BioLink : Jurnal Biologi Lingkungan, Industri dan Kesehatan, Vol. 8 (2) Feb (2022)
ISSN: 2356- 458X (print) ISSN: 2597-5269 (online)
DOI: 10.31289/biolink.v8i2.6167

BioLink
Jurnal Biologi Lingkungan, Industri, Kesehatan

Available online http://ojs.uma.ac.id/index.php/biolink

THE EFFECT OF PASTEURIZATION STAGE ON THE PRODUCTION OF STRAW MUSHROOM (VOLVARIELLA VOLVACEA, BULL. EX. FR./SING.)

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Submited : 26-11-2021; Reviewed :04-01-2022; Accepted : 31-01-2022

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Abstract

God created Indonesia with a tropical climate that is very appropriate to support the development of straw mushroom cultivation (Volvariella volvaceae). One of the stages of mushroom cultivation sequentially is pasteurization. This study aims to determine the effect of pasteurization stages, the accuracy of the pasteurization temperature, and the factors that influence the growth of straw mushrooms. The method in this study was carried out using livestock manure, with a composition of 400 gr goat manure and 500 gr rabbit manure. The pasteurization stage is maintained at a temperature of 60-70^{0}C with a humidity of 80-90%. The watering interval at the observation stage was 4 days with a frequency of 40% in experiment 1 and every day or a frequency of 100% in experiment 2. The results showed that the pasteurization stage was very influential on the mushroom growing media. Inaccuracy in pasteurization resulted in many weeds that thrived, thus inhibiting the growth of straw mushrooms. The optimal temperature in the pasteurization stage is 60-90^{0}C. The factors that influence the growth of mushroom are the selection of materials as fertilizers for mushroom cultivation, temperature, humidity include interval and frequency of watering, pasteurization process, weeding the contaminants, and time of observation.

Keywords: *Cultivation; Manure; Pasteurization; Straw Mushroom; Temperature*

How to Cite: *Bermuli, J.E., Irawati, W., & Tammu, R.M. (2022). The Effect of Pasteurization Stage on The Production of Straw Mushroom (Volvariella volvacea, Bull. Ex. Fr./Sing.), BioLink: Jurnal Biologi Lingkungan, Industri dan Kesehatan, Vol. 8 (2): Hal. 242-256*

INTRODUCTION

God created Indonesia with a tropical climate, so it is very proper to support business development in the field of horticulture, especially the cultivation of straw mushrooms (*Volvariella volvaceae*) (Setiyono *et al.,* 2013). In Indonesia, the mushroom is widely consumed by the public because it has a good taste and high protein content (Yuliati, 2016). These advantages make the demand for straw mushrooms in the community increase so that the mushroom has a high economic value (Ichsan *et al.,* 2011). Previous studies have explained that the nutritional and mineral content of edible mushrooms are vitamins B1, B2, D, niacin, potassium, calcium, sodium, magnesium, high fiber (Siregar & Ritonga, 2014), also containing vegetable protein that exceeds other vegetables (Agromedia, 2002).

Mushrooms or fungi are a group of living things that vary in size and body shape, from unicellular to multicellular that can form fruiting bodies, one of which is Basidiomycetes. Basidiomycetes act as important decomposers in the environment, especially in wood die, because of their ability to decompose complex polymers such as lignin (Urry *et al.,* 2017).

The life cycle of straw mushrooms starts from basidiospores that fall to a suitable place to grow to form hyphae, and from these hyphae will emerge primordium which then forms basidiocarps to produce basidiospores again (See Figure 1). The form of straw mushroom that is harvested and sold in the market is the button phase (Figure 1B).

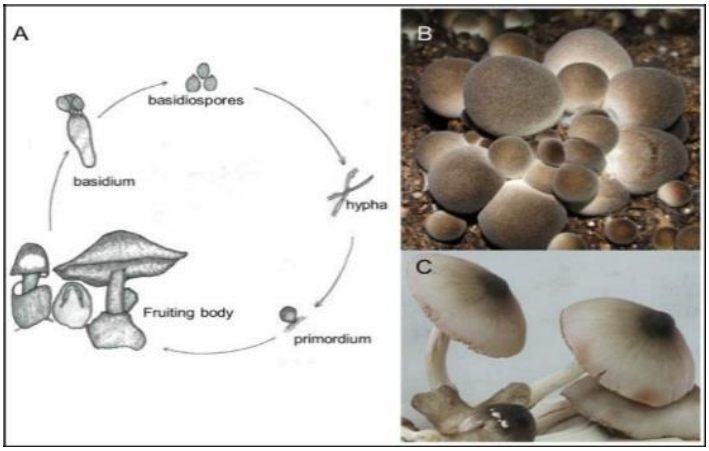

Figure1. Body structure and life cycle of straw mushroom (*Volvariella volvacea*)
Description: A) formation of basidiospores, B) button phase, C) ripening of mushroom fruiting bodies (Bao & Wang, 2016)

Mushrooms cannot make their food so the cultivation media must be rich in organic and mineral materials such as rice straw. Rice straw contains complete micro and macronutrients, cellulose, lignin, and high fiber so it is suitable for use as a growing medium for straw mushrooms (Rahmawati *et al.,* 2016).

There are several stages in mushroom cultivation i.e., making kumbung mushrooms, fertilizing, pasteurizing, planting seeds and harvesting. Of these several stages, the most important stage is during the pasteurization process where the process requires the right optimal temperature of 70-80^{0}C (Wardika & Karsid, 2016). The optimum temperature greatly affects the production of the enzyme lignin peroxidase which can help the growth of straw mushrooms (Madadi & Abbas, 2017). The process of heat accumulation in the white fungus Basidiomycetes can destroy or inhibit the growth and metabolism of fungi so that the optimal temperature needs to be considered (Rouches *et al.,* 2016).

Pasteurization temperature must be maintained so as not to damage the substances contained in the pasteurized mushroom growing media. If the pasteurization process is not perfect, the development of the fungal mycelium will be hampered. Previous research explained that the right temperature for pasteurization is 58- 60^{0}C (Achmad *et al.,* 2011), or 60-70^{0}C (Irawati, 2017) and humidity is around 80-90% with a heating time of about 6-8 hours. (Achmad *et al.,* 2011; Irawati, 2017). Based on earlier research, the pasteurization temperature range is 58-80^{0}C with a heating time of 6-8 hours.

One of the factors that support the success of mushroom cultivation is the use of manure. Manure is the right choice because it is rich in organic matter, environmentally friendly, and can improve soil structure (Ruminta *et al.,* 2017). Some examples of fertilizers that can support the success of mushroom cultivation are derived from livestock manure such as cow manure, rabbit manure, goat manure, etc. Rabbit manure has a higher nitrogen and phosphorus composition than cow manure or other ruminants. Rabbits weighing 1 kg produce 28.0 gr of soft manure per day and contain 3 gr of protein and 0.35 gr of nitrogen from bacteria or equal to 1.3 grams of protein (Sajimin *et al.,* 2005).

Straw mushrooms can grow on media derived from agricultural waste such as rice straw, this is because straw has high cellulose content, and straw can also be composed of various kinds of manure. In

the process of mushroom growth, apart from depending on the nutrients available in the media, it is also influenced by environmental factors. The thickness and placement of the growing media will create environmental conditions, especially temperature and humidity.

Information on the nutritional value of edible mushrooms has increased demand in the market so it is necessary to increase the production of straw mushrooms to meet market demand (Zuyasa *et al.,* 2011). In meeting market demand, it is necessary to cultivate straw mushrooms by paying attention to the nutrients available in the media as well as existing environmental factors. Thus, this study aims to determine the effect of the pasteurization step, the accuracy of the pasteurization temperature, and the factors that influence the growth of straw mushrooms.

MATERIALS AND METHODS

The research flow chart of straw mushroom (*Volvariella volvaceae*) production can be seen in Figure 2.

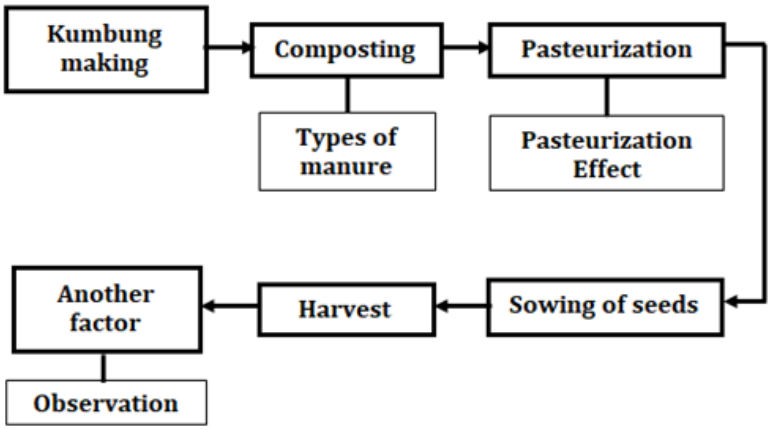

Figure 1. Flowchart of mushroom production research

Research sites, materials, and tools

The research was conducted in March - July 2019 at the garden in Pelita Harapan University campus area, Karawaci. The materials and tools used are straw mushroom seeds, rice straw, cotton (used cotton spinners), lime, rice bran, goat manure, rabbit manure (see Table 1), bamboo, nails, plastic, hammer, machete, pasteurized, thermometer, hygrometer, pH meter, box mold measuring 75x100x5 cm, scales, meter, tongs, water sprayer, caliper, stove, and a steam generator in the form of a drum.

Table 1. The manure that used in this research

No	Type of Manure	Composition	Labeled	Labeled in Figure 3 and Figure 4
1	Goat	400 gr	IB1 – IC3	a – f
2	Rabbit	500 gr	IIB1 – IIC3	g – l

Kumbung Making

The kumbung mushroom house consists of two rows. Each row consists of three stacking shelves, from top to bottom are blocks I, II, III respectively. The distance between the blocks is 60 cm. Between the rows and the others are given a distance of 50 cm for a place to walk. Shelves measuring 180x60 cm, where each shelf was divided into two plots as treatment plots. Each plot measures 60x60 cm. The finished mushroom house is covered with plastic tightly.

Composting

The rice variety used was IR64 with an average height of 100 cm as much as 200 kg. Rice straw was selected with the same length of 100 cm, then divided into two parts, each 100 kg, and dried in the sun for 6 hours.

The reversal of the planting medium was carried out in two stages. The first turning is done four days later. The layers of rice straw at the top will become at the bottom by turning each layer. At the time of turning each layer added additional materials in the form of 0.5 kg of bran, 0.25 kg of lime, and fertilizer (goat manure or rabbit manure); at a dose of 0.4 or 0.5 kg. The second turning is done after the mushroom growing media reaches a temperature of 60-70^{0}C. The compost was put into the experimental rack according to the information provided.

Pasteurization

Pasteurization is done by installing a steam-generating drum and then connecting bamboo or pipes to the mushroom house. The temperature of the mushroom cage during pasteurization was maintained at 60-70^{0}C with 80-90% humidity, for 10 hours.

Sowing and nurturing

Seedlings are sown after the temperature of the mushroom cage reaches 28-32^{0}C. The number of seeds per plot is 300 g. Mushroom seeds are sown evenly over the surface of the media. The temperature of the kumbung must be kept stable, ranging from 28-32^{0}C with 80-90% humidity.

Harvest

Mushrooms are harvested when they reach the egg stage. The mushroom fruiting body is picked by holding the base and then

slowly rotated until the mushroom fruit is released from the media. The collection is carried out every day for 10-15 days.

Observation

The observations made included: 1) the appearance of the mushroom fruiting bodies, 2) the collection of the mushroom fruiting bodies, 3) the total fresh weight of the mushroom fruiting bodies, 4) the number of mushroom fruiting bodies, 5) the height of the mushroom fruiting bodies, 6) the diameter of the mushroom fruiting bodies.

RESULTS AND DISCUSSION

The Effect of Pasteurization Stages

The straw mushroom cultivation process is carried out including the existing stages (Table 2). Table 2 shows the stages of mushroom cultivation. The seventh step shows the stages of pasteurization. Pasteurization aims to prevent the growth of all harmful microorganisms in the planting substrate or perhaps from raw materials, which can interfere with fungal growth (Kusuma *et al.,* 2018).

Pasteurization or sterilization can be done in various ways, for example with hot air and high pressure. Pasteurization can be carried out with hot steam and high pressure of 100^0C with a pressure of 2-3 atm. Pasteurization carried out in this study, lasted for 8 hours using hot steam from boiling water which was flowed into the kumbung. Hot steam piping uses 2 types of pan sizes, i.e. experiment 1 using a 3L water pot and experiment 2 with a large 10L boiled water vessel/drum. When the pasteurization process will be carried out, make sure the kumbung is closed and watertight. Every corner of the room is covered with plastic and insulated to prevent gaps.

The pasteurization method is a sterilization process to eradicate pathogenic microbes using hot steam for 8 hours at a temperature of 70^0C into a kumbung that has been filled with planting media and normal pressure through a drum. In the sterilization process, all the gaps in the kumbung are closed using insulation. This is done so that the entire kumbung is tightly closed and prevents the entry of outside air into the kumbung. It was further explained that the closing of the kumbung gap aims to kill the growth of microorganisms that are detrimental to fungal growth (Sunandar, 2010).

Table 2. The working steps of mushroom cultivation

No	Activity	Details
1	Kumbung making	3 weeks
2	Purchase research tools	12 working days
3	Purchase research materials	2-3 weeks
4	Rice straw cutting and weighing sown ingredients	1 day
5	Composting part 1	6 days
6	2 steps of reverse rice straw compost	11 days
7	Pasteurization	3-4 days
8	Sow the seeds	1 day
9	Watering media	Only when the media appears dry
10	Routine checking	Every day
11	Straw mushroom harvest	Day 7 to 11 after sowing the seeds
12	Cleaning the kumbung	1 day (no visible straw mushroom on the 12th day). The work was carried out on the 15th day

Based on Table 3, it was found that in experiment 1, water was heated in a 3L pan filled with water for approximately 8-10 hours. The temperature in the kumbung shows a minimum of 28^0C and a maximum of 40^0C. The pasteurization stage was carried out in the second experiment, using a different treatment from the first experiment. The pasteurization process in the second experiment was carried out by heating two 10L water pots for 8-10 hours. The temperature inside the kumbung shows a minimum of 27^0C and a maximum of 48^0C (Table 3). In previous studies, it was explained that if pasteurization was carried out at a temperature of 80-90^0C it would take 7-8 hours while if the temperature was above 90^0C, it would take about 4 hours (Suriawiria, 2002). Based on this statement, the temperatures from the two experiments that have been carried out show that these temperatures have not yet reached the optimum temperature for compost pasteurization, even though the evaporation time has reached 8-10 hours. This shows that the temperature used aims to kill all organisms that can live at the temperature that will be used to grow the fungus (Kurtzman, 2010). Thus, the two experiments carried out have not yet reached the optimum temperature for the pasteurization process.

Table 3. Temperatures recorded at the pasteurization stage

Details	Increased temperature (^{o}C) per jam									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Experiment 1	28	30	31	32	34	36	37	39	40	40
Experiment 2	27	29	30	32	35	38	41	44	46	48

Table 4 shows the data regarding the humidity recorded during the pasteurization process. The experiment lasts two times and with quite different treatments. Experiment 1 kumbung was heated using a 3L pan while in experiment 2 the kumbung was heated using a 10L pan. Heating in both experiments was carried out for 10 hours. The results recorded were the minimum humidity in experiment 1, which was 42%, and the maximum humidity, which was 65% (Table 4). The second experiment shows the minimum humidity data is 40% and the maximum is 81% (Table 4). Based on previous research, the humidity in the pasteurization process should be around 80-90% and with the pasteurization process for 8 hours (Irawati, 2017). This shows that the humidity that occurred in experiment 1 has not reached the limit, while in experiment 2 the humidity has reached the existing limit.

Table 4. Moisture is recorded at the pasteurization stage

Details	Humidity increase (%) per hour									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Experiment 1	42	45	49	53	55	58	61	62	64	65
Experiment 2	40	46	52	58	60	66	70	76	78	81

Experiment 1 (see Figure 3) shows the number of weeds or contaminants, i.e., mushrooms, which are not cultivated if the pasteurization step is not carried out using the optimal temperature. The temperature used aims to kill all organisms that can live at the temperature that will be used to grow the fungus (Kurtzman, 2010). In addition, the temperature at the pasteurization stage is not only limited to preventing the growth of other unwanted organisms that can damage fungal growth but aims to remove ammonia levels and help maximize the yield of compost fermentation to form simple substances needed for fungal growth (Setiyono *et al.,* 2013).

Figure 3 shows that the temperature has not yet reached the optimum temperature for compost pasteurization, even though the evaporation time has reached 8-10 hours. Based on the explanation above regarding the function and purpose of pasteurization, it can be said that the use of temperatures below the optimum provides opportunities for other organisms to grow and interfere with the growth of straw mushrooms. The pasteurization process also affects the rapid growth of the mushrooms planted. The use of hot water in the pasteurization process will accelerate the growth of mushrooms planted because it provides higher humidity conditions (Ejigu & Kabede, 2015).

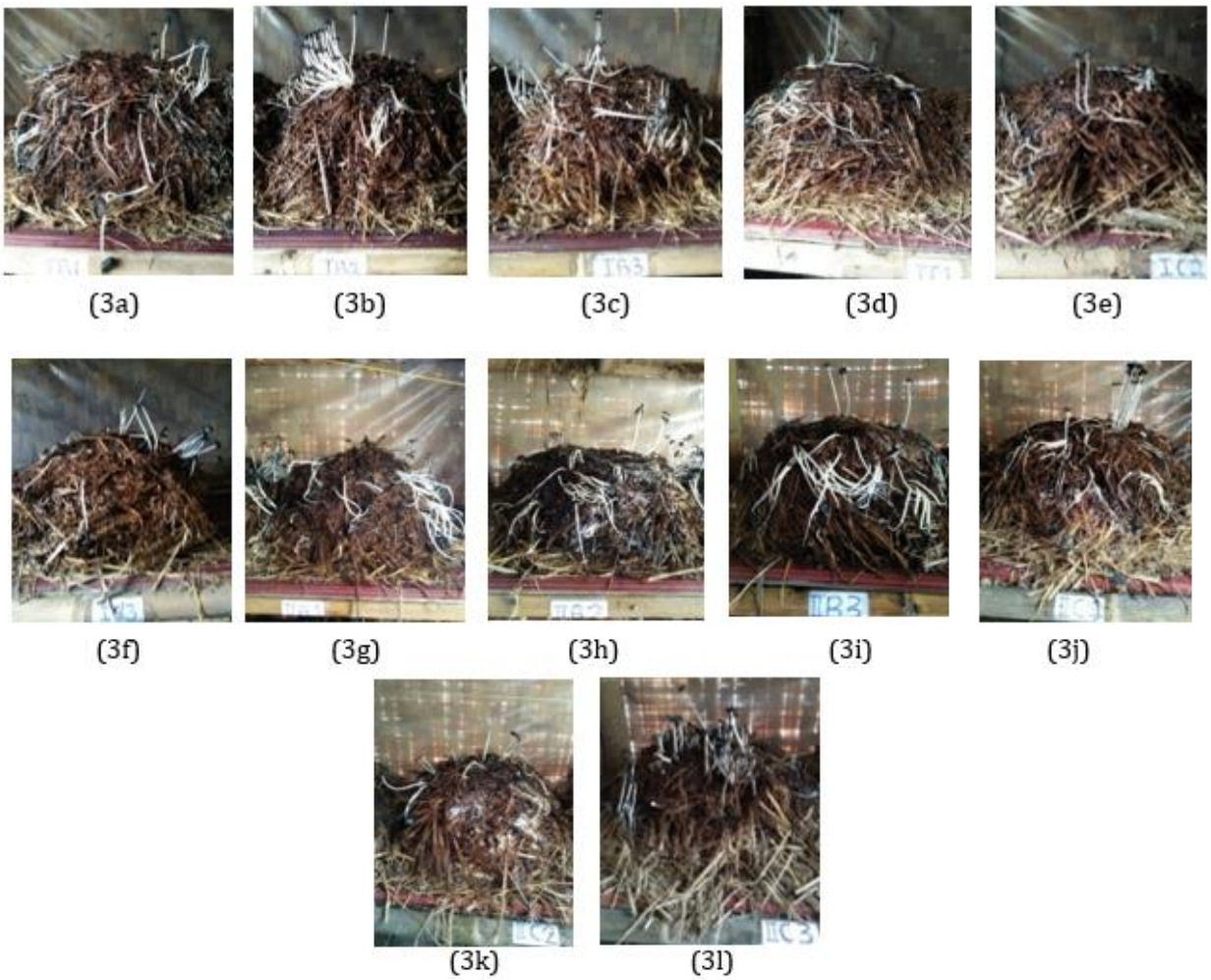

Figure 2 Effect of pasteurization, goat and rabbit manure on experiment 1 (details 3a–3f (IB1 – IC3): medium using goat manure, 3g–3l (IIB1 – IIB3): medium using rabbit manure)

Pasteurization Temperature Precision

Based on Figure 3, it can be seen that the growth of contaminants looks very fertile in each research media. This data proves that there is a relationship between temperature at the pasteurization stage and the growth of contaminants. The compost pasteurization stage should be carried out at a temperature of 58-80^{0}C for 6 to 8 hours, to make good selective compost for the growth of edible mushrooms (Achmad *et al.,* 2011). The temperature that is not optimal can cause the growth of contaminants in experiment 1 to look more fertile than the growth of straw mushrooms (see Figure 3), while the amount of contaminant growth in experiment 2 is less than the growth of straw mushrooms (see Figure 4). This happens because of the difference in the size of the pan and the number of pans used, thus making the pasteurization temperature different (Table 3). Comparison of Figure 3 and Figure 4 shows

that the contaminants that grew in experiment 1 were more than in experiment 2.

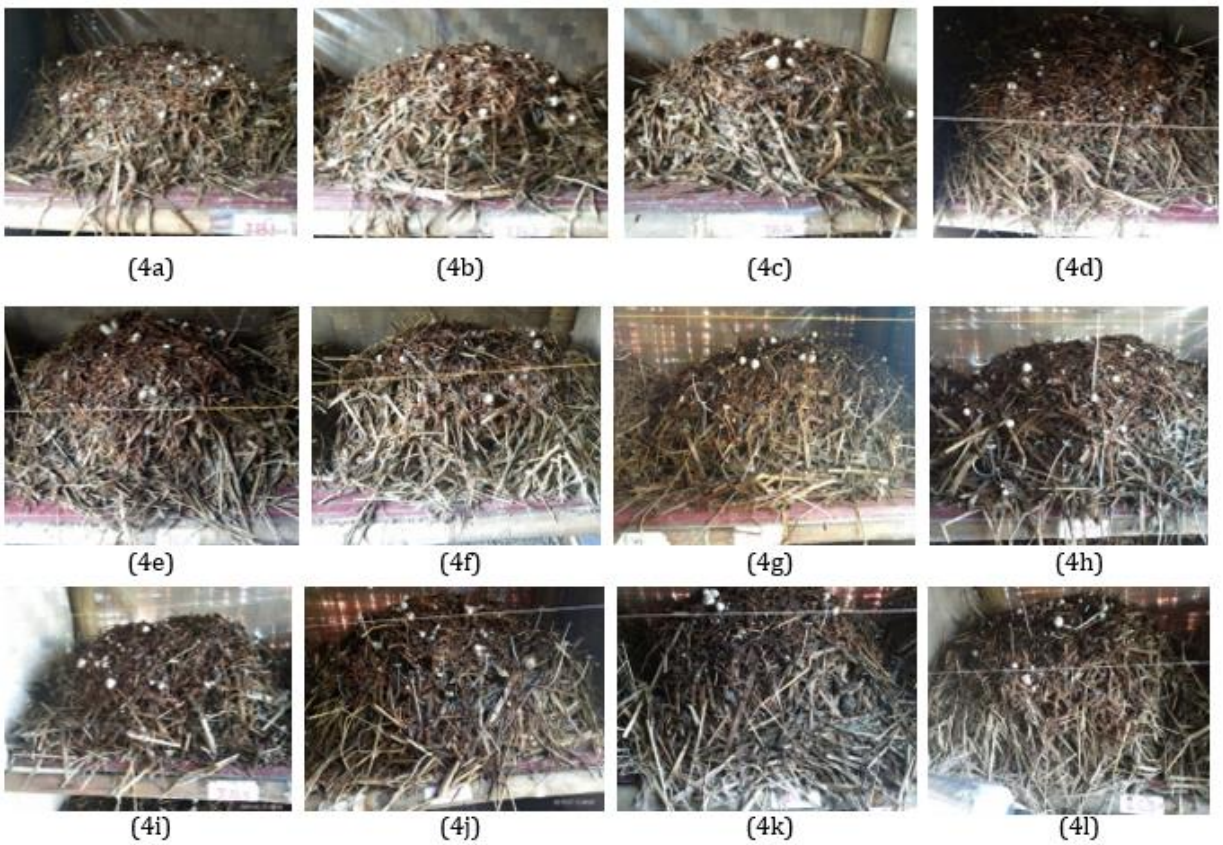

Figure 3 Effect of pasteurization, goat and rabbit manure on experiment 2 (details 4a – 4f (IB1 – IC3): medium using goat manure, 4g – 4h (IIB1 – IIB3): medium using rabbit manure)

This shows that pasteurization is a process of heating kumbung along with the growing media that plays a role in eliminating nuisance contamination microorganisms (Saputra, 2014). Failure in the pasteurization stage causes the growth of disturbing microorganisms. Failure in the sterilization process is caused by several things, such as:

- ✓ the required temperature (above 85^0C) is not reached or evenly distributed across the substrate in the drum
- ✓ the short heating time (less than 5 hours) causes the wild mushroom seeds contained in the spore-shaped substrate to not die
- ✓ The required vapor pressure is not achieved so that many pollutant bodies (in the form of fungi) will grow (Suriawiria, 2002).

Based on the statement above, it shows that the failure in mushroom

cultivation was due to the temperature not reaching the optimal temperature of 85^0C even though the heating time was more than 5 hours. The required hot water vapor pressure was also not achieved in this study. This causes other microorganisms, such as the contaminant fungus shown in Figure 3, to thrive more than the straw mushroom. Therefore, the growth of straw mushroom is inhibited. This happens because of the competition in taking the nutrients needed between the mushroom and other contaminant fungi.

Mushroom Growth Factor

Mushroom cultivation is one of the most widely practiced by people in Indonesia. The success of mushroom cultivation is influenced by the use of animal manure as manure, the suitability of the work stages, and the seeds used. The conditions found today are that some types of animal manure that are often used as raw material for composting are quite difficult to find, for example, chicken manure. One village in Magelang Regency found that a small number of farmers prefer to sell their livestock manure to buy chicken manure (Kasworo *et al.,* 2013). This is done because farmers think that chicken manure makes it easier for plants to germinate.

Table 5. Nutritional composition of chicken, goat, and rabbit (*Hartatik & Widowati, 2006; **Djatmiko & Anwar, 2017)

No.	Type of manure	Mass (g)	C (%)	N (%)	P (%)	K (%)
1	Chicken*	100	42.18	1.50	1.97	0.68
2	Goat*	100	46.51	1.41	0.54	0.75
3	Rabbit**	100	10-12	10-12	2.20-2.76	1.86

Chicken manure has a nitrogen content that is three times higher than other manure (Damanik *et al.,* 2010). In Table 5 was explained that 100 g of chicken manure contained 42.18% C; 1.50% N; 1.97% P; and 0.68% K, while in 100 g of goat manure it contains 46.51% C; 1.41% N; 0.54% P; and 0.75% K (Hartatik & Widowati, 2006). Chicken manure and goat manure have a nutritional composition that is not much different. Due to the lack of use of goat manure and the high use of chicken manure, there is a lack of availability of chicken manure. Based on research conducted by experts, said that rabbit manure has sufficient nutrients for the growth of organisms, i.e. C/N: (10-12%), P (2.20-2, 76%), K (1.86%), and Ca (2.08%) (Table 5) (Djatmiko & Anwar, 2017).

Based on the nutritional content of goat and rabbit manure described above, the addition of goat or rabbit manures aims

to meet the growing needs of fungi during the growth process. Provision of goat and rabbit manure as a source of N, P, and K nutrients that are beneficial for growth (Safitri *et al.,* 2017).

Another variable that supports the mushroom growth process is the use of manure. The manure used in this experiment is goat manure and rabbit manure. In the kumbung used, the media on the left of the kumbung are named IB1 – IB3, and IC1 – IC3 are media that use goat manure. The media on the right of the kumbung named IIB1 - IIB3 and IIC1 - IIC3 are media that use rabbit manure (see Figure 3 and Figure 4).

Another result obtained is regarding the use of water in mushroom cultivation. Irrigation media in mushroom cultivation needs attention. This is because straw mushrooms grow in moist conditions. This means that the amount of water in the mushroom growing medium must be sufficient, that is, it should not be too dry, and it should not be too wet. Drought causes the straw mushroom not to grow, due to a lack of the required amount of water, while excess water causes the mushroom to rot and die before it reaches the optimal size. This is following the statement which explains that fungal growth is influenced by external factors such as humidity, temperature, and light (Wangrimen *et al.,* 2017).

In the first experiment, watering was carried out on the first, fourth, seventh and tenth days (Table 6). Watering is done with the same spray medium and a consistent amount of water at each watering time. Thus, the total watering only occurred 40% of the total observation time with a 4-day watering interval. This condition occurred because in experiment 1 the media was not watered every day, so the media became dry (Table 6). This is different from the steps carried out in experiment 2. The growing media in experiment 2 received treatment where the media was watered every day so that the watering time was 100% of the total 10 days of observation with no interval (Table 6). This causes the medium in experiment 2 to be too wet. This also greatly affects the growth and development of straw mushrooms, so that the straw mushrooms grown in the second experiment could not reach the optimal size and rot faster. This is in line with the opinion of Rajup (2020) which explains that the harvest of edible mushrooms is strongly influenced by the watering interval. The right amount of concentration and watering interval can provide optimal results on mushroom growth. The proposed watering time interval is once

every 2 days (Rajup, 2020) or with a watering frequency of 50% of ten days from the total time of observation of mushroom growth. Yuliani (2009) also argues that planting media that is watered too often can cause high humidity in the media and kumbung. Increased humidity that is too high can inhibit the growth of straw mushroom primordia so that the appropriate frequency of watering is needed to optimize the growth of straw mushrooms.

Table 6. Watering schedule for straw mushroom in observation day

Experiment	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
1	✓	-	-	✓	-	-	✓	-	-	✓
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Description: (✓) watering; (-): not watering

Thus, things such as the selection of manure as fertilizer for mushroom cultivation, temperature, humidity, pasteurization process, the amount of water given, the interval and frequency of watering on the mushroom growing media, weeding weeds, and time to conduct mushroom research need to be done become the focus of study in researching terms of mushroom cultivation. This focus is expected to be a success factor for further research.

CONCLUSION

Based on the research of straw mushrooms, it was concluded that the pasteurization stage greatly affected the growth of straw mushrooms. This pasteurization process will affect the growth of straw mushrooms on the growing media because the pasteurization stage is a step taken to kill contaminant variables. The presence of weeds or contaminants will affect the growth of straw mushrooms so that the mushroom will not grow optimally.

A good pasteurization process generally lasts 8-10 hours, with temperatures reaching 60-80^{0}C and average humidity reaching 90%. In addition, the pasteurization process also affects the rapid growth of the mushrooms planted.

Other factors that influence the growth of straw mushrooms are the selection of manure as fertilizer for mushroom cultivation, temperature, humidity include interval and frequency of watering, pasteurization process, weeding the contaminants, and time of observation the straw mushroom.

ACKNOWLEDGEMENT

Thank you to Universitas Pelita Harapan for all the support, both in terms of research permits and funding for this

research. This research was conducted through a performance contract with the number P-037-FIP/I/2019.

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