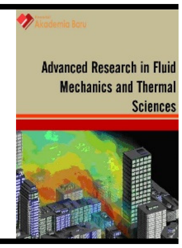
*Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 51, Issue 2 (2018) 215-226

Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879




# Effect of Holes System Designing for Low Energy Stove Using Coffee Husk Bio-Pellet as Solid Fuel

Open Access

Soni Sisbudi Harsono[1,*], Prayogo B[1], Tasliman[1], Maizirwan Mel[2], Fabrobi Ridha[3]

[1] Department of Agriculutral Engineering, Faculty of Agricultural Technology University of Jember (UNEJ) Indonesia, Jl. Kalimantan 57 Jember, East Java, 68121 Indonesia
[2] Department of Biotechnology Engineering, Faculty of Engineering, International Islamic University Malaysia, IIUM Gombak, Kuala Lumpur, Malaysia
[3] Department of Mechanical Engineering, Faculty of Engineering University of Jember (UNEJ) Indonesia, Jl. Kalimantan 57 Jember, East Java, 68121 Indonesia

**ARTICLE INFO**

***Article history:***
Received 17 October 2018
Received in revised form 9 November 2018
Accepted 10 November 2018
Available online 11 November 2018

***Keywords:***
Bio-pellet, biomass stove, heat, thermal efficiency, and emission

**ABSTRACT**

Bio-pellet is an important fuel for sustainable energy in future and a potential renewable energy substitute for rural areas, East Java of Indonesia in particular. One of the candidates for solid fuel is coffee husk pellets, it is a bio-product produced from coffee production waste. In this research, focus is on hole design of stove that could be used for generating energy from coffee husk pellet generally used as feedstock. This designed device also could be used as an alternative for gas-powered stoves. The variations in stove designs were proposed and has been modified as required. It is conducted in the stove's combustion cylinder. A particular stove (OS1) was used as control and other stoves were tested to measure the heat, thermal efficiency and emissions. The heat was produced at 316,880 kJ, 310,601 kJ, 308,229 kJ, and 306,833 kJ for stoves of 40, 20, 10 hole variation and OS1, respectively. Thermal efficiency for #OTHER stove were 16.47%, 16.39% for 10 holes, 15.96% for 20 holes of and 15.38% for 40 holes, respectively. The emissions results obtained were 333ppm for OS1, 298 ppm for 10 holes, 289 ppm for 20 holes, and 273 ppm for 40 holes of stove, respectively. As a conclusion, the stove with 40 holes variation, is selected as the most desired for this type of pellet stove.



## 1. Introduction

Energy consumption in Indonesia will continues to increase from year to year. This increase is occurring in almost all sectors including industrial, transportation, household and other sectors. The energy that most consumed is still based on fossil based fuel energy. The energy consumption has increased since 2003 from 117 million tons of oil to 174 million tons of oil in 2013 or an average growth of 4.1% per year [1, 2, 3].

* *Corresponding author.*
*E-mail address: s_harsono@yahoo.com (Soni Sisbudi Harsono)*

Indonesian crude oil production experienced decline in 1977 with production of 1.65 million barrels/day and in 1995 of 1.60 million barrels $day^{-1}$ . The decline in production was due to reduced production of wells and limited discovery of new wells. Although the government through Presidential Instruction 02/2012 on national petroleum production targets were increased (domestic oil production up to 1.01 million barrels $day^{-1}$ in 2014), the production is still insufficient. To reduce large dependence on the use of fossil fuels, the Government of Indonesia has carried out a program to convert kerosene to LPG [2, 3]. Unfortunately, the Government of Indonesia projects that Indonesia's gas production in 2017 of 7,966 million $m^3$/day, it will decrease to 3,339 million $m^3$/day in 2030 [3].

Every year, fuel and gas consumption increased but the production decreased. To overcome this decline in energy production, it is necessary to create renewable energy. One among many renewable energies is biomass. Biomass is an alternative energy derived from agricultural waste and other natural wastes. The Agricultural Research and Development Agency has mapped the potential of renewable energy sources from solid biomass materials in Indonesia at 756.08 million $GJY^{-1}$ [2]. The energy consists of 614.6 million $GJY^{-1}$ from agricultural residues and 141.48 million $GJY^{-1}$ from forestry waste. An example of agricultural waste are coffee husks that could be used as bio-pellets. According to RINEC Indonesia [3] and Ministry of Agriculture Indonesia [4], the productive area of coffee plantations in Indonesia is about 950,000 hectares and produces around 750,000 tons of coffee per year. In return, the resulting coffee husk waste is 307,500 tons per year [5].

A device that may utilize biomass for renewable energy is the biomass stove. Biomass stoves are a medium that functions to utilize biomass such as briquettes as a household-scale fuel [6, 7, 8]. In people's lives, this object is familiar and has an affordable price. However, some biomass stoves have a low level of efficiency and high emissions [6, 9, 10]. Some of these may be caused by the airflow of the burner stove cylinders, therefore it is necessary to modify the biomass stove with variations of the holes in the combustion cylinders. These holes will affect the air supply needed for combustion. The purpose of this hole variation is to get a suitable hole to produce high heat with high efficiency and low emissions.

Heat is a form of energy that moves from higher temperatures to lower temperatures. The amount of heat needed to raise the temperature of an object depends on the mass of the object, the heat capacity of object, and the change in temperature. Heat is a form of energy, and therefore the units for heat is equal to units of energy [6]. The amount of heat given is proportional to the increase in object temperature. The more heat given to the object, the greater the temperature rise of the object.

In this case, the heat is obtained by combustion. Combustion is a chemical reaction that involves mixing fuel and oxygen to produce heat [11]. The requirement for a combustion process to occur is fuel, oxygen supply and the heat energy availability. Fuel is a material which, if combusted, can continue the combustion process independently accompanied by heat exchange. The elements contained in the fuel are carbon, hydrogen and sulfur but would also need oxygen supply for the process to occur. Heat energy then activates the combustion reaction. However, sometimes in the combustion process results in incomplete combustion and produces carbon monoxide (CO). These emissions can cause air pollution in the form of CO gas, sulfur, nitrogen oxides and hydrocarbons [12]. CO gas emissions come from imperfect oxidation reactions of hydrocarbons and carbon contained in bio-briquettes, including the coffee-based briquettes.

The coffee structure is presented as in Figure 1. It could be divided into three parts as the following; a) exocarp/pericarp, which a thin outer layer and red colored when ripe, b) mesocarp, which a layer of fruit flesh. This flesh contains slimy and sweet fibers when ripe, and c) endocarp, hull husk or inner husk. This husk is a layer of hull husk which is the boundary of the husk and seeds.

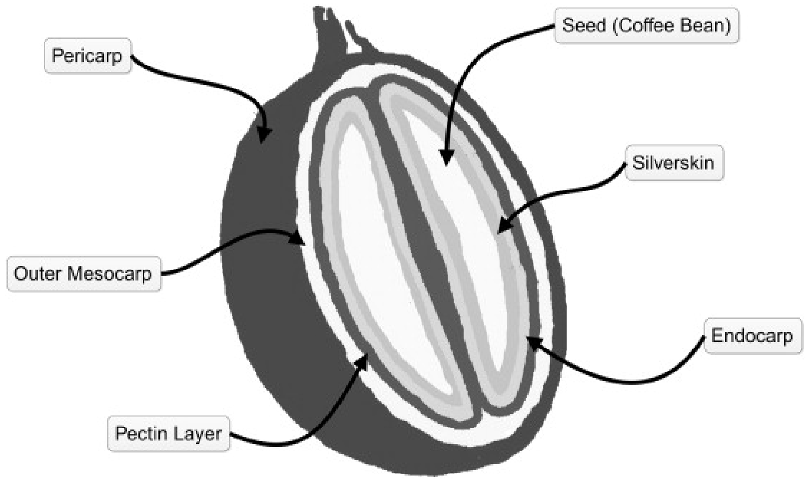



**Fig. 1.** Coffee structure layout [13]

After dry and wet handling in coffee processing, the endocarp will result in solid residues that are mainly unused. With the abundance of coffee husk waste, it is possible to process it into bio-pellets [6, 8, 14, 15]. According to Francis [14], the raw material that needs to be prepared is dry coffee husk and mixture of ingredients. The mixture consists of adhesives and other wastes such as wood sawdust, corncobs, and rice husks. Dry coffee husk and mixed ingredients are ground or chopped until it becomes smooth. Smooth dry coffee husk is then mixed with other waste and adhesives. After the ingredients are mixed, it is continued to print using a printing device. Printing will produce cylindrical bio-pellets with a size smaller than briquettes. After printing the bio-pellet, it is dried using the help of sunlight or with an oven [17].

## 2. Methodology

Design of biomass stoves is the application of the theory of heat transfer, combustion, and the principle of fluid flow to obtain complete combustion [10, 11, 12]. The maximum heat transfer is that transfer of fire to the cooking vessel with minimum heat loss. These criteria can be achieved by adding several components to the stove:

a) Combustion chamber/cylinder; the combustion chamber is the main component of the stove. In this space combustion occurs
b) Air holes; the presence of air holes in the stove can increase combustion efficiency because air can be distributed evenly to the bottom of the fuel because of air fuel mixture. This can increase the combustion rate to reduce heat loss to the wall.
c) Exhaust; installing an exhaust on the stove design will help with exhausting the excess gas. This is due to temperature difference where hot gas will move out through the chimney.
d) Fire regulator; this flame regulator is a plate that can open and close the airflow path on the stove. This plate is useful for regulating the supply of air in the stove, so that it can regulate the heat produced by the stove. There are two general positions for its layout, namely at the inside end of the chimney and the mouth of the combustion chamber.

The design of biomass stoves was conducted out at the Laboratory of Agricultural Equipment and Machinery, Department of Agricultural Engineering, Faculty of Agricultural Technology, University of Jember (UNEJ) Indonesia, from February 2018 to October 2018. The tools used in this study include electric welder, cutting pliers, drills, digital scales, thermometers, measuring cups, pans, stopwatches, emission meters, stationery, and cameras. The materials used in this study was bio-pellet of coffee husk waste that obtained from Sidomulyo Village, Silo District, Jember Regency - East Java of Indonesia. Coffee husk waste used is Robusta coffee. Another ingredient is galvalume as a stove-making material.

### *2.1 Research Stages*

The research stages that are carried out include literature studies, modification of biomass stoves, biomass stove testing, data analysis, and report arrangement. The illustration of the flow chart of the stove design can be observed in Figure 2. It is important to determine the variables that could be adjusted and modified to be applied and tested. The results are then analyzed if they are acceptable or not using data analysis method.

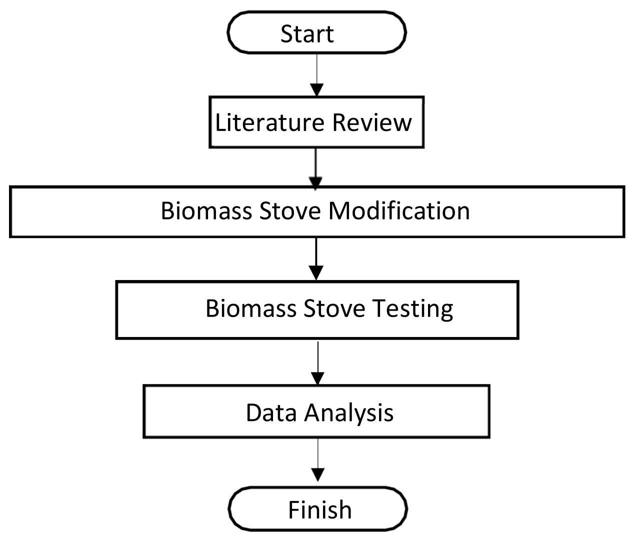


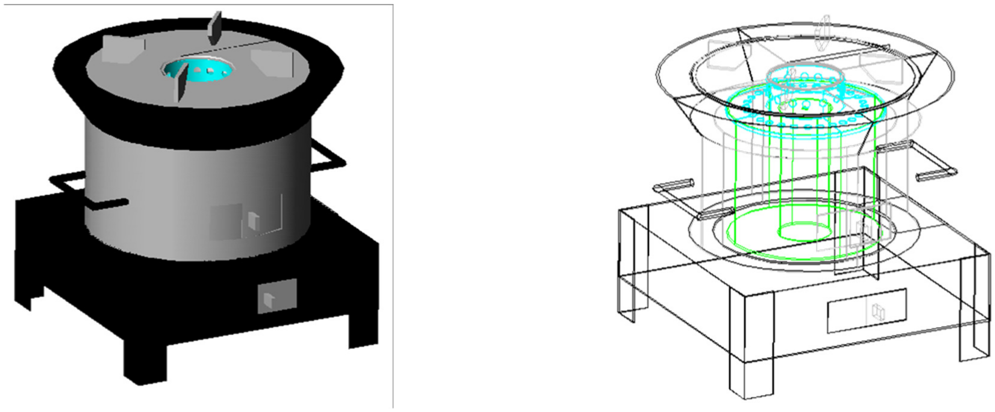

**Fig. 2.** The Flow Chart of Biomass Stove Research

### *2.2 Biomass Stove Modification*

The first modification is the size of the stove. This stove is reduced in size from #other stove to make it lighter. On the OS-1 stove, the dimensions are 28 cm x 28 cm x 36 cm, whereas in the #UNEJ-1 biomass stove the dimensions are 25 cm x 25 cm x 28.5 cm.

The second modification done on this stove is on the combustion cylinder. The hole in the modified biomass stove combustion cylinder is enlarged from 0.2 cm to 0.7 cm in diameter. The combustion cylinder is made in three types with different number of holes, namely 10 holes, 20 holes, and 40 holes.

The third modification is the handle grip on the side of the stove frame. The handle serves to make it easier for users to move the stove to another place. Biomass stove models are done using Auto Cad program. The 3-dimensional biomass stove illustration can be seen on the Figure 3.



(a) (b)

**Fig. 3.** Illustration of 3-dimensional biomass stove modification: (a) External appearance; (b) internal appearance

*2.3 Biomass Stove Experiment*

Stove testing was run to determine the performance of biomass stoves. In the testing process, primary data collection was taken directly in the field. Required primary data included such as the amount of bio-pellet needed (kg), the amount of water that evaporates (kg), time (minutes), heat, thermal efficiency, and the amount of emissions produced.

According to John [11], the equation for determining the amount of heat needed to raise the temperature of an object is used as follows.

$$Q = m \times c \times \Delta T \tag{1}$$

where,

Q = Required heat (J)
m = Mass of substance (kg)
c = Heat Capacity of substance (J/kg°C)
$\Delta$T = Temperature difference (°C)

Thermal efficiency is a comparison between the heat value used to heat and evaporate water compared to heat produced by bio-briquettes [16, 17]. The equation for determining the amount of thermal efficiency (ηT) is as follows

$$\eta T = \frac{ma \ x \ ca \ x \ \Delta T \ x \ \Delta ma \ x \ L}{\Delta mk \ x \ LHV} \times 100\ \% \tag{2}$$

where,

ma = Mass of water (kg),
ca = Heat capacity of water = 4186 (J/kg°C),
$\Delta$T = Temperature difference (°C),
$\Delta$ma = Evaporated water mass (kg),
L = Latent heat of water = 2,268.000 (J/kg),
$\Delta$mk = Burnt fuel mass (kg), LHV (low heating value) = 18.593.400 (J/kg).

In the stove combustion cylinder, there are three cylinder variations, namely a combustion cylinder with 10 holes, 20 holes, and 40 holes. From the results of the hole variation, the best number of holes for the combustion tube on the biomass stove will be obtained.

### 2.4 Data Analysis

The analysis used in this study is comparative analysis to test the comparison between the number of different holes in the combustion cylinder. This analysis was used to determine the best biomass stove between 10 holes, 20 holes, and 40 holes. The number of holes affects heat, thermal efficiency and emissions. The data obtained will be carried out by statistical analysis using the SPSS 16.0 application. If the results of the analysis are in accordance with the expected objectives, then it is proceeded with the composing of the research report.

Analysis of variance or ANOVA is a statistical technique that is used to determine whether two or more population means will be the same value using data from a sample of each population [16]. This concept is based on the concept of F distribution and can usually be applied to a variety of cases as well as in the analysis of the relationship between various observed variables [17]. According to [16] the initial hypothesis will be matched with the following decision-making criteria.

i. If F counts <F table then H0 is accepted
ii. If F counts> F table then H0 is rejected

## 3. Results and Discussion

### 3.1 Structural Design

Biomass stoves are a medium that used to burn biomass fuels such as bio-pellets and its design is crucial for the best result. Here, the biomass stove is determined based on the number of holes in the combustion cylinder. The picture of the biomass stove can be seen on the Figure 4.

(a) (b)

**Fig. 4.** Biomass stove: (a) Side view; (b) Top view

### 3.2 Biomass Stove Frame

This biomass stove frame was made of a type of mild steel called galvalume. The stove has a dimension of 25 cm x 25 cm x 28.5 cm, which consists of several parts. The bottom of the stove has a shape of a beam with dimensions of 25 cm x 25 cm x 7 cm. At the bottom and middle there is also an air vent hole with a size of 2.5 cm x 6 cm and 3 cm x 6 cm, which serves to regulate the incoming air. The outer cylinder has a diameter of 18 cm and a height of 11 cm. The inner cylinder has a diameter of 16.5 cm and a height of 12 cm. Each biomass stove is equipped with handles, so the user can move the furnace easily and safely. Most stoves available in Indonesia do not provide this and does not comply with the policy of the National Standardization Agency [14, 16]. This modified biomass stove has handles on the side and therefore in accordance with the guidelines of the National Standardization Agency.

### *3.3 Combustion Cylinder*

The combustion cylinder has a diameter of 14.5 cm and a height of 16 cm as shown in Figure 5. Each biomass stove has a different combustion cylinder. There are three variations of the combustion cylinders, the combustion cylinder with 10 holes, 20 holes, and 40 holes. In these cylinders, there are holes with a size of 0.7 cm, which serves as air circulation. These combustion cylinders can accommodate 260 grams of coffee husk bio-pellet waste. In the combustion process, not all cylinders receive the same air, as there are differences in the number of holes.

### *3.4 Emplacement and Lid*

The upper part of the stove has an emplacement for cooking utensils and a lid for when the stove is not in use (see Figure 5a and Figure 5b). The emplacement has an inner diameter of 10 cm, outer diameter of 20 cm, and height of 2.5 cm. turning off the stove would be by closing all ventilation holes and the upper part by using the 10 cm diameter lid.


(a)


(b)


(c)

**Fig. 5.** Combustion cylinders: (a) 10 holes; (b) 20 holes; (c) 40 holes

**Fig. 6.** Cooking utensil emplacement

**Fig. 7.** Stove lid

### 3.5 Stove Heat Test Result

The energy needed to raise the temperature of an object is influenced by mass, heat, and temperature differences [16, 17, 19]. In this test, the process of boiling water is used to determine the heat produced. The water used in this test is 1 litre. The heat calculation results can be seen in Table 1. The results of measuring the time needed to burn out can be seen in Table 2. The results of the highest temperature measurements produced in combustion can be seen in Table 3. The results of measurements of evaporated water masses can be seen in Table 4.

**Table 1**
Heat calculation results

| No | Stove Type | Heat (Joules) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 308508.20 | 308926.80 | 307252.40 | 308229.13 |
| 2 | 20 holes | 311019.80 | 311438.40 | 309345.40 | 310601.20 |
| 3 | 40 holes | 313950.00 | 318973.20 | 317717.40 | 316880.20 |
| 4 | #other | 306833.80 | 307252.40 | 306415.20 | 306833.80 |

**Table 2**
Time required to burn out

| No | Stove Type | Time (Minutes) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 7.58 | 7.28 | 7.32 | 7.39 |
| 2 | 20 holes | 7.29 | 6.53 | 6.86 | 6.89 |
| 3 | 40 holes | 6.50 | 6.34 | 6.40 | 6.41 |
| 4 | #other | 8.43 | 7.80 | 8.10 | 8.11 |

**Table 3**
Highest temperature during burning

| No | Stove Type | Temperature (°C) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 287.1 | 291.7 | 289.7 | 289.50 |
| 2 | 20 holes | 291.4 | 301.6 | 300.1 | 297.70 |
| 3 | 40 holes | 304.0 | 314.7 | 311.5 | 310.10 |
| 4 | #other | 257.5 | 282.1 | 281.9 | 273.83 |

**Table 4**
Evaporated water mass results

| No | Stove Type | Evaporated water mass (kg) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 0.049 | 0.048 | 0.050 | 0.049 |
| 2 | 20 holes | 0.059 | 0.052 | 0.051 | 0.054 |
| 3 | 40 holes | 0.066 | 0.061 | 0.059 | 0.062 |
| 4 | #other | 0.050 | 0.043 | 0.045 | 0.046 |

Based on the table above, from three repetitions, the average 10-hole stove has a heat production of 308,229.13 Joule, 20-holes stove 310,601.20 Joule and stove 40-holes 316,880.20 Joule. Stove #other had the lowest heat production of 306,833.80 Joule. It could be noted from here that each stove produces different temperatures. The 40-holes stove has the highest temperature of 310.10 $^{0}$C. The greater the temperature produced, the shorter the time needed to evaporate water and the greater the energy produced.

### *3.6 Thermal Efficiency Test Results*

Thermal efficiency of biomass stoves is obtained from the comparison between heat for evaporating water with heat produced by the bio-briquette [18]. Latent heat calculation results can be seen in Table 5. The bio-pellet mass calculation results needed to burn out can be seen in Table 6. The results of the calculation of heat produced by fuel can be seen in Table 7. The results of thermal efficiency calculations can be seen in Table 8.

**Table 5**
Latent heat calculation results

| No | Stove Type | Heat (Joule) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 133132.00 | 108864.00 | 113400.00 | 111132.00 |
| 2 | 20 holes | 133812.00 | 117936.00 | 115668.00 | 122472.00 |
| 3 | 40 holes | 149688.00 | 138348.00 | 133812.00 | 140616.00 |
| 4 | #other | 113400.00 | 97524.00 | 102060.00 | 104328.00 |

**Table 6**
Bio-pellet mass calculation for burn out

| No | Stove Type | Required bio-pellet mass (kg) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 0.127 | 0.141 | 0.138 | 0.135 |
| 2 | 20 holes | 0.145 | 0.147 | 0.146 | 0.146 |
| 3 | 40 holes | 0.158 | 0.163 | 0.159 | 0.160 |
| 4 | #other | 0.124 | 0.133 | 0.137 | 0.131 |

**Table 7**
Heat produced by fuel calculation results

| No | Stove Type | Heat (Joule) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 2691515.60 | 2621669.40 | 2565889.20 | 2559691.40 |
| 2 | 20 holes | 2696043.00 | 2733229.80 | 2714636.40 | 2714636.40 |
| 3 | 40 holes | 2937757.20 | 3030724.20 | 2956350.60 | 2974944.00 |
| 4 | #other | 2435735.40 | 2510109.00 | 2547295.80 | 2497713.40 |

**Table 8**
Thermal efficiency calculations

| No | Stove Type | Thermal Efficiency (%) | | | Average |
|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | |
| 1 | 10 holes | 16.84 | 15.94 | 16.39 | 16.39 |
| 2 | 20 holes | 16.50 | 15.71 | 15.66 | 15.96 |
| 3 | 40 holes | 15.78 | 15.09 | 15.27 | 15.38 |
| 4 | #other | 17.25 | 16.13 | 16.04 | 16.47 |

From the three replications, it was extracted the average efficiency of the stove 10-holes (16.39%), stove 20-holes (15.96%), stove 40-holes (15.38%), and stove #other (16.47%). The 40-holes stove has the least efficiency, as the bio-pellet mass needed to boil water is equal to 0.160 kg. With the amount of bio-pellet needed, it affects the temperature produced and boil water quicker.

### *3.7 Emission Test Results*

In the combustion process, there is often incomplete combustion that produces carbon monoxide (CO). High CO levels are indicative of incomplete combustion process [12, 17]. Emission measurement results can be seen in Table 9.

**Table 9**
Measurement results of emissions

| No | Stove Type | Emissions CO (ppm) | | | Avg | g/kg |
|---|---|---|---|---|---|---|
| | | Rep 1 | Rep 2 | Rep 3 | | |
| 1 | 10 holes | 289 | 290 | 314 | 298 | 0.298 |
| 2 | 20 holes | 274 | 295 | 297 | 289 | 0.289 |
| 3 | 40 holes | 235 | 290 | 293 | 273 | 0.273 |
| 4 | #other | 283 | 321 | 394 | 333 | 0.333 |

Based on the table above, each stove has different emissions. The #other stove has the highest emissions of 333 ppm. The 10-holes stove has 298 ppm emissions, 20-holes stove has 289 ppm emissions, and the 40-holes stove has 273 ppm emissions. The higher temperature of the fire, the higher heat is produced, and this can minimize CO that is exhausted [19, 20]. From Table 4-9, the 40-holesstove has the lowest emissions. This is because the 40-hole stove has the highest operating temperature. This indicates that on the 40-hole stove there is better combustion than other stoves. Biomass stoves are declared to pass the CO emission test if CO emissions do not exceed the maximum limit of 67 g/kg, equivalent to 67,000 ppm [21]. All stoves have emissions that are below the maximum limit. The 40-hole stove has the lowest emission of 273 ppm.

### *3.8 Heat Comparison Analysis Using F Test*

According to NS Agency [18, 19], before the F Test analysis the normality test should be first carried out. Data normality test is done to get information about the data with normal distribution or not. The steps taken are to input and analyse data using SPSS 16.0 with a level of $\alpha$ 0.05.

**Table 10**
The results of the heat normality test using Shapiro Wilk

| | Stove Type | Shapiro Wilk | |
|---|---|---|---|
| | | df | Sig |
| Heat | 10 holes | 3 | 0.463 |
| | 20 holes | 3 | 0.363 |
| | 40 holes | 3 | 0.463 |
| | #other | 3 | 1.000 |

## 5. Conclusion and Recommendations

Modification was successful in producing biomass stoves that use of coffee husk waste bio-pellets with dimensions of 25 cm x 25 cm x 28.5 cm and combustion capacity of 260 grams. The heat produced sorted from the highest to the lowest stoves is 40-holes for 316.880 kJ, 20-holes for 310.601 kJ, 10-holes for 308.292 kJ, and #OTHER stoves for 306.833 kJ, respectively. Thermal efficiency of the highest to lowest is #other stove 16.47%, 10-holes stove 16.39%, 20-holes stove 15.96%, and 40-holes stove 15.38%. Emissions produced from the highest to lowest are #other stoves of 333 ppm, 10-hole stoves of 298 ppm, 20-hole stoves of 289 ppm, and 40-hole stoves of 273 ppm. The best performing biomass stove is the biomass stove with 40 holes. This stove has the highest heat output, lowest emissions, but has the lowest thermal efficiency as well as low gas emissions than other types of stoves.

There needs to be further improvements to increase thermal efficiency and the need to add hooks or a similar device to the combustion cylinder. This would enable the removal of the cylinder even during a combustion.


### Acknowledgment
We thanks to the all staf of Laboratory of Agricultural Machinery in University of Jember in Indonesia for assistance during conducted this research. We also to the Ministry of Research Technology and Higher Education, Indonesia who fully supported the finance for applied research scheme of eexcellent university with contract number: 1325/UN25.3.1/LT/2018.


### References

[1] Ministry of Energy and Mineral Resources. 2014. Outlook Energi Indonesia 2014. Jakarta : Kementerian Energi dan Sumber Daya Mineral. http:// prokum.esdm.go.id/Publikasi/Outlook%20Energi%202014.pdf. [Accessed 9 Mei 2017].
[2] National Energy Council. 2014. Ketahanan Energi Indonesia 2014. Jakarta: 6.
[3] Republic of Indonesian National Energy Council. www.den.go.id/index.php/publikasi/ download/15.pdf
[4] Ministry of Agriculture. 2015. 2015-2019 Agricultural Research and Development Agency Strategic Plan. Jakarta: Badan Penelitian dan Pengembangan Pertanian. www.litbang.pertanian.go.id/profil/renstra2015- 2019.pdf.
[5] Wright Tom and Arif Arimulloh, Indonesian Coffee Farm, Indonesian Anual Report 2017, USDA
[6] Tama, A. S., Sarwono, dan Noriyati, R. D. "Perancangan Kompor Briket Biomass Untuk Limbah Kopi." *Jurnal Teknik Pomits*. 1, no. 1 (2012): 1
[7] Rukmana, H. Rahmat. "Untung selangit dari agribisnis kopi." *Yogyakarta: Lily Publisher* (2014).
[8] Sing, Chin Yee, and M. Shiraz Aris. "A study of biomass fuel briquettes from oil palm mill residues." *Asian Journal of scientific research* 6, no. 3 (2013): 537-545.
[9] Phusrimuang, J., and T. Wongwuttanasatian. "Improvements on thermal efficiency of a biomass stove for a steaming process in Thailand." *Applied Thermal Engineering* 98 (2016): 196-202.
[10] Igboanugo, A.C., Ajieh, M.U. , "Design And Construction Of A Biomass Stove For Cooking In Rural Settlements In Nigeria." *Nigerian Research Journal of Engineering and Environmental Sciences*, 2017.
[11] Lienhard IV, John H. "John H. Lienhard V. A heat transfer textbook third edition." (2001).

[12] Johnson, Michael A., Verónica Pilco, Rafael Torres, Sandeep Joshi, Rajeev M. Shrestha, Mahesh Yagnaraman, Nicholas L. Lam et al. "Impacts on household fuel consumption from biomass stove programs in India, Nepal, and Peru." *Energy for Sustainable Development* 17, no. 5 (2013): 403-411.

[13] Bresciani, Letizia, Luca Calani, Renato Bruni, Furio Brighenti, and Daniele Del Rio. "Phenolic composition, caffeine content and antioxidant capacity of coffee silverskin." *Food Research International* 61 (2014): 196-201.

[14] Francis, Abel Christena, A. Akhijith, Allen Alexander, and Bibin K. Baby. "Broquette burner." *International Journal of Research in Engineering and Technology, 3 (6)* (2014): 67-71.

[15] Anto Kusuma, 2015*. Budidaya Tanaman Kopi.* Yogyakarta: Kanisius.

[16] Harsono, Soni S,. "Utilisation of Coffee Waste as Renewable Energy." University of Jember, Indonesia, 2015.

[17] Hasanuddin, Idham HL. "Pembuatan Biopelet Ampas Kelapa Sebagai Energi Bahan Bakar Alternatif Penganti Minyak Tanah Ramah Lingkungan." *Laporan Penelitian Berorieantasi Produk. Fakultas Teknik Universitas Negeri Gorontalo* (2012).

[18] Inayati, F. "Perancangan Dan Optimasi Kinerja Kompor Gas-Biomassa Rendah Emisi Karbon Monoksida Berbahan Bakar Biopellet Dari Kayu Karet. Laporan Kemajuan." Jakarta : Program Studi Teknik Kimia Fakultas Teknik Universitas Indonesia, 2012.

[19] Harinaldi, Dr Ir, and M. Eng. "Prinsip-prinsip statistik untuk teknik dan sains." *Jakarta: Erlangga* (2005).

[20] Onukak, Imeh E., Ibrahim A. Mohammed-Dabo, Alewo O. Ameh, Stanley IR Okoduwa, and Opeoluwa O. Fasanya. "Production and characterization of biomass briquettes from tannery solid waste." *Recycling* 2, no. 4 (2017): 17.

[21] Mulyanto, Arif, Mirmanto Mirmanto, and Muhammad Athar. "Pengaruh ketinggian lubang udara pada tungku pembakaran biomassa terhadap unjuk kerjanya." *Dinamika Teknik Mesin* 6, no. 1 (2016).

[22] National Standardization Agency. 2013. Kinerja Tungku Biomassa. Jakarta : Badan Standarisasi Nasional Indonesia. https://cleancookstoves.org/binary- data/DOCUMENT/.../14-1.pdf [Accessed 25 Mei 2017].