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Biomass (rice husk) as a fuel for sterilizing oyster mushrooms: a case study of fuel efficiency comparison, temperature distribution and production effectiveness

To cite this article: Abdurrahman *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **460** 012041

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Biomass (rice husk) as a fuel for sterilizing oyster mushrooms: a case study of fuel efficiency comparison, temperature distribution and production effectiveness

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Abstract. The study on the efficiency of biomass fuel (rice husk) was carried out in the sterilization of oyster mushrooms by using drums as sterilization media and convection pipes as accelerators for heat transfer throughout the sterilization chamber. Variations in diameter and number of convection pipes were used as a comparison in this study. The measurement of thermal temperature was carried out using a thermo laser. In addition, the interpretation of the thermal distribution of the room was analyzed using Surfer software that was performed as a comparison between the number and diameter of convection pipes and determining the distribution of temperature using numeric interpolation. The use of oyster mushroom production using convection pipes 1 rod with a diameter of 8 cm showed the best results, temperature distribution, the efficiency of fuel use in this study. In addition, the comparison of the number of pipes also proved that convection pipes have a temperature distribution that is more equivalent to the number of convection pipes 3 rods. However, the efficiency in the use of fuel using convection pipes 1 rod with a diameter of 6 cm showed a better value than the other.

Keywords: Efficiency, Temperature Distribution, Biomass, Rice Husk, Oyster Mushroom

1. Introduction

Biomass generally means the total amount of natural resources that can be utilized in the form of energy [1]. Wood, grass, rice husks, marine algae, microalgae, agricultural waste, forestry waste, and household waste are included in this category. Energy crops are one promising biomass that makes it



possible to make large-scale energy plantations, although they have not been commercialized at this time [2].

One step to reduce carbon dioxide gas emissions is through the introduction of renewable energy. Renewable energy is energy of biomass, photovoltaic, geothermal, wind, hydro waves, and waves. Biomass is different from other renewable energy [3]. The concentration of carbon dioxide gas in the atmosphere will not be changed, as long as the carbon dioxide released by combustion after the utilization of energy is restored, after the reforestation process [4]. This is called carbon dioxide neutrality. The energy that replaces fossil fuels can be obtained from cycles, namely the combustion of biomass, carbon dioxide emissions, and carbon dioxide refraction. Therefore, emission of carbon dioxide can be reduced by replacing fossil fuels with biomass [5].

Biomass is the only organic material or carbonaceous material among renewable energy. In other words, ethanol, methanol, dimethyl ether, and hydrocarbons cannot be obtained from biomass or renewable energy. This means that biomass can be transported and stored in the form of fuels/bio-fuels [6].

Indonesia has enormous potential to produce bio-fuels given the vast amount of biological resources that exist both on land and in the ocean. According to research results Agency for the Assessment and Application of Technology, Indonesia has many types of plants that have the potential to become alternative fuel energy, for example oil palm, coconut, jatropha, soursop, srikaya, kapok as an alternative fuel source for diesel (diesel oil) [7]; sugarcane, corn, sago, cashew, cassava, sweet potatoes, and other sweet potatoes as a premium alternative fuel source [8]. Algae, azolla are most likely to be used as a source of kerosene, fuel oil or petrol. Agricultural waste, household waste, marine waste, etc. are also potential source [9].

The utilization of biomass, besides being able to replace fossil fuels, also gives benefits for developing countries, especially Indonesia, that is to be able to provide sales value for unused materials such as agricultural waste, household waste, fisheries waste as an economic improvement for the community [10]. **Table 1** shows a comparison of the energy produced between fossil fuels and gas (LPG) with agricultural waste [11].

Table 1. The energy contained in some fuels [12]; [13]

Equivalent fuel	The energy contained in the material (kcal/kg)
LPG	11767
Rice Husk	3300
Charcoal	5893
Kerosene	11000
Fuel	11528

In this research, agricultural waste was utilized, especially rice husk as biomass in oyster mushroom growing media sterilization. This research has been started and developed by Simorangkir et al. [2] since 1995 until now. The aim of this study was to investigate the comparison of energy efficiency in baglog sterilization (the media for oyster mushroom cultivation). In the sterilization process, convection pipes as an even distribution of temperature in the drum (sterilization chamber) were used. The number of convection pipes used was divided into 2 types, namely 1 convection pipe and 3 convection pipes. The aim was to compare the effectiveness of the temperature distribution.

Temperature measurements were carried out using Thermo Laser IT 1500 to determine the temperature distribution on the outside of the drum. This measurement value was further used to estimate the distribution of sterilization space by interpreting temperature measurements and connecting with each other using Surfer software for simulation (interpolation). Production effectiveness was also carried out and obtained from mushroom yields to support the hypothesis that the use of rice husk fuel and convection pipes is one of the efficient ways in the baglog sterilization

process and can reduce production costs in the agricultural sector especially oyster mushroom cultivation.

1.1 Technology of biomass (rice husk) and media (rice husk stove)

Husk is a part of grains (cereal) in the form of sheets that are dry, scaly, and inedible, which protects the inside (endospermium and embryo). Husk can be found in almost all members of grasses (Poaceae), although in some types of cultivation, variations are also found in grain without husks (eg corn and wheat). The use of husk as fuel aims to reduce the cost of spending on fuel in the cultivation of oyster mushrooms. The use of fuel oil whose price continues to increase will affect the daily cost of the household [14].

The husk furnace design developed by Simorangkir et al. [2] from Department of Physics of IPB is a stove fuelled with rice husk and called the Blast Furnace. Husk stove technology produces heat energy up to 700-800 °C. This stove is designed similar to an ordinary kerosene stove, but its size is bigger [15]. Inside is a cone-shaped zinc plate which is placed upside down as shown in **Figure 1**.



Figure 1. Rice Husk Stove Design

1.2 Calculation of fuel efficiency

To calculate the fuel efficiency, it is necessary to determine the required energy rate as fuel using the equation (1) [13]; [16].

$$Qn = \frac{(m_a \times c_a \times \Delta T_1) + (m_u \times L_v) + (m_u \times c_u \times \Delta T_2)}{t} \quad (1)$$

Information:

- Qn : The required energy rate (kcal/day)
- m_a : The initial water mass (kg)
- m_u : Mass of evaporated water (kg)
- c_a : Heat of water (kcal/kg °C)
- c_u : Heat of water vapor (kcal/kg °C)
- L_v : Latent heat of water vapor (kcal/kg)
- $\Delta T_{1,2}$: Temperature changes (°C)
- t : Time (Day)

The thermal energy efficiency of fuel can be calculated using equation (2) [16] :

$$\eta = \frac{Qn}{HVF \times FCR} \times 100\% \quad (2)$$

Information:

- η : Fuel efficiency (%)
- FCR : Fuel consumption rate (kg/day)
- Qn : The required energy rate (kcal/day)
- HVF : Heat value fuel (kcal/kg)

Value of FCR (*Fuel consumption rate*) can be calculated using equation (3) and (4) [16]:

$$\Gamma = M_s - M_a \quad (3)$$

$$FCR = \frac{\Gamma}{t} \times 24 \text{ hours} \quad (4)$$

Information:

M_s : Mass of rice husk (kg)

M_a : Mass of rice husk ash (kg)

FCR : Fuel consumption rate (kg/day)

Γ : Mass of fuel (kg)

t : Time (hours)

1.3 Sterilization of Oyster Mushroom Planting Media (Baglog)

Sterilization of the oyster mushroom growing media is one of the most important processes of oyster mushrooms cultivation. In the baglog sterilization process, a uniform and constant temperature is needed around 112 °C-142 °C. If the temperature of the sterilization chamber does not reach the desired temperature, contamination may occur in the form of other unwanted fungi (pests). If the temperature is too high, it may damage the nutrients contained in baglog. These nutrients are used as ingredients for growing mushrooms [17].

In the baglog sterilization process, the addition of a convection iron pipe was carried out, which aimed to flatten the temperature at the top. In previous studies, baglog which was at the top experienced very high contamination. Therefore, the use of convection pipes was expected to distribute the temperature evenly. Variations in the use of convection pipes were applied to differentiate iron diameter and number of pipes used (**Figure 2**).

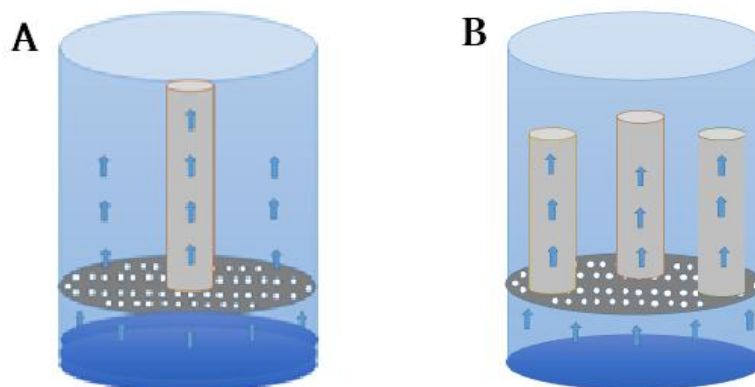


Figure 2. Chamber design using two types of convection pipes for oyster mushroom media sterilization; A. 1 convection pipe; B. 3 convection pipes

2. Materials and Method

The equipment and materials used in this study were a set of husk furnaces, 8 cm and 6 cm diameter iron pipes, 56 cm diameter drums, drum covers, and dual laser infrared thermometers. The use of convection pipes was applied into 2 types, namely the use of 1 convection pipe and the use of 3 convection pipes (Figure 2). The flow of research is shown in **Figure 3**.

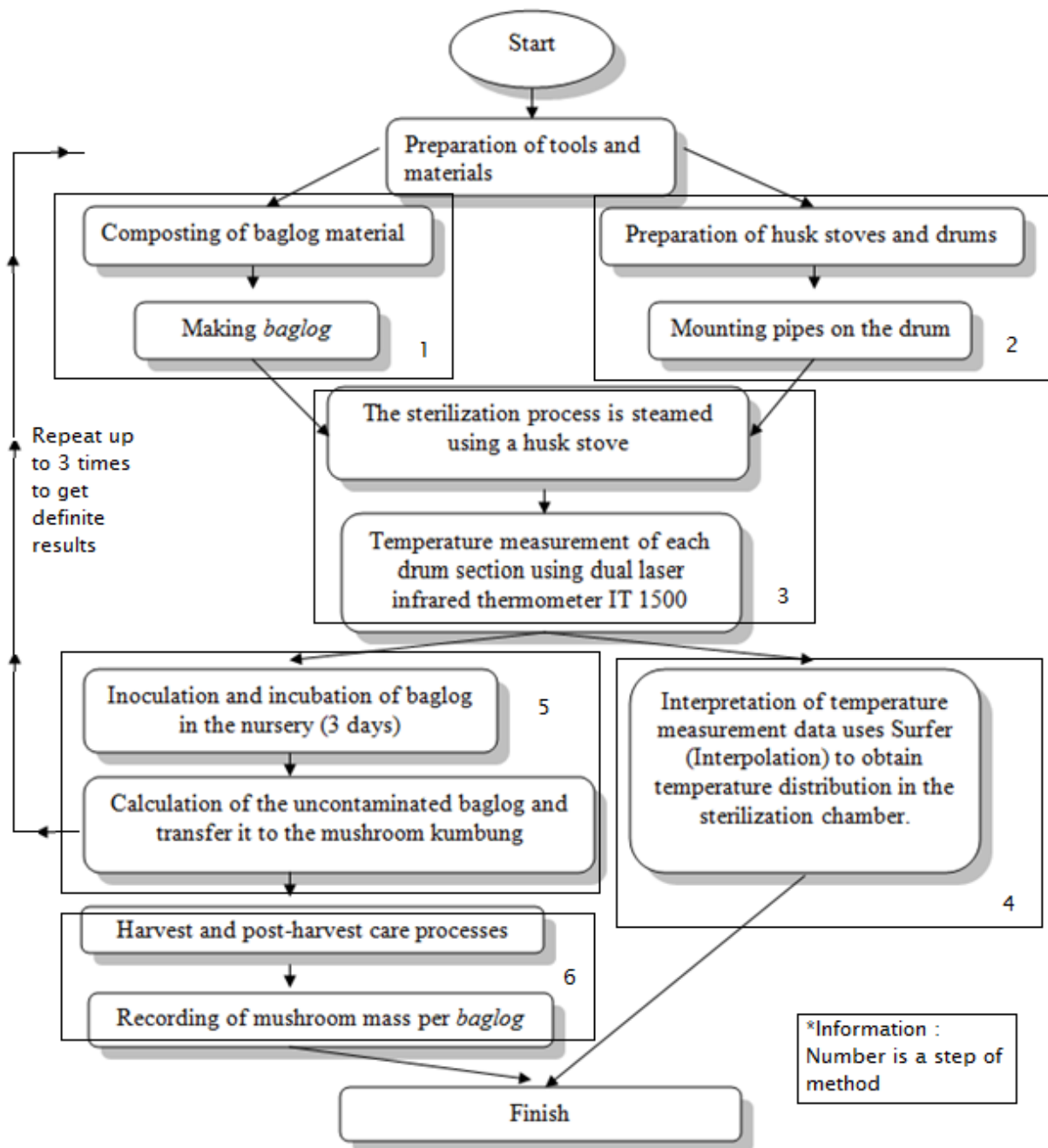


Figure 3. Research flow chart

3. Results and Discussion

3.1 Temperature measurement using 1500 IT thermo laser

The difference in the size of the convection pipe caused the heat to be transferred in the form of water vapor inside of the drum to be different. The heat produced from combustion using rice stoves with rice husk reached an average temperature of 697.78 °C. It was found that the heat distribution produced inside of the drum was different. This occurred because the diameter of the convection pipe used was different, which was 6 cm and 8 cm, so the water vapor that rose above the discharge number was different. Since the heat produced was different, the distribution of heat and pressure in sterilization will also be different. The measurement results are shown in **Figure 4**.

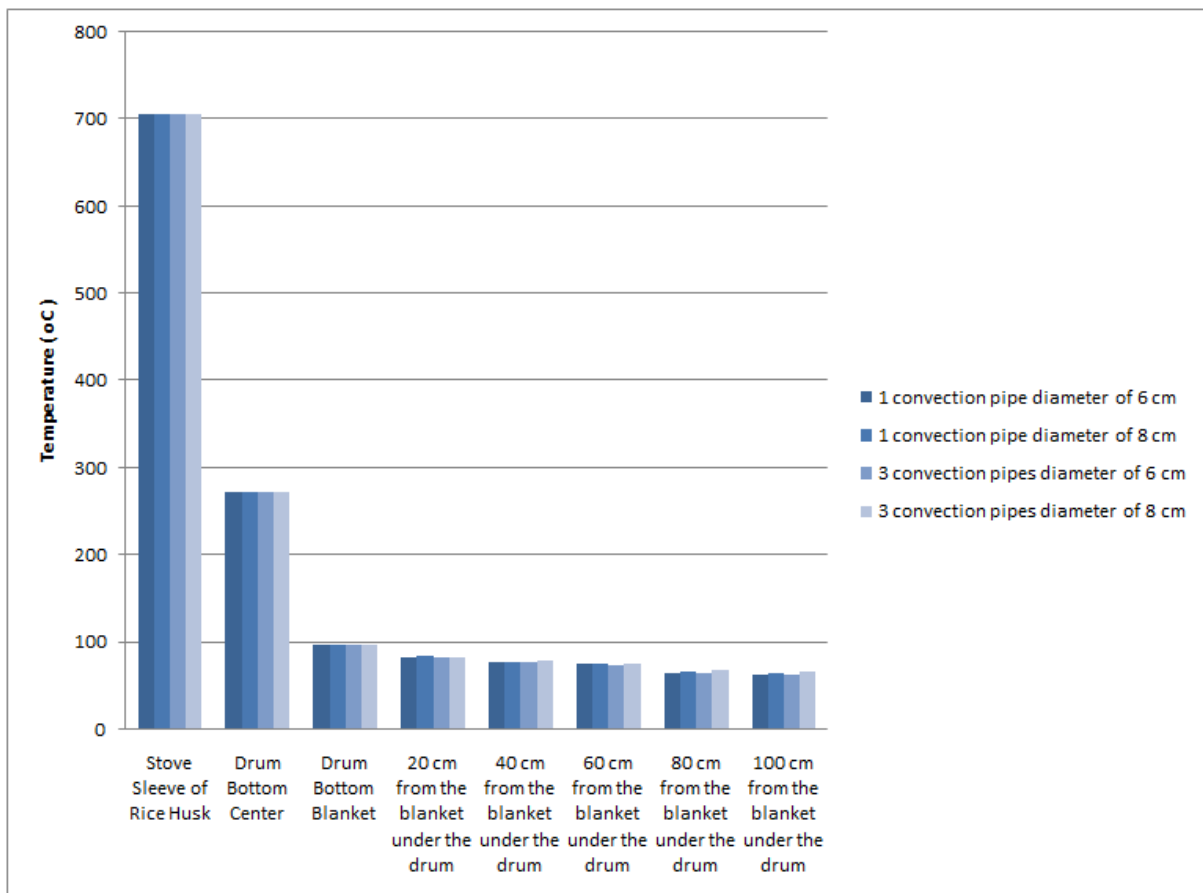


Figure 4. Temperature measurements at each point of 2 different sterilization chambers

For the heat distribution in the drum by using 1 convection pipe with a diameter of 6 cm in the sterilization process of white oyster mushrooms baglog, in the first 1 hour the temperature started to be constant, if averaged then at the center of the lower drum temperature achieved 272.70 °C, in the blanket under the drum it was 97.18 °C, while the temperature at the water level limit was 83.27 °C, the temperature in the blanket of 40 cm from the bottom of the drum was 78.24 °C. Temperature in the blanket from a height of 80 cm from the bottom of the drum was 64.95 °C, the temperature in the blanket from a height of 100 cm from the bottom drum was 62.82 °C, to the temperature on top of the outer drum. The constant temperature becomes a boundary condition in the calculation of heat distribution using the finite difference method with initial conditions at zero hours.

In drums using 1 convection pipe of 8 cm diameter at the bottom of the drum center, temperature was 272.70 °C, in the outer circle of the drum base it was 97.15 °C, while the temperature at the water level limit was 84.76 °C, the temperature in the blanket from 40 cm from the bottom of the drum was 78.53 °C, the temperature in the blanket from a height of 60 cm from the bottom of the drum was 75.75 °C, the temperature in the blanket from a height of 80 cm from the bottom of the drum was 66.45 °C, the temperature in the blanket from a height of 100 cm from the bottom of the drum was 65.68 °C, to the temperature on top of the outer drum.

Furthermore, in drums using 3 convection pipes of 6 cm diameter at the bottom of the drum center, temperature was 272.70 °C, in the outer circle of the drum base it was 97.10 °C, the temperature at the water level limit was 82.23 °C, the temperature in the blanket from a height of 40 cm from the bottom of the drum was 78.01 °C, the temperature in the blanket from a height of 60 cm from the bottom of the drum was 74.25 °C, the temperature in the blanket from 80 cm from the bottom

of the drum was 64.12 °C, the temperature in the blanket from 100 cm from the bottom of the drum was 63.93 °C, to the temperature on the outer drum.

Meanwhile, in drums using 3 convection pipes of 8 cm diameter at the bottom of the drum center, temperature was 272.70 °C, in the outer circle of drum base it was 97.13 °C, the temperature at the water level limit was 83.12 °C, the temperature in the blanket from a height of 40 cm from the bottom of the drum was 78.98 °C, temperature in the blanket from a height of 60 cm from the bottom of the drum was 75.02 °C, the temperature in the blanket from a height of 80 cm from the bottom of the drum was 67.94 °C, the temperature in the blanket from a height of 100 cm from the bottom of the drum was 66.03 °C, to the temperature on the outer drum.

3.2 Interpretation of heat distribution using interpolation model

Interpretation of heat distribution was based on measurement data using thermo laser and based on the results of the FDM (Finite Difference Method) simulation for convection pipes that equipped in the sterilization chamber [18]. FDM simulations have been carried out in previous studies by Noor et al. [19]. The measurement data obtained at several drum points was then interpolated to obtain a correlation between one point to another point. Software Surfer was used for interpreting 2D mapping data. In interpreting the temperature distribution, an interpolation formula was also used to estimate the distribution value based on correlation or relationship between points. The results of the interpretation are shown in **Figure 5** and **Figure 6**.

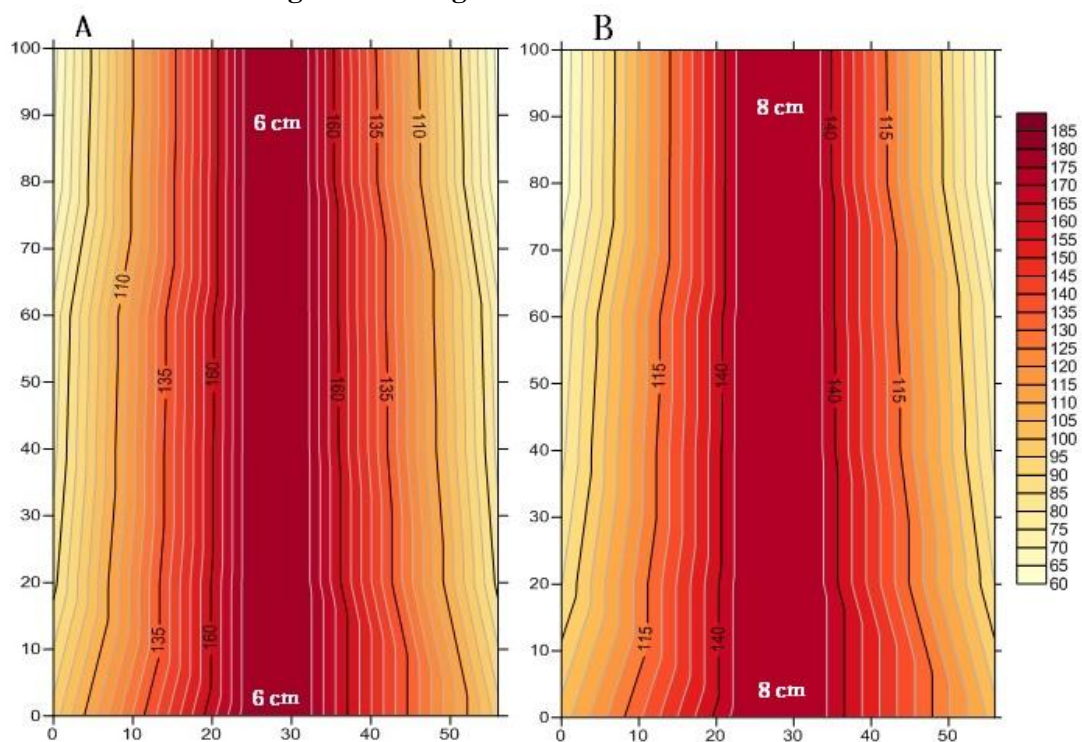


Figure 5. Interpretation of heat distribution in the sterilization chamber using 1 convection pipe: A (6 cm diameter) and B (8 cm diameter)

Figure 5 shows that the temperature distribution in the drum using 1 convection pipe of 8 cm diameter showed a more evenly distributed temperature compared to 6 cm diameter and in the variation of the 3 convection pipes. **Figure 6** shows that the use of 3 convection pipes showed a temperature distribution that is almost the same as 1 pipe, but the temperature distribution in the sterilization chamber was hotter than using 1 convection pipe. In addition, the use of 1 pipe convection made the space for steaming or sterilizing baglog bigger than the drum that used 3 convection pipes. Therefore baglog capacity was bigger than using 3 convection pipes.

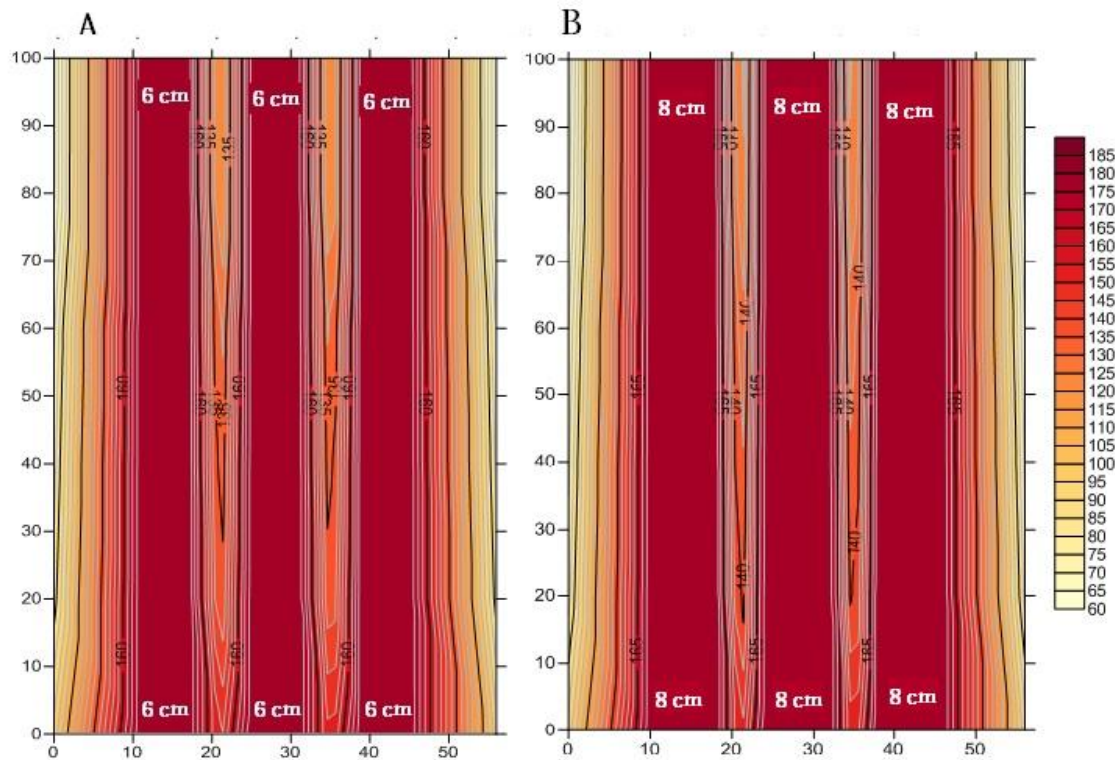


Figure 6. Interpretation of heat distribution in the sterilization chamber using 3 convection pipes: A (6 cm diameter) and B (8 cm diameter)

3.3 Efficiency of Thermal Energy

Based on **Table 2**, the steaming using 1 and 3 convection pipes with a diameter of 6 cm and 8 cm achieved HVF (Heat value fuel) value or the energy contained in rice husk fuel of 3,300 kcal/kg. Based on Figure 6, in 1 convection pipe of 6 cm diameter, the size of FCR (Fuel consumption rate) or the rate of fuel needed (kg/day) was 150 kg/day, whereas for 1 convection pipe of 8 cm diameter, FCR value was 130.01 kg/day. The results of using 1 convection pipe were not much different from using 3 convection pipes with a diameter of 6 cm and 8 cm. However, when compared to the time needed to achieve a stable temperature, the use of 3 convection pipes had a faster time than the use of 1 convection pipe. Although the use of 3 convection pipes showed faster temperature stability, but the use of 1 convection pipe with a diameter of 8 cm has maintained more stability. This was obtained from the temperature measurement data every 1 hour, which is not shown on this article, but the results of the temperature distribution in **Figure 4** are the average results obtained from measurements every 1 hour after the temperature reached a stable point.

Table 2. Comparison of the results of HVF, FCR, Qn, and Efficiency of calculations Energy

Total of Convection pipe	Steam duration (hours)	Convection pipe of diameter (cm)	HVF (kcal/kg)	FCR (kg/day)	Qn (kcal/day)	Efficiency (%)
1	6	6	3,300	150.00	40,986.30	8.28
1	6	8	3,300	130.01	46,105.26	10.74
3	6	6	3,300	158.03	48,595.48	9.31
3	6	8	3,300	143.04	49,893.48	10.56

The efficiency of using 1 convection pipe with a diameter of 6 cm in husk fuel was 8.28% with a steaming duration of 6 hours. The efficiency value of 1 convection pipe of 8 cm diameter with husk

fuel was 10.74% with 6 hours steaming time. Meanwhile, the efficiency value of using 3 convection pipes of 6 cm diameter was 9.31% and for the diameter of 8 cm, the efficiency value was 10.56%.

3.4 Comparison of yield based on the number of growing baglogs

Recording of harvests was done after the sterilization process and nursery inoculation. However, in this stage, not all mushrooms can grow, because some baglog were also contaminated. This contamination occurred due to many factors, for example the dirty environment and the inoculation room and also the uneven temperature distribution. The results of the percentage of crops based on differences in the use of convection pipes are shown in **Figure 7**.

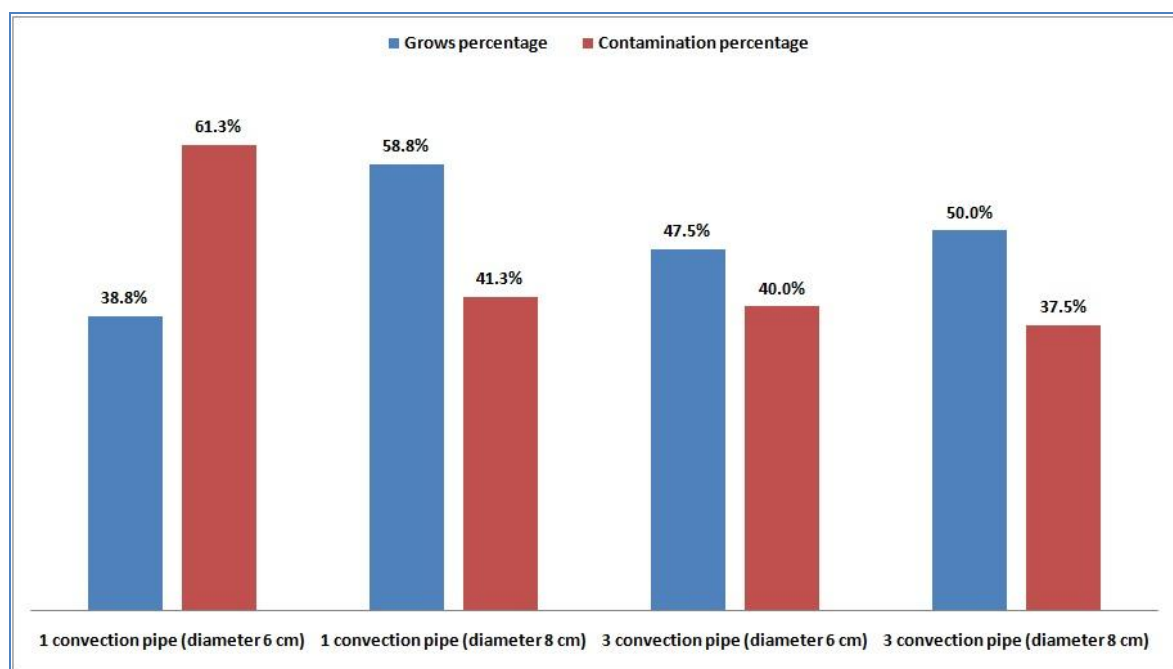


Figure 7. Percentage of growing baglog (blue) and contaminated baglog (red)

From the results, it was found that the least contaminated baglog was 8 cm convection pipe with 6 hours steaming time, i.e., 33 baglogs from a total sample of 80 pieces. Meanwhile, sterilization using a 6 cm diameter pipe with 6 hours steaming time showed number of contaminated baglog was 49 from a total sample of 80 pieces. In addition, sterilization using 3 convection pipes of 6 cm diameter showed 32 contaminated baglogs from a total of 70 baglogs. Sterilization using 3 convection pipes of 8 cm diameter showed 30 contaminated baglogs from a total of 70 baglogs. From these differences, it can be concluded that by using 1 convection pipe with 8 cm diameter showed less contaminated baglog, in which more than 50% baglog of mushrooms were grown and can be harvested within one month.

4. Conclusion

Based on this research that was performed using Thermo Laser IT 1500, the difference in temperature measured in each drum height point showed no significant differences. Therefore, most likely the temperature was distributed in the sterilization chamber, especially in the area close to the circumference of the drum for various use of convection pipes which showed almost the same temperature. However, in the sterilization chamber, especially in the middle, the difference was quite high.

Temperature differences in the baglog sterilization chamber can be estimated through interpretation results based on two methods, i.e., measurements using the IT thermo laser 1500 and FDM simulation for the heat distribution of convection pipes. From these results, as shown in Figure 5

and Figure 6, the temperature distribution in the sterilization chamber using 1 convection pipe tends to have a more stable and evenly distributed temperature than the sterilization chamber using 3 convection pipes. In addition, when comparing between baglog sterilization capacities, the use of 1 convection pipe was more profitable than 3 convection pipes because more baglog can be sterilized.

Based on calculations of HVF, FCR, Qn, and energy efficiency, the difference in the number of convection pipes between the use of 1 convection pipe and 3 convection pipes was not significant. When comparing based on the diameter of the pipe used, the use of 8 cm diameter showed a higher efficiency value. Therefore, it can be concluded that the value of energy efficiency was more influenced by the use of convection pipes based on pipe diameter compared to the number of convection pipes.

The correlation between temperature measurements using Thermo Laser IT 1500, interpretation of temperature distribution, energy efficiency values, and the number of successfully grown baglogs became the conclusion in this study. The experimental results of one convection pipe with 8 cm diameter produced the highest grown baglog with an intermediate contamination.

References

- [1] O. Ismail, M. Urbanus, H. Murage, and O. Francis, "Conversion of Rice Husks into an Energy Source through Gasification Technology," *International Journal of Science and Research (IJSR)*, vol. 5, no. 9, pp. 1264–1268, 2016.
- [2] H. Simorangkir, Irzaman, H. Darmasetiawan, A. Yani, Amas, and Musiran, "Kajian Efisiensi Energi Tungku Sekam Berdasarkan Jumlah, Bentuk, dan Ukuran Sirip yang Dipasang Kajian Efisiensi Energi Tungku Sekam Berdasarkan Jumlah, Bentuk, dan Ukuran Sirip yang Dipasang," *Prosiding Seminar Nasional Fisika 2010*, no. May 2010, 2010.
- [3] C. Santasnachok, W. Kurniawan, C. Salim, and H. Hinode, "The Utility of Rice Husk Ash from Biomass Power Plant: Synthesis of Na-A and Na-X Zeolites Using the Two Step Method Hydrothermal," *Journal of Advanced Agricultural Technologies*, vol. 1, no. 2, pp. 75–81, 2014.
- [4] R. F. Irwansyah, R. Umam, Nofitri, M. Risantis, Irzaman, and Irmansyah, "Pemodelan ikatan kimia pada baglog miselium dan jamur tiram menggunakan konstanta pegas dan frekuensi vibrasi," *Prosiding Semirata IPB*, no. February 2016, 2014.
- [5] F. A. Kirana, H. Alatas, and I. S. Husein, "A Coupled Phase-Temperature Model for Dynamics of Transient Neuronal Signal in Mammals Cold Receptor," vol. 2016, 2016.
- [6] I. I Sintha, M Dahrul, S Ismawati, M Kurniati, Irmansyah, "Optimalization of silicon extraction from husk ashes by excessive magnesium addition on increasing rate of temperature reduction," *IOP Conference Series: Earth and Environmental Science*, vol. 012032, no. 65, 2017.
- [7] O. Mohiuddin, A. Mohiuddin, M. Obaidullah, and H. Ahmed, "Electricity production potential and social benefits from rice husk, a case study in Pakistan," *Cogent Engineering*, vol. 15, no. 1, pp. 1–13, 2016.
- [8] T. A. Memon, K. Harijan, M. I. Soomro, and G. Valasai, "Potential of Electricity Generation from Rice Husk-A Case Study of Rice Mill," *Sindh University Research Journal (Science Series)*, no. May 2018, 2017.
- [9] Abdurrahman *et al.*, "Optimization and Interpretation of Heat Distribution in Sterilization chamber Using Convection Pipe," *Indonesian Journal of Science & Technology*, vol. 4, no. 2, 2019.
- [10] R. A. N. C, R. Blanchard, and A. Mena, "Use of Rice Crops Waste for Energy Production in Ecuador," *Energy and Power*, vol. 3, no. 3, pp. 27–36, 2013.
- [11] et al Rofiqul Umam, "VIBRASI BAGLOG MISELIUM DAN JAMUR TIRAM PUTIH MENGGUNAKAN METOD," no. February 2016, 2014.
- [12] S. Desna, R.D. Puspita, H. Darmasetiawan, Irzaman, "Kajian Proses Sterilisasi Media Jamur Tiram Putih Terhadap Mutu Bibit Yang Dihasilkan," vol. 13, no. 2, pp. 45–48, 2010.
- [13] F. Nawafi, R. D. Puspita, D. Fiska, and I. P. Bogor, "Optimasi Tungku Sekam Skala Industri Kecil Dengan Sistem Boiler," vol. 12, no. 3, pp. 77–84, 2010.

- [14] I. F Nawafi, R Puspita, Desna, "Optimasi Tungku Sekam Skala Industri Kecil Dengan Sistem Boiler," *Berkala Fisika*, vol. 12, no. 2, pp. 77 – 84, 2010.
- [15] L. Quyen and A. Halog, "Rice husk based bioelectricity vs . Coal-fired electricity : Life cycle sustainability assessment case study in Vietnam," *13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use*, vol. 40, pp. 73–78, 2016.
- [16] R. D. Puspita, A. D. Husin, H. Darmasetiawan, D. Fiska, D. Matematika, and K. Dramaga, "Alternatif Pada Sterilisasi Media Jamur," vol. 13, no. 2, pp. 45–48, 2010.
- [17] M. Anshar, F. N. Ani, and A. S. Kader, "ELECTRICAL ENERGY POTENTIAL OF RICE HUSK AS FUEL FOR POWER GENERATION IN INDONESIA," *ARPJ Journal of Engineering and Applied Sciences*, vol. 11, no. 6, pp. 3616–3624, 2016.
- [18] I. Noor, F. Ahmad, Irzaman, and H. Alatas, "Simulation of Heat Transfer in Husk Furnace with Cone Geometry Based on Conical Coordinate System Simulation of Heat Transfer in Husk Furnace with Cone Geometry Based on Conical Coordinate System," *Journal of Physics: Conference Series*, vol. 877, 2017.
- [19] I. Noor, Irzaman, H. Syafutra, and F. Ahmad, "Simulation of Heat Transfer in Cylinder Husks Furnace with Finite Difference Method," *IOP Conference Series: Earth and Environmental Science*, vol. 31, no. 1, 2016.