Characteristic of flame length on spuyer diameter in conventional LPG stove

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Abstract. Biogas is an alternative fuel in the form of gases derived from dirt or waste. In general, biogas is used as a fuel source for cooking stoves for daily needs. The stove has a special design so it has not been reached by the community, especially in the countryside. One alternative to solve this problem was to modify the spuyer of stove of conventional LPG to be compatible with biogas fuel. The purpose of this paper was to determine the ability of conventional LPG stoves in terms of flame height to the diameter of the spuyer hole on the stove. The variation of the hole was 2; 2.5; 3; and 3.5 mm in diameter. The conventional LPG stove used the Rinai RI-511E type with medium of input control. While the biogas pressure from the digester to the stove was 0.106 MPa. The results showed an increase in flame height from 30.79 mm to 166.95 mm if the spuyer diameter was enlarged from 2 mm to 3.5 mm. So that the increase of flame height could reach 442.22%.

1. Introduction

The limitation and scarcity of fuel oil as a non-renewable energy source demands to seek the development of other alternative energy sources which are quite abundant and environmentally friendly. The development of alternative energy has become a strategic instrument to reduce dependence on fossil energy and create environmental sustainability. One of the energy developed at the local level is biogas fuel [1].

Biogas is an alternative fuel produced from the fermentation process (decay) of organic materials by anaerobic bacteria. It can be used for cooking daily needs. To use biogas, a special type of stove is needed which has not been reached by the community, especially rural areas. One alternative of solving the problem is to modify a conventional LPG stove especially spuyer in order that it can compatible with biogas fuel. Conventional LPG gas stove cannot work in biogas fuel, because the stove spuyer hole are too small which compared to special biogas stoves.

According to Yunaidi et al, modifications were made by increasing the diameter of output spuyer at 1.5 - 2 mm [2]. The output of flow of gas became more so that it got enough flame for cooking needs. Bajet et al. modified nozzle, air regulation parts and in the injector. The design of modification produced effective for biogas source as substitute for LPG [3]. Itodo et al. conducted a study on the ability of biogas stoves in cooking in Nigeria [4]. This test was carried out in cooking water, rice and beans which results in efficiency for each type of cooking. Orhorohoro et al. did the design and construction of a biogas stove. The stove consisted of several components including burner, injector opening, mixing tube, burner support. The ability of the stove was tested by boiling water [5]. Ovueni et al. made a comparison of the heat capacity of biogas and conventional gas in cooking using the Mann-Whitney U statistical test method. This test was carried out by boiling water with a volume of 1000 cm3 for 4 minutes [6]. Kurchania et al. designed and evaluated the capabilities of biogas stoves in cooking. The test used a method of cooking bread and other food on a hot plate [7]. The biogas source was produced from a 25 m3 of floating digester at the Asha Dham Ashram plant, Udaipur India. Decker conducted development and testing of tools that aim to optimize the geometry of port flames for burning biogas in households [8]. The analysis method used computational fluid dynamic (CFD) with variations in circular and rectangle geometry at the output of the biogas stove. Suwansri et al. also converted LPG stoves to use biomethane. Modification of fuel flow, pressure, combustion efficiency is done to get optimization on the biomethane stove [9].

From the tests of several researchers above, this paper would discuss about the characteristic in flame height produced by Rinnai RI-511E of LPG stoves by using biogas fuel with 12 m3 of digester capacity in Indramayu. The LPG stove would be modified by changing the hole diameter of the spuyer attached to the stove. In addition, calculations would be carried out to determine the efficiency of the stove due to changes in spuyer diameter.

2. Methods

This research process should have a flow chart which could reduce the occurrence of errors and run systematically, controlled, and reliably. The process is depicted by figure 1.

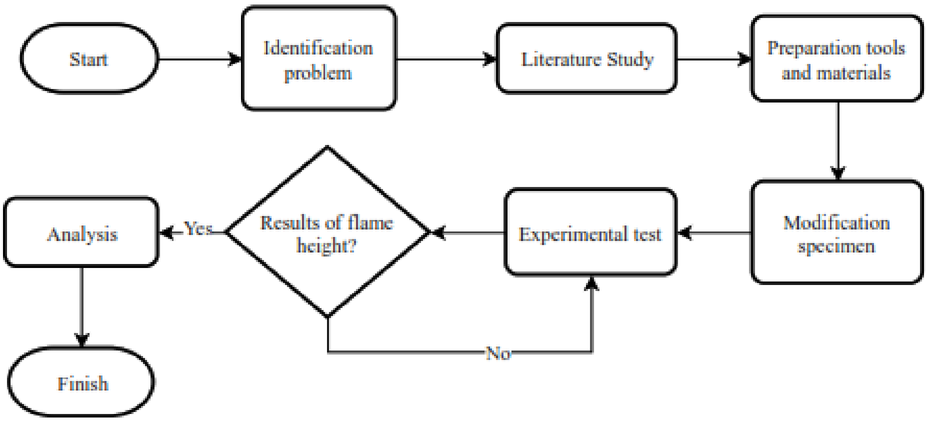

Figure 1. Flowchart of process.

Experimental testing was carried out to determine the characteristics of the height of the flame and the value of the efficiency of the stove against variations in the diameter hole of the spuyer on the LPG gas stove. Diameter holes were 2 mm, 2.5 mm, 3 mm, and 3.5 mm as depicted by Figure 2b. The choice of spuyer hole diameter variation was obtained from the problem of LPG gas stoves that cannot work in using biogas fuel. This was because the diameter hole of LPG gas stove was too small 0.5 mm. While the diameter hole of the spuyer on the special stove (Butterfly brand) is 2 mm. The type of LPG gas stove was the Rinnai RI-511E of brand LPG gas stove because many Indonesian people use gas stoves under that brand.

2.1. *Efficiency of stove*

The efficiency of a stove is the ratio between the useful heat needed to cook something in a certain amount from the initial temperature to cooking with the heat provided by the fuel. The most effective way to test the efficiency of a stove was the boiling water method. The formula for calculating the efficiency of a stove was produced in Equation 1 [10]:

$$\eta = \frac{(m_w C_{pw} + m_b C_{pb})(T_2 - T_1) + m_u H}{m_f E} \quad (1)$$

Where:

η : Efficiency (%)
m_w : Mass of water (kg)
m_v : Mass of vessel (kg)
m_f : Mass of fuel used (kg)
m_e : Mass of water after evaporating (kg)
C_{pw} : Specific heat of water (J/kg0C)
C_{pv} : Specific heat of vessel (J/kg0C)
T_1 : Initial temperature of water (0C)
T_2 : Final temperature of water (0C)
H : Latent heat (J/kg)
E : Heating fuel (J/kg)

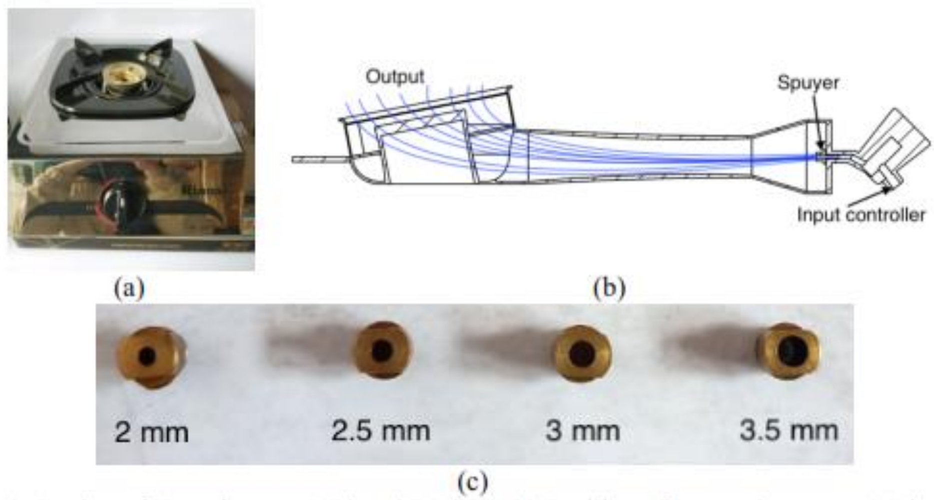

Figure 2. Design of experiment: a) Rinnai RI-511E, b) Position of spuyer in stove, c) Diameter of spuyer.

2.2. Concept
The concept of this test used several tools such as height measuring devices, camera, U manometer and 12 m^3 in capacities of biogas digesters as shown in Figure 3.

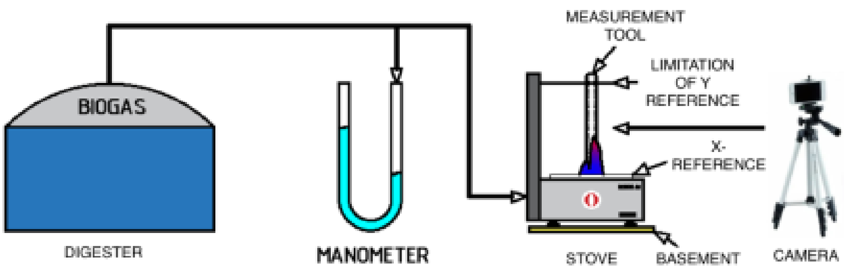

Figure 3. Experimental set up (edited in [11]).

The measurement of this test used process of taking pictures of flame which was produced by camera. The camera would observe the flame height for 30 seconds for each condition. Reference of X-axis and Y-axis were used as a reference during the scaling process to determine the height of flame which can be seen in figure 3. Scaling process used AutoCAD software which produced real height of flame as figure 4.

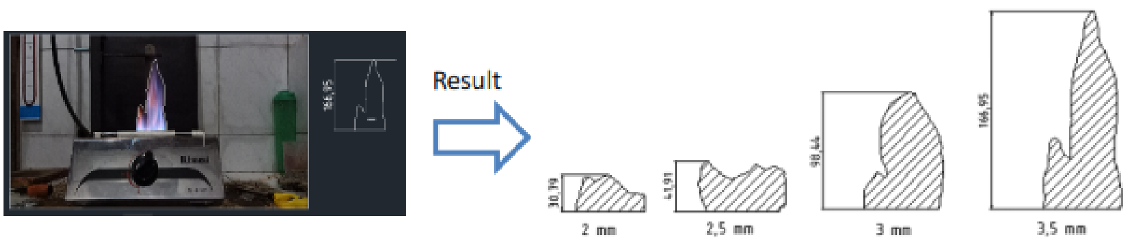

Figure 4. Result of flame height.

3. Results and discussion
In this research, spuyer of LPG gas stove was modified as specimen. The test conducted characteristic of flame height and stove efficiency. The results of flame height can be seen in figure 4 and figure 5.

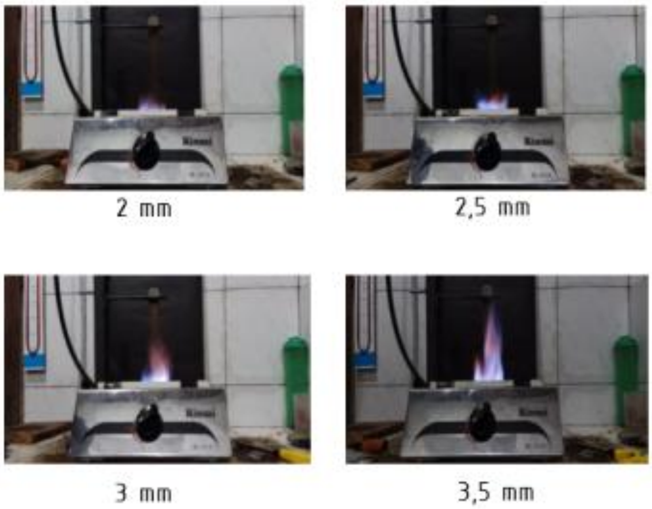

Figure 5. Image of flame.

On figure 5 shows that the colour of the resulting flame was more dominant blue which had a high heating value. Moreover, the flame had a type of premixed flame which based on turbulent flame. In order to find the efficiency of stove, this testing used boiling water method which variation of 2 mm, 2.5 mm, 3 mm, and 3.5 mm in diameter of spuyer.

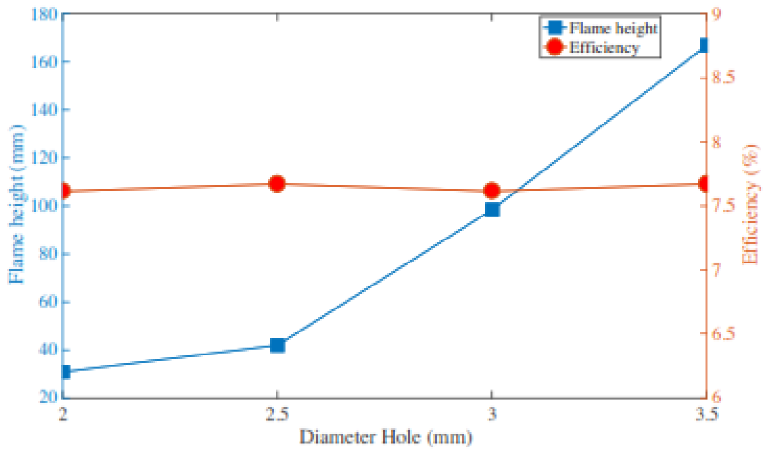

Figure 6. Graphic effect of spuyer hole.

Figure 6 shows a graphic between flame height to diameter hole of spuyer. The hole 3.5 mm in diameter produced a maximum flame 166.95 mm in height and the minimum height 30.79 mm for 2 mm of diameter hole. There was a very significant difference between flame height of 2 mm to 3.5 mm in diameter which was 136.16 mm or 442.22%. There was no change significantly in efficiency of stove which had 7.6% in average.

4. Conclusion

The height of the flame produced 30.79 mm, 41.91 mm, 98.44 mm, and 166.95 mm by variating diameter hole of spuyer. The maximum flame height was produced 3,5 mm in diameter by 166.95 mm. The minimum flame height was in 2 mm by 30,79 mm. This change experienced a significant increase 442.22%. But the efficiency was not change significantly which the average was 7.6 %.

Acknowledgments

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