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Optimization and Interpretation of Heat Distribution in Sterilization Room Using Convection Pipe

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A B S T R A C T

In mushroom cultivation of white oyster mushroom (*P. ostreatus*), problems in the contamination during the production are typically found. This contamination is due to the issue in controlling temperature during the media sterilization for growing the fungus (*bag-log*). This suboptimal sterilization causes unwanted bacteria and spores to grow. To reduce the amount of contamination, the purpose of this study was to demonstrate and evaluate the temperature distribution using one convection pipe with diameter of 6 and 8 cm. The fuel used for this sterilization process is rice husk. Sterilization itself aims to kill other unwanted bacteria and spores on the *bag-log*. Sterilization was done by traditional steaming *bag-log* drums arranged in four rows upwards for 6 hours. Convection pipes were built in drums. The steamer was done by performing two retrievals of data. From the experiment results, the use of convection pipe of 8 cm was better than the convection pipe of 6 cm. This is shown from the amount of fungal contamination in convection pipes were less in 8. The result of temperature measurement using dual laser infrared thermometer was also completed and interpreted using Matrix Laboratory with interpolation method to get heat distribution result.

A R T I C L E I N F O

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1. INTRODUCTION

Mushrooms are one of the most well-known foods as a good source of protein. In mushroom, proteins are usually ranging from 14 to 44 of dry weight. The cultured mushrooms (e.g. *P. ostreatus*, *P. sajor-caju,* and *A. bisporus*) contain more protein than wild mushrooms (e.g. *P.ostreatus*, *P.sajor-caju,* and *A.bisporus*). The highest protein content (41.6%) was obtained from *P. ostreatus*, while the lowest (27.8%) was obtained from *A. bisporus*. Fungal protein content is reported to have variations according to the genetic structure of the species. Protein content may change, depending on the growing medium. *P. ostreatus*, *P. sajor-caju,* and *A. bisporus* contained less fat than other common fungi (1.0 - 9,5%). The highest coarse cellulose content of 16.2% is in *P. ostreatus*, while the lowest was 10.0% in *A. bisporus*. In addition, the organic content of *P. ostreatus* was 84.0% (Akyüz and Kirbağ, 2010).

Mushrooms have a percentage of carbohydrate ranging from 40.6 to 53.3% of dry weight (Chang *et al*., 1981). The free nitrogen extract on *P. ostreatus* was 26.7%, and it is 36.8% on *A. bisporus*. The highest level of potassium is found in *P. ostreatus*, while the potassium content *of A. bisporus* is underneath. For the highest calcium content reaching 1.2 g/kg is found in *P. ostreatus*, while the lowest reaching 0.2 g/kg is in *A. bisporus* (Akyüz and Kirbağ, 2010).

The fungus is good for the anti-hypertensive diet and lowers blood pressure due to low sodium concentrations and high potassium concentrations (Manzi *et al*., 2001). Mushrooms are also excellent food that can be used in a balanced diet for their low-fat content, functional compounds, and other nutritional values (Akyüz and Kirbağ, 2010).

The development of the world's mushroom consumers seems to be enough to encourage mushroom cultivation in Indonesia to encourage increased efforts to develop edible fungi species and the development of cultivation that encourages the expansion of production (Anita *et al*., 2015). *P. ostreatus*or white oyster mushroom is one type of wood fungus that is relatively easy to adapt to the surrounding environment, is also easy to cultivate (Anita *et al*., 2015; Dündar and Yildiz, 2009).

Figure 1. White oyster mushroom (tropical forest, Indonesia).

White oyster mushrooms as shown in **Figure 1** can be found in the wild, especially during the rainy season. They grow in a humid environment. The white oyster mushrooms grow overlapping on the surface of rotted tree trunks, making it called as one type of wood fungus. In general, mushroom growth is divided into two phases, vegetative and generative. The vegetative phase is characterized by the growth and spread of mycelial mycelia within the media. Miselia secretes enzymes that can decompose complex compounds, such as lignin into the simpler compounds necessary for growth. After some time, the mycelia meet each other and developed into a fruit body called the generative phase (Anita *et al*., 2015).

In this study, we optimized the temperature distribution of drum or *bag-log* steaming medium using 1 pipe placed in the middle of the drum to distribute hot spreading. The *bag-log* used as a mushroom growing place is not easily contaminated and get high quality and quantity (Desna *et al*., 2010). Temperature distribution results measured using dual laser infrared thermometer on the outside of the drum interpreted and searched temperature distribution within the drum with data interpolation using Matrix Laboratory (MATLAB). Based on other report (Sivrikaya and Peker, 1999), steaming or sterilization is to remove fungi and bacteria present in *bag-log* or compost and maintain nutrients on the *bag-log* to facilitate the development of mycelium.

The factors that affect growth such as temperature, air humidity (RH), air circulation, light, and nutrition factor in media. Several studies have reported that the use of heat such as sterilization has been done in the developed world and produced the best results (Moonmoon *et al*., 2010). *Bag-log* sterilized in autoclave 3 times trial with a duration of 1 hour, 1 hour 40 minutes, and 2 hours at a constant temperature of 121°C and pressure of 1.2 Pa (Philippoussis *et al*., 2007).

Media or *bag-log* (See **Figure 2**) has been sterilized and inoculated using a substrate or fungus seeds. *Bag-logs* that already contained the inoculum substrate are then stored in the room at 23°C. Oyster mushrooms can grow at a moderate temperature, ranging from 18 to 30°C (Philippoussis *et al*., 2007). For cultivating *P. high-king, P. ostreatus*, and *P.geesteranus,* the culture room temperature is maintained between 22 and 25°C (Ahmed *et al.,* 2013). According to literature (Hoa and Wang, 2015), the optimal temperature for *P. ostreatus* and *P. cystidiosus* was found to be 28°C. In other report (Neelam *et al.,* 2013), the optimal temperature for the growth of mycelium in oyster mushroom *P. florida* is between 25 and 30°C (Djatna *et al.,* 2013). These mushrooms are able to grow better during the summer and autumn in the subtropical and tropical regions as a potential opportunity to develop oyster mushroom production in poor and developing countries (Hoa and Wang, 2015).

Mushroom fruit growth will be perfect if the humidity of the room ranges from 85 to 95%. To be able to keep the humidity, growing chamber must be considered, especially how to open and close the vertical/window. Saturated humidity in the room will cause the fungus, while the ready-to-harvest fungus will absorb the water vapour. Thus, the mushrooms will be wet. Otherwise, if the room normal air humidity can be obtained by closing the ventilation, humidity in the room can use ThermoHygrometer (Philippoussis *et al.,* 2007).

Studies of photobiology and light penetration on mushrooms using molecular devices and genome analysis have demonstrated specific phytochrome,

photoreceptor proteins, transcription factors, causing fungal development and spore viability (Philippoussis *et al.,* 2007).

There are species of fungus that thrive in darkness and some fungus require light (Philippoussis *et al.,* 2007). However, almost all fungi require light in its growth, such as *P. ostreatus*. *L. edodes* requires light for the formation of primordial (Nakano *et al*., 2014). This was confirmed by other report (Mohamed and Farghaly, 2014). In general, to increase mycelium stimulation in the formation of fungal fruit bodies, sufficient light and temperature are required in accordance with the fungal species (Ahmed *et al.,* 2013). However, too much light can cause paleness, deformations, elongated stipe, and reduction of pileus staining (Vieira *et al*., 2013).

Air circulation greatly supports primordial growth. This is also necessary because indoor carbon dioxide levels are always increasing. Air containing high levels of CO_2 can cause mold with stipe pileus and stunted growth of fungi (Philippoussis *et al*., 2007). Therefore, during the fruiting stage, good circulation is required through ventilation so that the results in mushroom cultivation are also good (Bonner and Hoffman, 1963).

2. THEORIES

2.1. *Bag-log*

Bag-log is one of the name media for the growth of oyster mushrooms should be made to resemble the conditions where the oyster mushroom grows in nature that is growing on the already rotted wood (Desna *et al*., 2010; Puspita *et al*., 2010). The oyster mushroom media are shown in **Figure 2** (Anita *et al*., 2015). Several media can be used:

1. Wood powder;
2. Bran as a source of carbohydrates and protein;
3. Lime ($CaCO_3$) as a regulator of pH and mineral sources;
4. Gypsum as a material to strengthen the media and mineral enhancer;
5. Corn breaks as a glucose enhancer;
6. Provision of water, water content ranges of between 60 and 65%.

Figure 2. Media for the growth of oyster mushrooms (*bag-log*).

2.2. Heat transfer energy

Heat is energy transferred due to temperature differences (Putra, 2017). The heat transfer system is divided into 3 types, namely conduction, convection, and radiation. In general, the three types are distinguished by the media in an effort to move the heat energy. Conduction uses solid media, convection using fluid media, while radiation using electromagnetic wave media (Khaled and Vafai, 2003; Puspita *et al*., 2010).

Conduction is the transfer of heat energy that occurs through interactions between atoms or molecules, which are not accompanied by the displacement of atoms and molecules. Heat conduction will only occur if there is a temperature difference in an object. Thermal conductivity (*k*) for various substances where when k is greater then the heat delivered is greater (Khaled and Vafai, 2003).

Convection is the process by which heat is transferred by the movement of molecules from one place to another by involving the movement of molecules within a great distance. Although liquids and gases are generally not very good heat carriers, they can transfer heat quickly enough through convection (Khaled and Vafai, 2003).

2.3. Sterilization of media

Media sterilization is one of the most important processes in the cultivation of oyster mushrooms because the media that have been made usually still contain many microbes, especially wild mushrooms. Many harvest failures are caused by less than perfect media sterilization process. The remaining wild mushrooms in the bag-log will flourish and inhibit the growth of white oyster mushrooms if the sterilization process is not perfect. Wild mushrooms that still exist in bag-log will flourish and inhibit the growth of white oyster mushrooms if the sterilization process is not perfect. Some techniques can be done to sterilize the oyster mushroom media. One way of sterilization is by steaming the oyster mushroom media using a drum (Desna *et al*., 2010).

The use of drums as sterilizers has a 70 to 80% success rate, though farmers still use drums because they are affordable. Boiling is not a sterilization method. Sterilization is generally performed using an autoclave to use high-pressure heat. Another way that is now developed is wet sterilization for products that can't stand the heat (Puspita *et al*., 2010).

Pipe of Convection is a tool that is used as an instrument of heat in the form of water granules or water vapor so that the heat on the media sterilization of oyster mushrooms become more evenly (Puspita *et al*., 2010). In previous research, oyster mushroom sterilization media that have not used convection pipe still fail especially in the process of sterilization of oyster mushroom. Many crop failures are caused by a less perfect media sterilization process. This is due to the dissemination of heat on sterilization medium has not been evenly distributed, for that by using the pipe convection that has been perforated, is expected to level the temperature on the media sterilization (Noor *et al.,* 2016).

2.4. Energy contained in the fuel

The amount of heat that is released during combustion or heat value fuel is equivalent to the energy contained in the fuel. The amount of heat released during the burning of rice husk fuel is 3300 kcal/kg, indicating that rice husk is able to deliver the heat to the sterilization medium greater than the amount of heat incombustion of gasoline, kerosene,

LPG, and charcoal. **Table 1** shows the amount of heat released at the time of burning some of the frequently used fuels (Nawafi *et al.,* 2010; Desna *et al*., 2010).

2.5. Calculation of fuel efficiency

To calculate the fuel efficiency, it is necessary to find the required energy rate (fuel). The equation is shown in the following (Nawafi *et al.,* 2010).

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

where Q_n is the required energy rate (kcal/hari), m_a is the initial water mass (kg), m_u is the mass of evaporated water (kg), C_a is the heat of water (kcal/kg°C), C_u is the heat of water vapor (kcal/kg°C), L_v is the latent heat of water vapor (kcal/kg), $\Delta T_{1,2}$ is the temperature changes (°C), and t is the process time (day).

The thermal energy efficiency of fuel can be calculated using equation (2) (Puspita *et al*., 2010):

$$\tau = \frac{Qn}{HVF x FCR} x\ 100\% \quad (2)$$

where τ is the fuel efficiency (%), *FCR* is the fuel consumption rate (kg/day), *Qn* is the required energy rate(kcal/day), HVF is the heat value fuel (kcal/kg). FCR can be calculated using equation (3) and (4) (Puspita *et al*., 2010):

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

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

where *Ms* is the mass of rice husk (kg), M_a is the mass of rice husk ash (kg), and Γ is the mass of fuel (kg).

2.6. Calculation of the distribution heat

In the heat transfer, at the time of sterilization in the drum, there are two factors: (1) the convection heat transfer that occurs in the water, and (2) heat transfer by conduction that occurs on the *bag-log* (Noor *et al.,* 2016; Nawafi *et al.,* 2010; Desna *et al*., 2010). The drum used in the form of a tube. The tube is symmetry so that the heat propagation that occurs does not depend on the angle ϑ. The calculation of the heat conductivity is found in Equation (5) (Desna *et al*., 2010; Noor *et al*., 2016; Noor and Ahmad, 2017).

$$\frac{1}{\alpha}\frac{\partial T}{\partial t} = \frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial r^2} + \frac{\partial^2 T}{\partial z^2} \quad (5)$$

where *z*, *T*, *t*, *r*, and α are the high of the drum (meters), temperatures (°C), time (seconds), radius of a circles (meters), and thermal diffusion (m^2/s), respectively.

T(r,z,t) is the temperature at the time of sterilization with *r* ($0 \le r \le 28$) and *z* ($0 \le z \le 120$) at time *t*, and converted to Equation (6) (Noor *et al*., 2016; Noor and Ahmad, 2017).

Table 1. The energy contained in some fuels (Desna *et al*., 2010; Nawafi *et al.,* 2010).

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

$$T_{N,j,k+1} = T_{N,j,k} + \frac{2\alpha\Delta t}{\Delta^2 r}\left[T_{N-1,j,k} - T_{N,j,k}\right] + \frac{\alpha\Delta t}{\Delta^2 z}\left[T_{N,J+1,k} - 2T_{N,j,k} + T_{N,j-1,k}\right] \quad (6)$$

Temperature data retrieval follows the design in **Figure 3**, in which this solved the above equation using different methods up to. Another equation that can be used to analyze the heat dissemination in the sterilization process of *bag-log* white oyster mushroom is analytic equations (Noor *et al*., 2016; Noor and Ahmad, 2017).

3. MATERIALS AND METHODS

The tool used in the research is divided into two types: the main tool and tools. The main tool consists of a set of husk furnaces with rice husk fuels used to produce heat, iron pipe with a diameter of 8 and 6 cm, a drum with a diameter of 56 cm, drum cover, and dual laser infrared thermometer. Tools such as plastic sheeting, scales, ruler, stopwatch, computer. **Figure 3** shows the drum design with 1 convection pipe.

The information for the tool used are:

1. Drum with diameter of 56 cm and height of 117 cm
2. Convection pipe with a diameter of 6 and 8 cm.
3. The direction of vapor motion (upwards)
4. Room of *bag-log*
5. Bag-log mat
6. Water (42.75 liters)

In **Figure 4**, it shows that the steps performed in the data retrieval recorded the temperature at the points specified with the laser thermometer.

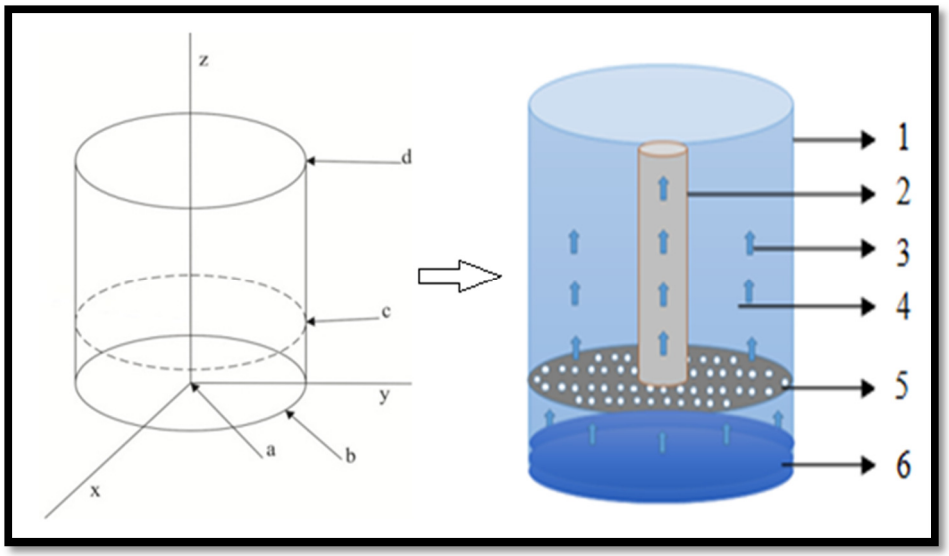

Figure 3. (a) Drum point of data collection temperature (Noor and Ahmad, 2017); and (b) Drum design of a convection pipe.

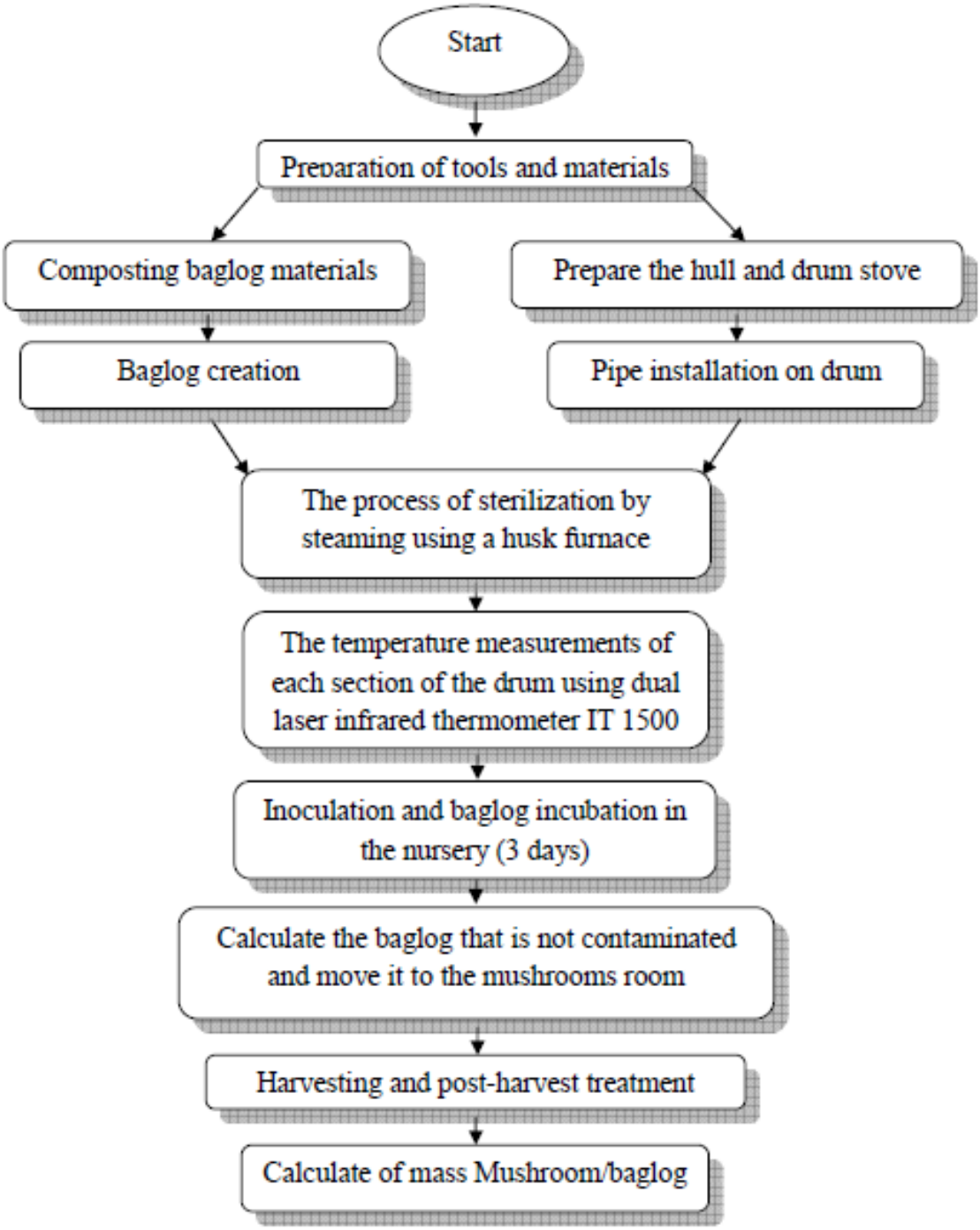

Figure 4. The research flow diagram.

4. RESULTS AND DISCUSSION

4.1. Distribution of temperature on sterilization process *bag-log* with 1 convection pipe of 6 cm

The result of measuring on research using dual laser infrared thermometer was applied in *bag-log* sterilization process with 1 convection pipe of 6 and 8 cm. The differences in diameter sizes of the convection pipe caused the heat transferred in the form of water vapor on the inside of the drum. The heat generated from combustion using a rice husk furnace reaches an average temperature of 697.78°C. It turned out that the distribution of heat produced on the inside of different drums. This happens because the diameter of the convection pipe used is different, that is 6 and 8 cm so that the water vapor rises upwards the amount of discharge participate differently. Because the resulting heat is different, the heat distribution and pressure on sterilization will also be different.

Based on **Figure 5**, the distribution of heat the drum using 1 convection pipe of 6 cm was on the sterilization process of white oyster mushroom planting medium (*bag-log*). This temperature measurement was performed every one hour with 6 hours of steaming process. The measurement results were done at the average temperature at each drum point, starting from the bottom of the drum to the top of the drum (see also **Figure 6**).

The average temperature at the bottom was 272.70°C, the average temperature on the bottom blanket of the drum was 97.18°C, the mean temperature at the water level limit or 20 cm from the bottom of the drum was 83.27°C, the average temperature at the height of 40 cm from the bottom of the drum was 78.24°C, the average temperature at the height of 60 cm from the bottom of the drum was 76.35°C, the average temperature at an altitude of 80 cm from the bottom of the drum was 64.95°C, and the average temperature at the height of 100 cm from the bottom of the drum was 62.82°C. The average temperature becomes the boundary condition or the reference temperature in the calculation of the distribution of heat using finite different methods and interpolation method. Then, the data were interpreted of heat distribution in Matlab (an initial requirement at zero hours) (see **Figures 7 and 8**).

4.2. Distribution of temperature on sterilization process *bag-log* with 1 convection pipe of 8 cm

For the heat dissipation, it limits on the drum at a temperature of 200^{o}C, which is fed from a furnace with rice husk fuel using 1 pipe of 8 cm convection pipe in the sterilization process of white oyster mushroom media (bag-log). In the **Figure 6**, in the first hour that the temperature starts to look constant under 6 hours of sterilization, the condition were: (i) the bottom of the drum center was 262.53°C, (ii) the outer drum base was 97.15°C, (iii) the temperature at the water level was 84.76°C, (iv) the temperature on blanket from height of 40 cm from under drum was 78.53°C, (v) the temperature on blanket from height of 60 cm from under drum was 75.75°C, (vi) the temperature on blanket from height of 80 cm from under drum was 66.45^{o}C, and (vii) the temperature on blanket from height of 100 cm from under drum was 65.68^{o}C. When the constant temperature, it becomes a boundary condition in the calculation of the distribution of heat using a different method up under initial condition at zero hour.

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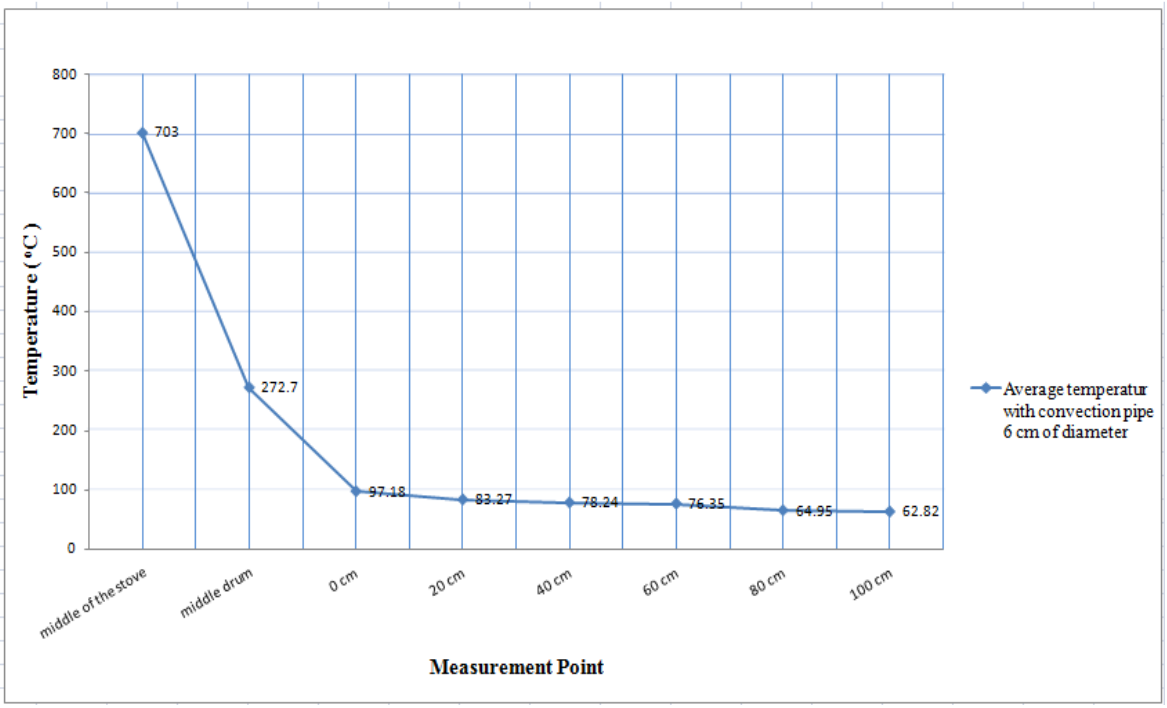

Figure 5. The average temperature at each drum point using convection pipes of 6 cm.

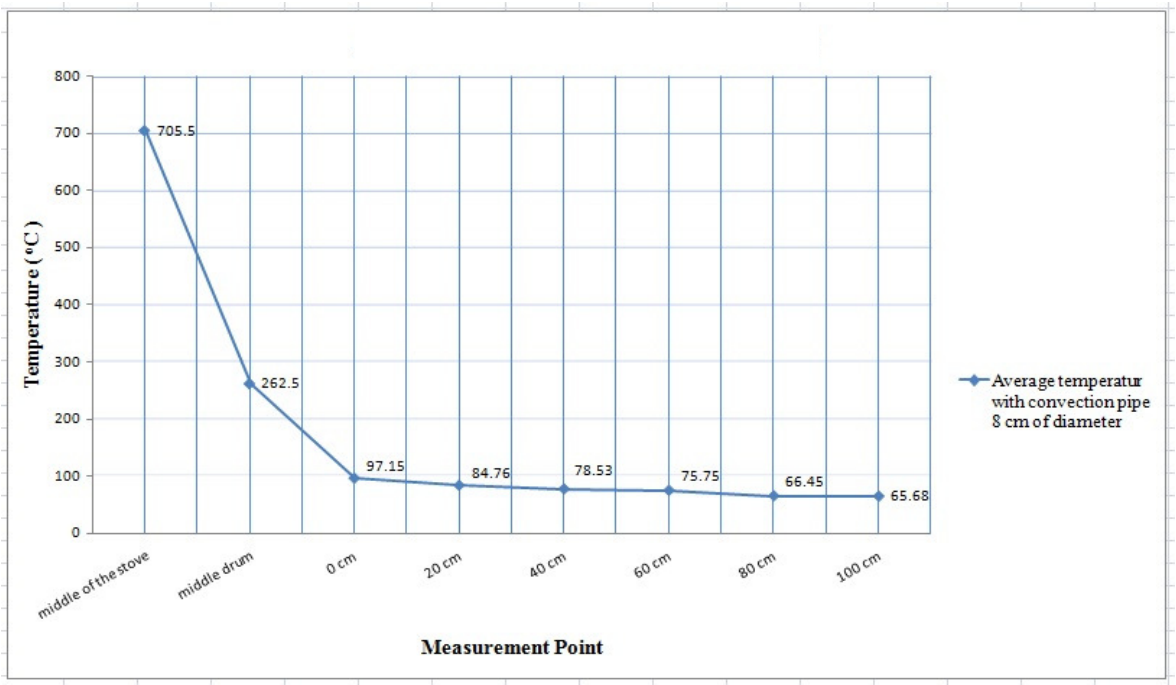

Figure 6. The average temperature at each drum point using convection pipes of 8 cm.

4.3. Interpretation heat distribution using matrix laboratory (Matlab)

Finite Difference Method (FDM) was used in the analysis of the distribution of heat in the sterilization of oyster mushrooms with drums. FDM simulation is a physics simulation using computerized in Matlab software. In the simulation of heat distribution with this Matlab, we got the value of heat distribution by entering the value of heat at the bottom of the pipe, pipe diameter, pipe height, and temperature of the pipe. So, we got the value of heat distribution on convection pipe blanket (Noor *et al*., 2016).

In this case, if we showed the result (see **Figure 7**) by entering the measurement value at the bottom of drum using dual laser infrared thermometer, we got 272.7°C for 6 cm of pipe and 262.5°C for 8 cm of pipe. We predicted the value by simulating of the heat distribution on the 6 and 8 cm of convection pipes. It shows that in the convection tube of 6 cm, the average in the center of the pipe was 180°C, while on the side of convection pipe obtained the average value of heat was 150^{o}C. For pipe diameter of 8 cm, we obtained average heat distribution at the center of pipe that was 198^{o}C, whereas the temperature on convection pipe side was an average value of heat of 170°C. The difference in the distribution of heat is because the diameter of the convection pipe is different. Thus, the rate of heat transfer on the pipe is different. The differences in hole or diameter of convection pipes also played an important role.

The result of the interpretation of heat distribution data was measured using a dualthermo laser (see **Figure 8**). These results indicated that the heat distribution on drums using convection pipes of 8 cm is faster heated than using convection pipes of 6 cm. This is because the amount of water vapor that is transferred upwards is more than the convection pipe of 6 cm. The diameter of the pipe of 8 cm is larger, causing the radius of heat distribution to be bigger.

4.4. Thermal energy efficiency using convection pipes of 6 and 8 cm

In steaming using a convection tube of 6 and 8 cm, HVF (Heat value fuel) or energy contained in rice husk fuel was 3300 kcal/kg. Based on equations (4), 6 cm of convection pipe had FCR (Fuel consumption rate) or required fuel rate of 150 kg/day for the first replication and 197.21 kg/day for the second repeat. For 1 pipe convection with diameter of 8 cm, we got FCR ofequal to 130.01 kg/day in first replication, and 163.61 kg/day in second repeat (See **Table 2**).

The result from calculating the value of thermal energy efficiency based on equation (2) is shown in **Table 3**. In diameter of 6 cm, the convection pipe fueled husk is 8.28% for 6 hours steam at the first repeat, and 7.15% for 6 hours steam on the second repeat. The efficiency value of 8 cm of convection pipe for husk fuel was 10.75% for 6 hours steam at the first repeater, and 9.18% for 6 hours steam on the second repeat.

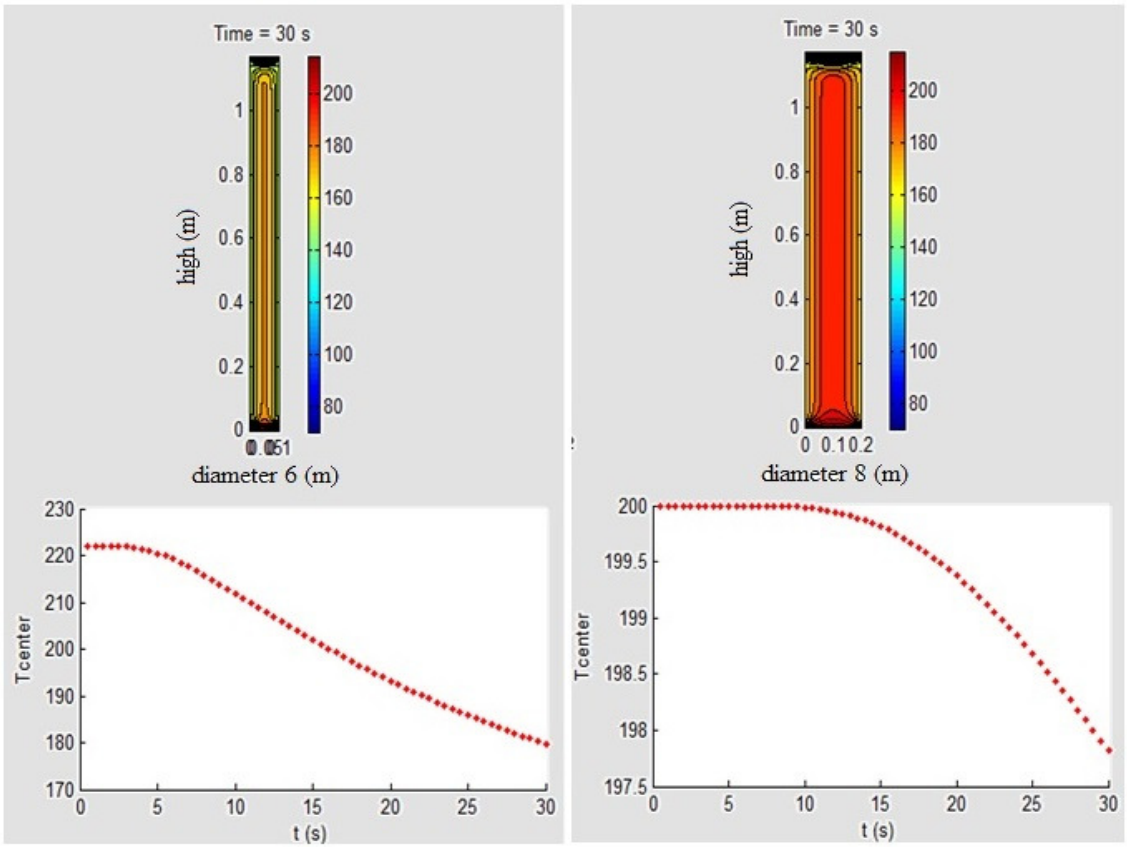

Figure 7. Heat distribution in convection pipes of 6 cm (left) and 8 cm (right).

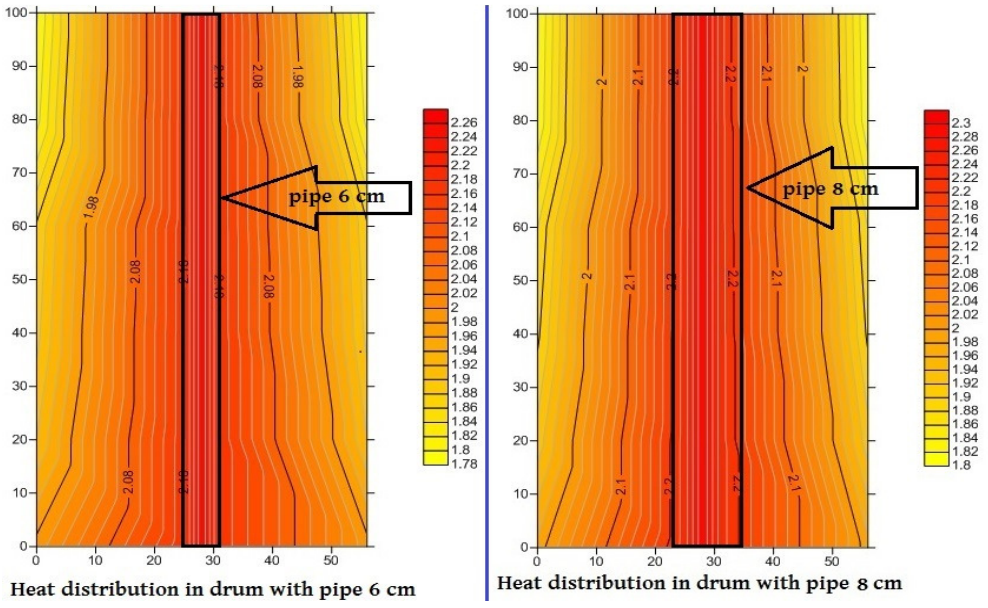

Figure 8. Heat distribution in drum with convection pipes of 6 cm (left) and 8 cm (right).

Table 2. Value of FCR (Fuel Consumption Rate) on the pipes of 6 and 8 cm during 6 hours.

Fuel	Repetition	Steam duration (hours)	Convection pipe of diameter (cm)	Mass of husk (kg)	Mass of husk ash (kg)	Mass of chaff that burned (kg)	FCR (kg/day)
Rice husk	First time	6	6	61.50	24.00	37.50	150.00
Rice husk	Second time	6	6	63.00	13.70	49.30	197.21
Rice husk	First time	6	8	52.00	19.50	32.50	130.01
Rice husk	Second time	6	8	55.40	15.50	39.90	163.61

Table 3. Comparison of efficiency on pipes of 6 and 8 cm with a time of 6 hours.

Repetition	Steam duration (hours)	Convection pipe of diameter (cm)	HVF (kcal/kg)	FCR (kg/day)	Qn (kcal/day)	Efficiency (%)
First time	6	6	3300	150.00	40986.30	8.28
Second time	6	6	3300	197.21	46570.64	7.15
First time	6	8	3300	130.01	46105.26	10.75
Second time	6	8	3300	163.61	49595.48	9.18

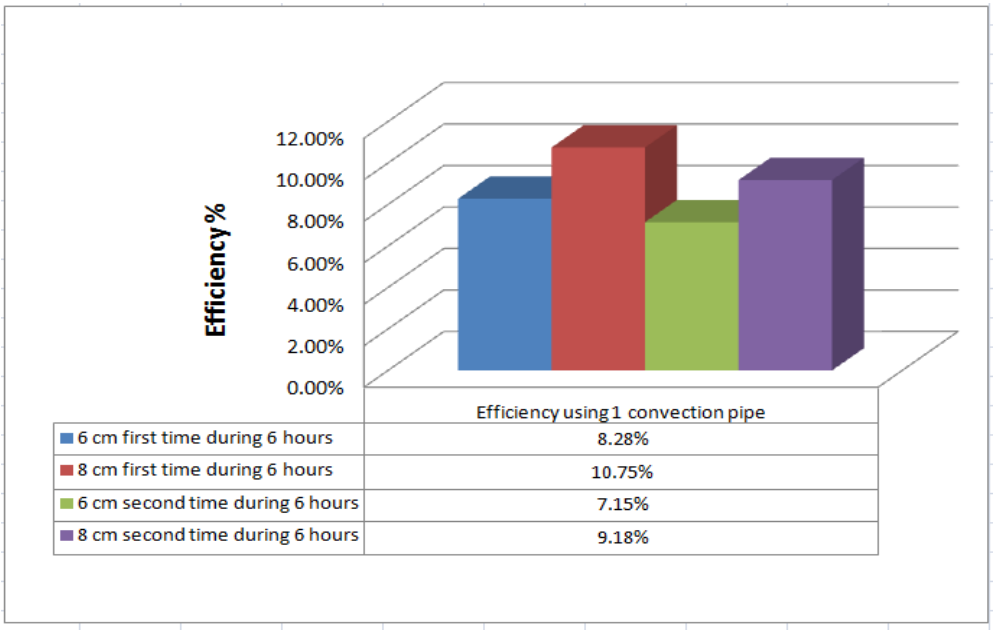

Figure 9. Efficiency of 6-hour heating on convection of 6 and 8 cm.

Based on **Figure 9**, it can be seen that the efficiency of oyster mushroom sterilization fuel for 6 hours of steaming is not very different. In 6 cm of convection tube, the first treatment was obtained that the boiling efficiency is 8.28%. In the first 8 cm of convection tube, the value was 10.75%. On the second 6 cm of convection pipe, it reached 7.15%, while on 8 cm, it was 9.18%.

The main reason is because convection pipe diameter of 8 cm can be quicker to have heat inside of the drum to reach all positions and distributions inside the targeted

sterilization. Rice husk fuel used to the heat is directly proportional to the temperature produced at the same time (that is 6 hours).

4.5. Comparison of harvest results in design of 6 and 8 cm

Design 1 used convection pipe of 6 cm, and design 2 used convection pipe of 8 cm. The use of convection pipe size on sterilization influenced the distribution of heat in the drum, so it also affected the amount of contamination of white oyster mushroom plant media in **Table 4**. It turned out that the least contaminated *bag-log* is on 8 cm of convection pipe with 6 hours of steaming duration of 33 *bag-logs* fruit of the total sample 80 pieces . Steaming was done for 6 hours using a hull furnace and a convection pipe in the middle of an oyster mushroom sterilizer drum.

In **Table 5**, sterilization using a 6 cm of diameter pipe with 6 hours of steaming duration has contamination amount of 49 *bag-logs* from a total sample of 80 units. It can be seen that using convection pipe diameter of 8 cm was less contamination. It means more than 50% of *bag-log* mushrooms grow and can be harvested within one month.

Seeds of white oyster mushrooms that do not grow will experience decay since it has *bag-log* contamination. Sterilization is a major factor causing media contamination, but there are other small factors that can also cause contamination such as the material from the *bag-log* itself or during inoculation. Thus, sterile media can have contamination due to the influence of room temperature incubation and weather. A dirty and wet incubation place is often the cause of contaminated *bag-log*. So, it is necessary to provide a more sterile place for the inoculation process and incubation for 1 week or until the mycelium on bag-log to have covered *bag-log* of 80%.

Table 4. Amount of mushrooms growing in *bag-log* and the average mass of white oyster mushroom per *bag-log*, using pipes of 6 cm, for 6 hours, first time, for 3 times. harvest.

No	Amount of *bag-log*	Amount of contaminated *bag-log*	Number of mushrooms growing in *bag-log*	Total mass of mold growing on *bag-log* (gram)	The average mushroom mass per *bag-log* (gram)
1	20	13	7	2160	102
2	20	13	7	2050	97
3	20	11	9	2820	104
4	20	12	8	2500	104
Total	**80**	**49**	**31**	**9530**	**407**

Table 5. Amount of mushrooms growing in *bag-log* and the average mass of white oyster mushroom per *bag-log*, using pipes of 8cm, for 6 hours, first time, for 3 times harvest.

No	Amount of *bag-log*	Amount of contaminated *bag-log*	Number of mushrooms growing in *bag-log*	Total mass of mold growing on *bag-log* (gram)	The average mushroom mass per *bag-log* (gram)
1	20	10	10	2900	97
2	20	8	12	3450	95
3	20	7	13	4370	112
4	20	8	12	3610	100
Total	**80**	**33**	**47**	**14130**	**404**

5. CONCLUSION

This study has successfully performed sterilization of oyster mushrooms with variations of 1 pipe convection of 6 and 8 cm using a rice husk furnace. The experimental data obtained that the temperature distribution in the 8 cm of sterilization process is better than the temperature distribution at 6 cm. This can be found from the amount of contamination on *bag-log*. The amount of contamination using 6 cm of convection pipe is 49 pieces, while using 8 cm of convection pipe is 33 pieces. The amount of contamination on *bag-log* steamed using pipes of 8 cm is less than that using pipes of 6 cm. The result of heating efficiency using a convection pipe of 8 cm is bigger than those convection pipe 6 cm. The large efficiency of using convection pipe of 6 cm is 8.28%, while that using convection pipe of 8 cm is 10.75%.

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