogas in the polyethylene plastic and the discharge is uneven. This condition greatly affects the process of cooking activities for daily needs.

CONCLUSION

1. Produced biogas stove with specifications: body made of zinc (9: cm high, width: 38 cm and length: 70 cm), two furnaces, gas distribution line made of brass pipe with a diameter of 5 mm, burner measuring 4.1 mm and 4.5 mm, blower: 2.5 watts, factory valve opens to a maximum of 5 mm, refillable gas lighter in the form of a separate gun with stove, fuel is cow dung.
2. Water boilling test results: the power of the stove with a 4.1 mm burner and a 2.5 watt blower is 0.904352 KW, with an efficiency of 55.748%); while the power of the stove with a burner of 4.5 mm and a blower of 2.5 watts is 1.185 KW, with an efficiency of 51.838%.
3. With the same blower (2.5 watts), the smaller the burner, the smaller the power and the more efficient. The larger the burner, the greater the power, wasteful of fuel, but can save time.

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