Pot Skirt Configuration on the UB-03 Biomass Stove: Taguchi Approach Optimization

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Abstract: A biomass stove is a technology that can utilize biomass fuel as an alternative energy source. This stove is considered effective for saving fossil energy because it uses fuels such as wood, waste, and plants so that it can reduce the effects of global warming because it can minimize the emissions it produces. In its technological development, UB-03 is a biomass stove product with compact construction and affordable prices for rural communities. However, there needs to be an increase to *produce more* efficient performance. In this case, additional configurations in the form of a pot skirt can be used to increase the efficiency of the biomass stove. The pot skirt is a device that focuses the fire's direction on the load to minimize wasted heat and increase the efficiency of the biomass stove. This study used the Water Boiling Test (WBT) method for experimental testing. In addition, the Taguchi method was used to analyze the data obtained. This study aims to determine the optimum conditions of the biomass stove with the addition of a pot skirt using the Taguchi method with orthogonal array L9 (33) with three factors, namely angle (64°, 65°, 66°), number of holes (9,10,11) and hole diameter (0.8 cm, 1 cm, 1.2 cm). The results of this study indicate that the optimal configuration obtained is by adding a pot skirt at an angle of 65° with 9 holes and a hole diameter of 1 cm, where the highest efficiency value is obtained, namely 21.19%.

Keywords: biomass stove; optimization; pot skirt; Taguchi; UB-03

INTRODUCTION

Biomass stoves have been widely used and developed, especially in rural areas. From an economic point of view, biomass stoves are cheaper, can be reached by all levels of society, and can be practically designed. This reason can drive the use of biomass stoves to date (Dickinson et al., 2019; Huang et al., 2022; Stanistreet et al., 2021). Biomass stoves also play a role in keeping the environment clean and can reduce the impact of global warming (Kole et al., 2022). This stove has a closed or isolated room from the outside environment to burn fuel and produce heat (Lachowicz et al., 2022). However, the combustion quality of this biomass stove is still not good, where traditional biomass stoves have a furnace efficiency of only 5-10% (Budianto et al., 2014). Biomass stove can also cause smoke, which has a negative impact when inhaled by humans. Gases such as hydrogen (H_2), methane (CH_4), and carbon monoxide (CO) are produced from the combustion process. (Gao et al., 2021; Pambudi et al., 2017; Suryawanshi et al., 2021).

Indonesia is a developing country where most people use a lot of biomass fuel. Using biomass stoves is an alternative to utilizing the energy source (Mekonnen, 2022). The biomass stove has undergone developments to date, starting with the three-stone stove design. The biomass stove was introduced in the 1940s and developed into a multi-pot mud cookstove design. Then in the 1970s, due to environmental issues, a rocket stove design was developed (Sedighi & Salarian, 2017). In Indonesia, a UB-03 biomass stove has been developed to maximize the utilization potential due to the abundance and variety of biomass energy sources. The UB-03 biomass stove has advantages such as a larger combustion tube, a cleaner flame, and a very simple use compared to traditional biomass stoves (Oktaviani & Rudiyanto, 2021; Safitri et al., 2020). However, to produce significant improvements in addressing environmental issues and realizing zero emissions, further research is needed to improve the performance of the stoves that have been developed to date.

Much research has been done on biomass stoves before. This is because the biomass stoves the community uses are still too simple, and the resulting efficiency is still low, around 5-10% (Budianto et al., 2014; Shaisundaram et al., 2020). One of the things that can be done to increase the efficiency of the biomass stove is to use a variation in the form of a pot skirt (Bentson et al., 2022; Chica & Pérez, 2019; Mekonnen, 2022). Pot skirt is a tool to prevent heat being wasted into the surrounding environment by reflecting the fire back to the combustion area, thus minimizing heat loss. With the pot skirt, energy loss in the fire can be minimized by focusing heat energy into energy that is truly utilized (Chica & Pérez, 2019; Mekonnen, 2022; Pundle et al., 2019; Sedighi & Salarian, 2017). The pot skirt acts like a reflector on a biomass stove which functions as a combustion air distribution to the combustion chamber to obtain complete combustion. In addition, the reflector can capture radiation losses from the fire around it and focus the direction of the resulting fire to minimize wasted heat (Hasanah & Rudiyanto, 2021). It can be seen that another function of the reflector here is to focus the direction of the fire to minimize wasted heat and also increase the efficiency of the biomass stove (Oktaviani & Rudiyanto, 2021).

Various studies to optimize the use of biomass stoves using a pot skirt configuration have been carried out. In this case, with the number of holes in the pot skirt as many as 8 points, the highest efficiency was obtained at the 60° pot skirt angle variation of 16.37% (Safitri et al., 2020). Using a pot skirt on an improved biomass cookstove (IBCS) can also increase the combustion efficiency from 8-12% to 20% (Chica & Pérez, 2019). In addition, Mekonnen (Mekonnen, 2022) shows that using a pot skirt on a rocket stove can produce a thermal efficiency of up to 32% compared to a three-stone stove with only a thermal efficiency of 14%. On the other hand, adding a jet flame to increase the combustion air in a biomass stove with a pot skirt can produce a thermal efficiency of up to 34% (Bentson et al., 2022). These various studies show that pot skirts can provide promising performance on biomass stoves. However, further studies in optimizing the performance of pot skirt integration in biomass stoves still need to be carried out to produce the best performance.

In this study, the UB-03 biomass stove was chosen because of its reliability based on developing biomass stoves in Indonesia. This research aims to determine the efficiency value of the biomass stove and determine the optimum conditions of the three angle variations, the number of holes, and the diameter of the holes. In the design of the pot skirt, which was used as the research subject, the angle of inclination of the pot skirt, the number of holes, and the diameter of the pot skirt holes were various design parameters to obtain the most optimal configuration of the performance of the UB-03 biomass stove. In addition, the Taguchi analysis method was used in this study to optimize and determine the most influential factors from the various design parameters used. Taguchi is a new method in the field of engineering that aims to optimize product and process quality and can reduce costs to a minimum. The Taguchi method aims to make the product robust against noise because it is often called a robust design. The Taguchi method aims to determine the influencing, non-influential, and level of each factor to obtain an optimal product or process (Bărbulescu et al., 2021; Hasanzadeh et al., 2022; Vieira et al., 2020).

METHODS

Experimental Design using Water Boiling Test (WBT) Method

In this study, the biomass stove used was UB-03, developed by Universitas Brawijaya with patent number ID P000040866 in 2016. This stove uses stainless steel material with a 0.6-1 mm thickness in each part. The UB-03 stove has dimensions of 28 cm × 28 cm × 36 cm, producing a flame of 1-1.5 hours when the fuel tank is full without adding (1.2 kg) (Nurhuda, 2016). Figure 1 shows the design of the UB-03 biomass stove that has been developed.

Figure 1. Biomass cookstove UB-03

In testing the pot skirt used as a research variable, it consists of angle variations 64°, 65°, and 66°, the number of holes 9, 10, and 11, and the diameter of the holes 0.8 cm, 1 cm, and 1.2 cm. The pot skirt has a bottom diameter of 8 cm, a top diameter of 12 cm, and a height of 6 cm, as shown in Figure 2 below.

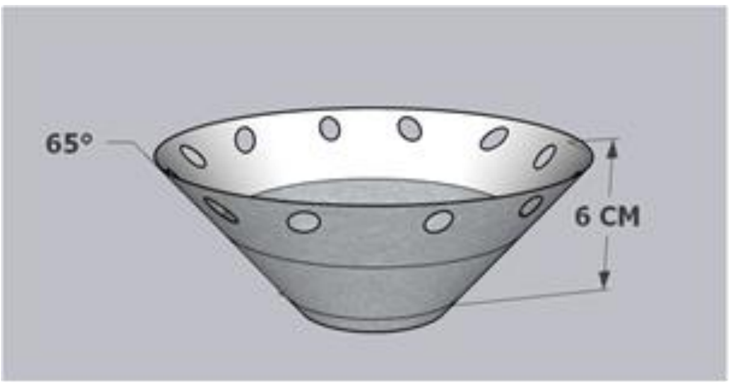


Figure 2. Pot skirt design development

This study aims to determine the efficiency value of the biomass stove and determine the optimum configuration of the three angle variations, the number of holes, and the diameter of the holes using the WBT (Water Boiling Test) method. This WBT method is a simulation test to calculate the efficiency of the stove through cooking or boiling water, as well as knowing the emissions produced during the cooking process (Chica & Pérez, 2019; Mekonnen, 2022; Wijianto et al., 2018). In this case, the WBT test includes (a) cold start, in which the stove is turned on at ambient temperature; (b) hot start, when the stove is heated to start the test; and (c) low heat or simmering, which is when the cooking process is simulated.

The WBT testing method provides advantages in simplicity of implementation and repeatability in the experiment (Chica & Pérez, 2019; Kole et al., 2022). In this WBT method, 1 kg of water is used in the tests carried out and placed in a pan with temperature measurements at various points and recording the cooking time until it boils. Figure 3 shows the experimental test design using WBT.

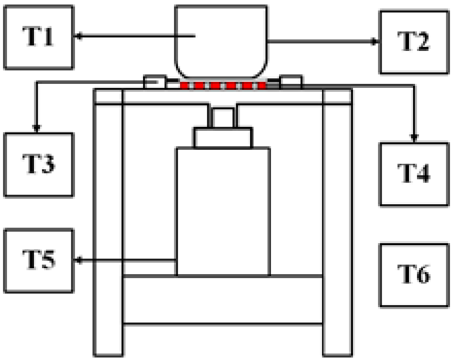


Figure 3. Temperature measurement in WBT

Figure 3 shows the temperature measurement points at WBT where T1 = water temperature, T2 = pot temperature, T3 = fire temperature, T4 = reflector temperature, T5 = stove wall temperature, and T6 = ambient temperature. The fuel used in this study was dried coconut shell (Cocos Nucifera). Table 1 below shows the specifications of the fuel used in the WBT test.

Tabel 1. Coconut shell properties (cocos nucifera)

Parameters	Value
Size	3-5 cm
Mass	820.5 gr
LHV Fuel	27234.2 kJ/kg

Technical Stove Analysis

The ratio of the heat required to cook a certain amount from the initial temperature to cooking with the heat provided by the fuel used during cooking is called the efficiency of the stove (Rasoulkhani et al., 2018). The basic theory for stove technical calculations includes sensible heat, latent heat, heat energy input, heat loss, and thermal efficiency (Subekti, 2012). Sensible heat refers to the heat energy required to raise the temperature of the water. Sensible heat is measured before and after the water reaches the boiling temperature, which can be formulated by Equation (1) below (Harsono et al., 2022):

$$Q_{sensible} = m.C_p.\Delta T \text{ .... (1)}$$

$Q_{sensible}$ is sensible heat (kJ), m is distance (m), C_p isspecific heat of water ((kJ/kg°C), and ΔT is different water temperatures (°C). Latent heat is the amount of heat energy used to evaporate water. Latent heat can be formulated by Equation (2) below (Ndukwu et al., 2020):

$$Q_{laten} = m.hfg \text{ .... (2)}$$

Q_{laten} is latent heat (kJ), m is mass of evaporated water (kg), and hfg is latent heat of vaporization (kJ/kg). The amount of heat energy available in the fuel is called the heat energy input. The formula for determining the heat energy input is shown in Equation (3) as follows (Phusrimuang & Wongwuttanasatian, 2016):

$$Q_{in} = m_{fuel}.LHV \quad \text{...} \quad (3)$$

Q_{in} is heat energy in fuel (kJ), m_{fuel} is mass of fuel used (kg), and LHV is low heating value of fuel (kJ/kg). η is thermal efficiency (%), it is the ratio of the energy used in boiling and evaporating water to the heat energy available in the fuel. The thermal efficiency of the stove can be determined by Equation (4) as follows (Rasoulkhani et al., 2018):

$$\eta = \frac{Q_{sensible}+Q_{laten}}{Q_{in}} \times 100\% \quad \text{...................................} \quad (4)$$

Q_{loses} is heat loss (kJ), it is heat that is wasted on the surrounding environment and causes a loss. Heat loss can be determined by Equation (5) below (Phusrimuang & Wongwuttanasatian, 2016):

$$Q_{loses} = Q_{in} - Q_{absorb} = Q_{in} - (Q_{sensible} + Q_{laten}) \quad \text{......} \quad (5)$$

Taguchi Method Optimization

The Taguchi method was adopted for the experimental design, such as the orthogonal array L_9 3^3 with 9 trials. It has three factors, namely angle (64°, 65°, 66°), number of holes (9, 10, 11), and hole diameter (0.8 cm, 1 cm, 1.2 cm), as shown in Table 2.

Tabel 2. Experimental factors and level

Factor	Variation		
	Level 1	Level 2	Level 3
Angle	64°	65°	66°
Number of Holes	9	10	11
Holes Diameter	0.8 cm	1 cm	1.2 cm

The response parameters used are the S/N ratio and the mean of the efficiency values obtained from testing using WBT. Calculations and data analysis used in this study used the optimization of the Taguchi method with Orthogonal Arrays through the Minitab 17 software, as shown in Table 3.

Tabel 3. Orthogonal matrix L_9 (3^3) for pot skirt

No. Test	Angle	No. of Holes	Holes Diameter
1	64°	9	0.8 cm
2	64°	10	1 cm
3	64°	11	1.2 cm
4	65°	9	1 cm
5	65°	10	1.2 cm
6	65°	11	0.8 cm
7	66°	9	1.2 cm
8	66°	10	0.8 cm
9	66°	11	1 cm

The characteristic of the S/N ratio used is Larger the Better (l.t.b). This characteristic has a sustainable and non-negative quality with a value of 0 until the expected target value is other than 0. In other words, it has the greatest possible value. The signal-to-noise ratio can be calculated using Equation 6 below.

$$S/NR = -10log_{10}\left[\frac{1}{2}\sum_{i}^{n} = 1\frac{1}{y_i^2}\right] \qquad (6)$$

In this case, the Analysis of Variance (ANOVA) is used to look for factors that significantly influence the response. The target value is used to distinguish differences in quality characteristics in the Taguchi experimental design.

RESULT AND DISCUSSION

UB-03 Biomass Stove Experiment without Pot Skirt Configuration

In testing the biomass stove, several factors affect the performance or combustion process, including air velocity, primary air door with a certain area to regulate incoming air, fuel with a high combustion temperature, and the size of the combustion chamber. These factors can affect the speed of temperature increase, the amount of heat loss, and effective heat, which in turn can affect the efficiency value of the stove (Bentson et al., 2022). Table 4 below shows the UB-03 biomass stove test results without adding a pot skirt.

Tabel 4. Data on UB-03 biomass stove test results without addition of pot skirt

No.	Parameters	Repetition 1	Repetition 2	Repetition 3
1	Initial water mass (gr)	1000	1000	1000
2	Steam mass (gr)	104	108	109.5
3	Initial fuel mass (gr)	820.5	820.5	820.5
4	The mass of fuel used (gr)	380	376.5	394.2
5	Water cooking time (minutes)	18	18	18
6	LHV fuel (KJ/kg)	27234.2	27234.2	27234.2
7	$Q_{sensible}$ (kJ)	1430.52	1430.52	1423.38
8	Q_{laten} (kJ)	235.456	244.296	247.689
9	Q_{in} (kJ)	11996.66	12091.98	11601.77
10	Q_{loses} (kJ)	10330.68	10417.17	9930.7
11	Thermal Efficiency	13.88%	13.85%	14.40%

Based on the test results on the UB-03 biomass stove without adding a pot skirt, it shows that in the first repetition of the UB-03 biomass stove, it takes 18 minutes to boil 1 litre of water. However, the water started to boil from the 9th minute to the 12th minute. 11996.66 kJ of fuel energy was used, which was obtained from 820.5 grams of coconut shell which had been crushed into small pieces with a diameter of 3-5 cm and dried or sun-dried and had a calorific value of 27234.2 kJ/kg and produced an efficiency value of 13.88 %. On the second repetition, it takes 18 minutes to bring 1 litre of water to a boil. The fuel energy used is 12091.98 kJ, obtained from 820.5 grams of coconut shell fuel and producing an efficiency value of 13.85%. On the third repetition, it takes 18 minutes to boil 1 litre of water. The fuel energy obtained from the coconut shell is 11601.77 kJ with a fuel weight of 820.5 grams and produces an efficiency value of 14.40% with a heat loss of 1930.7 kJ. The average efficiency of the three repetitions is 14.04%.

In this experiment, observations were made of temperature increases, including water temperature, pan temperature, fire temperature, stove wall temperature, and ambient temperature, without adding a pot skirt. Temperature observations were recorded every 3 minutes during the boiling point, which was 18 minutes. The temperature changes that occurred during the test are shown in Figure 4 below.

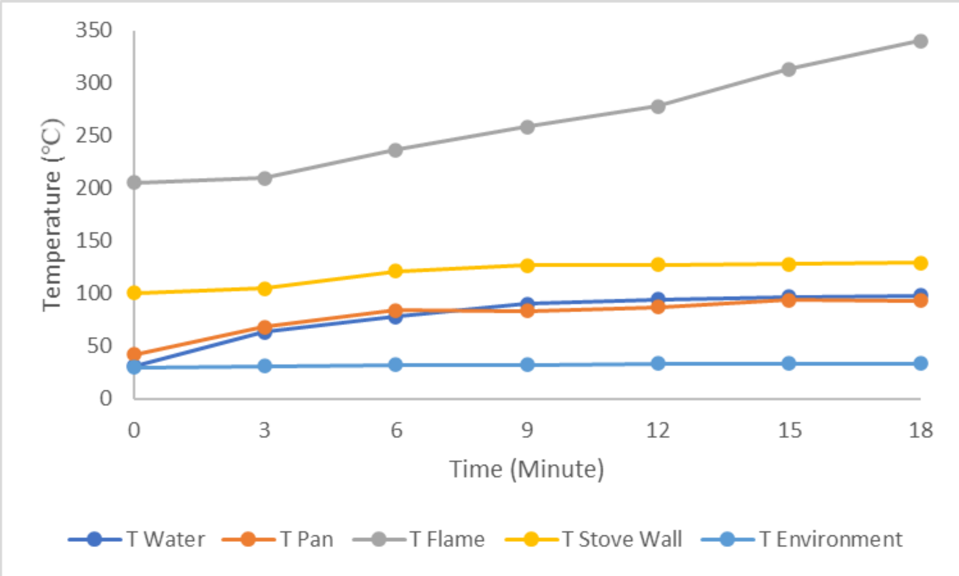


Figure 4. Changes in temperature on the UB-03 biomass stove test without a pot skirt configuration

Figure 4, which shows the relationship between temperature and time above, shows that the relationship between the temperature of the water, pot, stove wall, and fire is directly proportional to time. The longer the ignition time, the higher the temperature (Jain & Sheth, 2019; Maxwell et al., 2020). If seen from the 3rd minute, the water temperature increases due to the conduction process from the fire in the pan due to the combustion process, so that the temperature of the pan walls increases and is followed by a convection process that occurs in the water (Singh et al., 2022). In this observation, three repetitions were carried out to obtain the average temperature value being analyzed. In this case, when the water starts to boil in the 9th minute, the water temperature can be higher than the pot temperature. This is because most of the heat energy from the pot absorbed by the water has been used to change the state of the water from liquid to steam.

UB-03 Biomass Stove Experiment with Pot Skirt Configuration

The working system of the UB -03 biomass stove uses a turbulent motion system which causes complete combustion. This movement is the principle of a counter-flow burning mechanism, namely a flow mechanism against the fire's upward direction, which causes complete and more efficient combustion. Adding a pot skirt to the UB-03 biomass stove aims to increase the efficiency value of the stove. Compared to without a pot skirt, adding a pot skirt functions as a focal point of fire to the pan. When the pot's temperature increases, the water's temperature also increases, speeding up the water's boiling. This will result in a more efficient process than without adding a pot skirt.

In the test using a pot skirt, three variables were carried out, namely the tilt angle of the pot skirt (64°, 65°, 66°), the number of holes in the pot skirt (9, 10, 11), and the diameter of the pot skirt holes (0.8, 1, 1.2). Based on the experiments that have been carried out with three repetitions of the test, the efficiency value data of the UB-03 biomass stove with the variations determined by the orthogonal array matrix L_9 (3^3) obtained from the Taguchi method are obtained as shown in Table 5 below. Based on the results obtained in three repetitions of testing for each of these variables, it can be seen that the 65° angle configuration with 9 holes with a diameter of 1 cm can produce the highest average stove efficiency of 21.19%.

Tabel 5. Biomass stove efficiency result

Variable			Stove Efficiency (%)			
Angle (°)	Number of Holes	Holes Diameter (cm)	1	2	3	Average
64	9	0.8	20.56	20.47	20.46	20.50
64	10	1	17.67	17.48	17.58	17.58
64	11	1.2	16.95	16.82	16.85	16.87
65	9	1	21.20	21.22	21.16	21.19
65	10	1.2	18.62	18.42	18.57	18.54
65	11	0.8	18.51	18.46	18.74	18.57
66	9	1.2	19.70	19.97	19.75	19.81
66	10	0.8	16.76	16.81	16.65	16.74
66	11	1	17.63	17.56	17.73	17.64

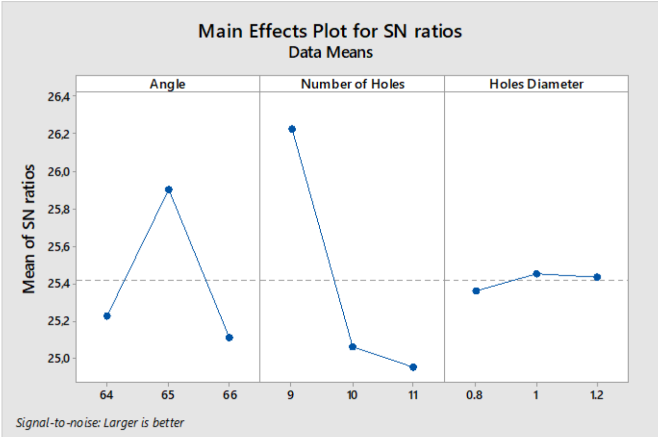
Optimization of UB-03 Biomass Stove with Pot Skirt Configuration using the Taguchi Method

In analyzing the results obtained, first look for the value of the S/N ratio and the mean value using the efficiency value on the stove in each experiment. In this case, because looking for the variation with the highest stove efficiency is better, using the larger is a better characteristic. Table 6 below shows the results of the S/N ratio and mean that have been searched using the Minitab 17 software.

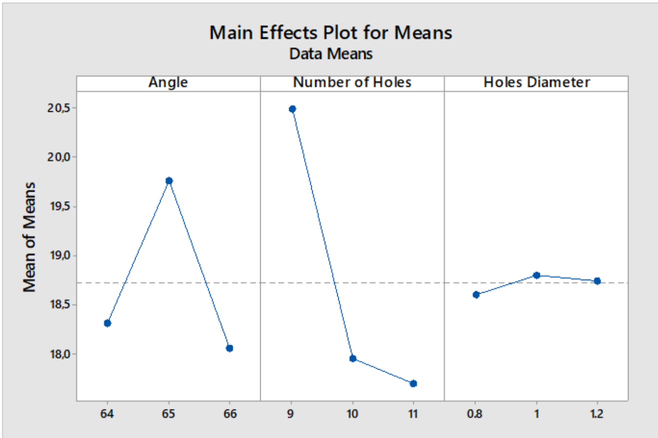
Tabel 6. Data processing using the Taguchi method

Factor Composition	Stove Efficiency (%)			Results of the Taguchi Method			
	1	2	3	SNRA1	LSTD1	STDE1	MEAN1
1	20.56	20.47	20.46	26.2336	-2.89905	0.055076	20.4967
2	17.67	17.48	17.58	24.8985	-2.35342	0.095044	17.5767
3	16.95	16.82	16.85	24.5439	-2.68724	0.068069	16.8733
4	21.20	21.22	21.16	26.5240	-3.48837	0.030551	21.1933
5	18.62	18.42	18.57	25.3604	-2.26256	0.104083	18.5367
6	18.51	18.46	18.74	25.3757	-1.90158	0.149332	18.5700
7	19.70	19.97	19.75	25.9358	-1.94042	0.143643	19.8067
8	16.76	16.81	16.65	24.4749	-2.50282	0.081854	16.7400
9	17.63	17.56	17.73	24.9298	-2.45994	0.085440	17.6400

From the responses for the S/N ratio and the mean, it appears that the sequence of factors that have the largest to smallest influence on the efficiency of the biomass stove is the number of holes, the angle of the pot skirt, and the diameter of the holes. These results are also supported by a graphic plot of the influence of the main factors, namely the angle of the pot skirt, the number of holes, and the holes' diameter on the biomass stove's efficiency, as shown in Figure 5. The results are not too different, as shown by the angle factor and hole diameter. However, with $\alpha = 0.05$, the most significant factor is the number of holes.



(a)



(b)

Figure 5. Graph of (a) S/N Ratio Effect and (b) Mean

This result is also reinforced by the magnitude of the R-square value of 96.11% and the adjusted R-square of 84.2%, as shown in Table 7. This shows that the model resulting from the experiment has an effect of 96.11% on the variation of the response variable or the variation of stove efficiency biomass. Based on data processing, it can be seen that the angle of 65°, the number of holes is 9, and the diameter of 1 cm gives the best results for stove efficiency. This means that a pot skirt with an angle of 65°, 9 holes, and a hole diameter of 1 cm can produce better stove efficiency than other compositions. This can be seen from the S/NR (Signal to Noise Ratio) results using Larger is Better with a value of 25.3640. S/NR is a parameter in the Taguchi experimental design used to determine the best combination of the experiments.

Tabel 7. Model summary R-square

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.543532	97.07%	88.30%	11.9648	40.75%

In the Taguchi design, the analysis of variance uses a two-way analysis of variance because the Taguchi experimental design consists of two or more factors and two or more levels. Analysis of variance consists of calculating the Degrees of Freedom (DF), Sum of Squares (SS), Mean Square (MS), F-count, and also the P value or probability value. Based on the parameter estimation test results for the S/N ratio, it is known that the constant number of holes 9 has a significant P-value at α = 0.05. This shows that the number of holes factor 9 significantly affects the efficiency of the biomass stove. These results are shown by the results from the ANOVA table for the S/N ratio in Table 8.

Tabel 8. Analysis of variance for S/N ratio

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Angle	2	3.1936	15.81%	3.1936	1.5968	5.40	0.156
Number of Holes	2	16.1716	80.08%	16.1716	8.0858	27.37	0.035
Holes Diameter	2	0.2374	1.18%	0.2374	0.1187	0.4	0.713
Error	2	0.5909	2.93%	0.5909	0.2954		
Total	8	20.1933	100.00%				

In addition, from the results of the ANOVA table obtained, the number of holes 9 significantly affects the efficiency of the biomass stove. This shows that the number of holes has a big influence on increasing the efficiency of the stove. From the experimental results, the angle of 65°, the number of holes 9, and the diameter of the hole 1 cm give the best stove efficiency value. This composition causes an increase in the wall temperature of the pot skirt to increase quickly, as well as focusing on the stove fire, which increases the pot wall's temperature. This configuration will result in an acceleration of the material cooking process (Water Boiling Test). The experimental results in this configuration show that the average temperature of the pot skirt is 320.7°C, and it can boil 1 litre of water in about 8 minutes and 56 seconds. The experimental angle of 64°, number of holes 9, and hole diameter of 0.8 cm give a lower stove efficiency value than the previous composition. The average time needed to boil 1 litre of water is 9 minutes 47 seconds, with an average pot skirt temperature of 317.6°C. The experiment results with the lowest stove efficiency was obtained at a shrinkage composition of 66°, the number of holes was 11, and the diameter of the holes was 1 cm, which was an average of 16.74%. In this configuration, the time needed to boil 1 litre of water is 12 minutes, and the temperature of the pot skirt is around 308°C.

Based on Table 8 above, it can be seen that the variations in the angle and diameter of the pot skirt have no effect or contribute less to the performance process of the UB-03 biomass stove to determine efficiency. In Table 8, it can also be seen that the variation in the number of holes in the pot skirt has the highest contribution value compared to the variation in the angle and diameter of the holes, namely 80.08%, so it can be concluded from the analysis of variance (ANOVA) the factors that influence the performance of the UB-03 biomass stove in determining the value of efficiency is the number of holes in the pot skirt. In this case, the number of holes in the pot skirt configuration has the greatest influence on efficiency because it affects the air input in the reflector to better circulate air and improve the combustion quality of the stove. (Safitri et al., 2020).

CONCLUSION

Biomass stoves are a promising solution for utilizing alternative energy sources, such as biomass, in rural areas that still have many resources. Biomass stoves can be used for daily cooking and other purposes to meet needs. However, using this biomass stove cannot be separated from environmental issues such as the potential for emissions that can harm health and the environment. Therefore, various efforts to improve efficiency and minimize emissions generated from biomass stoves, including pot skirts, continue to be carried out. The pot skirt itself is a device that concentrates the flame to reduce wasted heat and maximize the resulting efficiency. This study chose the UB-03 biomass stove based on its reliability and compact design. The test results with the Taguchi analysis method obtained the most optimal configuration at an angle of 65° with 9 holes and a hole diameter of 1 cm, where the highest efficiency value was obtained at 21.19%, compared to without the addition of pot skirt which only had an average efficiency value -average 14.04%. In addition, it was also found that the most influential factor on the performance of the UB-03 biomass stove was the variation in the number of holes in the pot skirt, with a contribution value to the analysis of variance

(ANOVA) of 80.08%. Based on these results, it can be seen that adding a pot skirt to the UB-03 biomass stove can effectively increase the efficiency of the stove. In this case, the design development of the pot skirt can be a challenge to produce configurations with even higher efficiency values in the future.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest with any party.

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