Journal of Mushrooms 한국버섯학회지 Research Article

Characteristics for the growth and yield of *Pleurotus ostreatus* by air velocity

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ABSTRACT: This study was carried out to investigate optimum wind velocity for growth of *Pleurotus ostreatus*. In the chamber experiments, the divergence of pileus was 63° in 0.3m/s, and it showed the tendency that the more the air velocity was increased, the more the divergence became small. And the ratio of commercial yields was 96% in the air velocity of 0.3m/s. In the cultivation room experiments, the divergence of pileus was 64° in 0.3m/s, and it was the tendency that the more the air velocity was fast, the more the divergence became larger. And the commercial yields was similar to the trend of the chamber experiment as 94.8% in 0.3m/s, and the quality characteristics of the fruit-body showed the uniform quality in comparison with other treatment because the standard deviation of the size of the pileus, etc. was the lowest in 0.3m/s like the chamber experiment.

KEYWORDS: Air velocity, Bottle cultivation, Environment, Fruit body, Mushroom cultivation houses, *Pleurotus ostreatus*

INTRODUCTION

Mushroom production in Korea is 149,890M/T, and the number of farmhouse are the decrease trend as 2,159 households (Ministry of agriculture, 2018), but the annual productivity per farmhouse reaches to 69.4M/T due to the increase of a large-scale protected cultivation farmhouse.

Because the nutrition condition, and light, temperature, humidity, CO_2, air velocity and gravity which are the external environmental condition in the mushroom cultural environment are closely related to the production, a heating/air-conditioning equipment is installed for the cultivation of mushroom, and in this case, the main equipments are a refrigerator, heater, unit cooler, and ventilation fan, etc. If these main equipments are operated for the growth of mushroom, wind is generated in the cultivation room, and the intensity of air velocity has an effect on the growth of mushroom. It has reported that the quality of air and the air exchange in the cultivation room are very important in the mushroom cultivation (Styer, 1933). The study on the air velocity and humidity associated with the evapotranspiration at the time of the mushroom cultivation has conducted by Flegg(1974), and Bowman(1987) has reported that the velocity of air flow passed over the mushroom bed in the cultivation room was 0.06~0.44 m/s. Evaporation power(EP) is the value that multiplies the vapour pressure to the speed of air flow, and it has reported that when EP value was 4~10mbar·m/min, it was the optimal mushroom cultivation environment (Bowman, 1991). And in order to present the basic data needed for environment control of the cultivation room of mushroom, and also Lomax *et al.* (1995) has measured the speed of air flow passed between the mushroom beds by using flags to sense the air flow. Also Takatsuji *et al.* (2001) have reported that there was a need to prevent the drying of seed and medium by weakening winds of the cooler and heater in each process such as cultivation, germination and growth at the installation of air-conditioning system. Recently, the cultivation rooms under structure are increased, and *Pleurotus ostreatus* takes possession about

J. Mushrooms 2019 June, 17(2):41-46
http://dx.doi.org/10.14480/JM.2019.17.2.41
Print ISSN 1738-0294, Online ISSN 2288-8853
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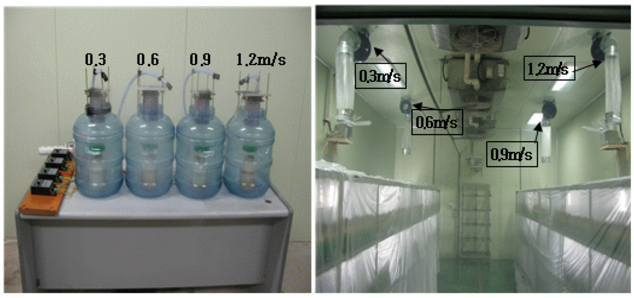
Received June 18, 2019
Revised June 20, 2019
Accepted June 20, 2019

35.7% of mushroom production (Ministry of Agriculture, 2018), and on the other hand, the basic research is unsatisfactory condition, and there are many cases that depend on experience to regulate the environment in the cultivation room in farmhouse. Thus, this study has carried out to investigate the suitable air velocity for cultivation of the *P. ostreatus* in the cultivation room under structure.

MATERIALS AND METHODS

The strain used for the test was incubated for 20 days in a conical flask which sawdust and rice bran was mixed in the ratio of 80:20(v/v) after incubating the Chunchu 2ho (oyster mushroom) which possessed in the Mushroom Research Institute for 5 days in PDA plate medium, and then was used as the starter (seed) by incubating for 25 days in 850 mL bottle which sawdust and rice bran was mixed in the ratio of 80:20(v/v). For chamber experiments, the chamber was produced as shown in Fig. 1 by applying the wind generator which Jhune *et al.* (2006) has reported. The wind generator is the equipment which 7 plastic cylinders of 2.5 cm diameter and the wire net of 0.05 mesh are attached to the fan (DP23092A, Sunon Wealth Elecmachind Co. Ltd). The size of the chamber was 0.02 m^3, and 4 ventilating openings of 2.5 cm diameter were installed to the lower part of the chamber for natural ventilation. The electrical apparatus for converting (APC-100, Alpha Industry Co. Ltd) was connected to the wind generator, and it was adjusted by the processing air velocity of 0.3, 0.6, 0.9 and 1.2 m/s per each chamber. At this time, the wind speed by the treatment was frequently checked by the air velocity sensor (AS-201, Graywolf Sensing Solutions., Co), and the humidity was automatically controlled in 90±5% by putting the humidity sensor into the chamber. For humidification, the equipment was fabricated so that moisture was automatically injected by connecting the tube of 1 cm diameter to an ultrasonic humidifier. The investigation of 10 times by one bottle per treatment was carried out by repeating 3 times. In order to demonstrate the results of the chamber experiments, the experiments were conducted in the cultivation room, and as shown in Fig. 1, for the treatment of 0.3 and 0.6 m/s, the fan with the maximum air volume of 6 m^3 was adjusted by connecting to 0.2 kw inverter (output control device), and for the treatment of 0.9 m/s and 1.2 m/s, the fan with the



A B

Fig. 1. The photograph of wind velocity equipment for characterizing growth properties of oyster mushroom. A, chamber; B, cultivation room.

maximum air volume of 22 m^3 was connected to 0.4 kw inverter. At this time, the air velocity by the treatment was made to reach at the top portion of the mushroom bed, and the experiment was conducted only in the top portion. A vinyl duct was installed for the air distribution by the experiment, and it was prepared so that the air velocity according to the treatment has uniform effect on the mushroom beds. In addition, authors were conducted the cultivation experiments of three times after installing the vinyl sheets on the mushroom beds so that the change in the air velocity according to the treatment was prevented and the air velocity generated from the unit cooler has no effect on the mushroom beds, and the air velocity by the treatment was verified by using a air velocity sensor (AS-201, Graywolf Sensing Solutions. Co), and the growth in the cultivation room experiment was investigated over three times with 32 bottles by the treatment in the top portion.

The incubation temperature of both the chamber experiments and the experiment in the cultivation room experiments was 20±0.5°C, the relative humidity was controlled in 70±2%, and the experimental objects were incubated for 25 days. After the completion of the incubation of strain, the strain by scraping was standing upside down, and the growth temperature was 15±1°C, and the relative humidity was 90±5%, and the concentration of CO_2 was growth-managed as 1,000±200 ppm. To investigate the growth of the fruit body, the diameter of the wide end was measured as the size of a pileus, and the thickness of the lower portion away 10 mm from the wrinkle formation part was measured as the thickness of the stipe, and the yield per bottle was the total weight measured after remaining and cutting the base of 10mm from the entrance of the bottle. The divergency of the

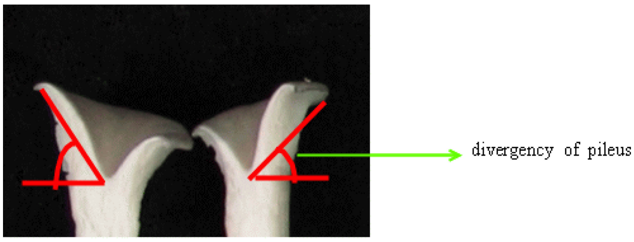


Fig. 2. Divergency of pileus

Table 2. Effect of air velocity on the physical properties of stipe of fruit body by chamber experiment

Air velocity (m/s)	Cohsivness (%)	Springiness (%)
0.3	68.9	88.4
0.6	66.0	70.3
0.9	58.1	65.3
1.2	55.4	60.8

pileus was the same as shown in Fig. 2, and it was measured by a goniometer. The commercialization ratio(%) of the fruit body was expressed multiplying 100 after dividing the quantity of good fruit body by the whole quantity. And the pileus of the fruit body which the growth has been completed were separated, and their cohesiveness and springiness were measured by a measuring instrument of properties (SUN RHEO meter, Compac-100D, Japan), and the pileus of the fruit body according to the air velocity treatment was obtained by 105°C dry weight method to investigate the moisture content of the pileus.

RESULTS AND DISCUSSION

Table 1 shows the growth characteristics according to the air velocity in the chamber, and it shows that the more the air velocity is faster, the less the thickness of a stipe becomes smaller, and the length of the stipe becomes shorter, and the standard deviation is larger. It showed that the quantity in 0.3 m/s treatment was larger than 133.1 g of 1.2 m/s treatment as 156.9 g. Table 2 shows the results analyzing the physical properties of the pileus, and because the cohesiveness in the 0.3 m/s treatment was larger than other treatment as 68.9%, and also the springiness was higher than other treatment as 88.4%, the more the air velocity was weaker, the springiness of the pileus showed a good tendency. Furukawa Furukawa (1992) has reported that the change of composition of cell wall according to the increase of a stipe had the positive correlation to the springiness increase of the mycelia and the increase of a stipe depending on the decomposition of the glucan molecule of wall structure, and also in this experiments, because the more the air velocity was weak, the more the increase of the stipe was developed, it was shown the tendency that the springiness was good. And it is determined that the more such springiness is good, the more it will be advantageous for the decrease of the damage rate of a pileus at the time of the packaging.

The quality in the chamber and the ratio of the commercial yield according to the air velocity are the same as shown in Table 3. As the results that investigate the angle between the end portion of a pileus and a stipe as the divergency of a pileus, the angle was the largest as 63° in 0.3m/s, and it was the smallest as 52° in 1.2m/s treatment. The moisture content of a pileus was also larger than other treatment as 90.2%, and it showed the tendency that the commercialization ratio was the highest in 0.3m/s treatment as 96%, and the more the air velocity is fast, the less both the moisture content and the commercialization ratio became lower. Fig. 3 shows the growth form in the chamber according to the air velocity processing. Viewing the growth initial germination characteristics after the first primordial day, the primordia form was uniform and the growth was good, whereas, partially browning phenomenon was generated in 0.6 m/s treatment. In

Table 1. Effect of air velocity on properties of fruit body by chamber experiment

Air velocity (m/s)	Size of pileus (mm)	Thickness of stipe (mm)	Length of stipe (mm)	Yield (g/850 ml)
0.3	31.0±1.3	9.1±1.0	93.1±6.1	156.9a[a]
0.6	30.1±1.9	9.4±1.2	88.6±9.4	142.1b
0.9	31.1±1.2	9.3±1.6	87.1±10.3	139.2b
1.2	30.0±1.5	8.9±1.2	80.5±13.2	133.1b

[a] Values followed by the same letter do not differ significantly at p>0.05 according to Duncan's multiple range test.

Table 3. Effect of air velocity on the development properties of fruit body and yields by chamber experiment

Air velocity (m/s)	Divergency of pileus(°)	Water content of pileus(%)	Commercial yields (g/850 ml)	Ratio of commercial yields (%)
0.3	63.0a[a]	90.2a	150.6	96
0.6	56.5b	86.3a	123.6	87
0.9	54.5b	77.1b	91.9	66
1.2	52.0b	72.6b	69.2	52

[a] Values followed by the same letter do not differ significantly at $p>0.05$ according to Duncan's multiple range test.

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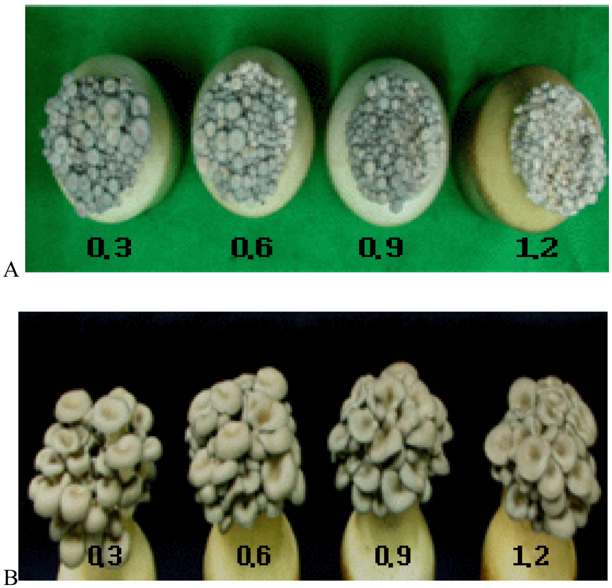

Fig. 3. Morphological properties according to air velocity. A. Formation of primordia (unit: m/s); B. Status of fruit body (unit: m/s)

addition, the pileuses were small in treatment of 0.9 m/s or more, and the browning phenomenon was generated. The growth from the growth initial to the harvest showed the bad growth condition that as the air velocity was faster, the entity growing at lower part of a pileus and entities growing at the upper area by being earlier generated showed the lump form by sticking to each other. According to Akira(1991), it has reported that the rising of air velocity allowed to increase the moisture transpiration of the fruit body and the moisture content of the fruit body was lowered and the growth was inhibited, and also in this experiments, it was the tendency that as the air velocity became faster, the moisture content of fruit body was lowered, and the growth was inhibited.

As the results that investigate the growth characteristics according to the air velocity in the actual cultivation room, they were the same as Table 4. Like the chamber experiment, the effect on the size or thickness of pileus did not significantly appear, and the thickness and length of stipe showed the tendency that the uniformity was decreased because the more the air velocity was faster, the more the standard deviation became larger. Also, the water quantity in 0.3 m/s was larger than 122.5 g in 0.9 m/s as 133.6 g.The yield and the commercialization ratio according to the air velocity are the same as shown in Table 5. The divergence of a pileus was similar to 63° of the chamber experiment as 64° in 0.3m/s, but it was the tendency that the more the air velocity was strong, the more the angle became larger unlike the chamber experiment. It is considered owing to the difference that in the chamber experiment, the air velocity is applied in the vertical direction from the top, and in the cultivation room, the air velocity is applied in the horizontal direction from the side(Fig. 4).

Akira(1991) has reported that if the wind enters in the

Table 4. Effect of air velocity on properties of fruit body by cultivation room experiment

Air velocity (m/s)	Size of pileus (mm)	Thickness of stipe (mm)	Length of stipe (mm)	Yield (g/850 ml)
0.3	30.5±1.7	8.1±0.9	86.4±4.1	133.6a[a]
0.6	30.3±2.0	8.1±1.2	85.4±5.3	129.4ab
0.9	30.0±2.4	8.0±1.3	83.6±5.6	122.5b
1.2	30.2±2.5	9.6±1.7	82.4±6.6	109.0c

[a] Values followed by the same letter do not differ significantly at $p>0.05$ according to Duncan's multiple range test.

Table 5. Effect of air velocity on the development properties of fruit body and yields by cultivation room experiment

Air velocity (m/s)	Divergency of pileus(°)	Water content of pileus(%)	Commercial yields (g/850 ml)	Ratio of commercial yields (%)
0.3	64.0c[a]	90.5a	126.7	94.8
0.6	67.1bc	90.2a	80.0	61.8
0.9	70.1ab	89.7b	42.5	34.7
1.2	74.5a	89.4c	22.5	20.6

[a] Values followed by the same letter do not differ significantly at $p>0.05$ according to Duncan's multiple range test.

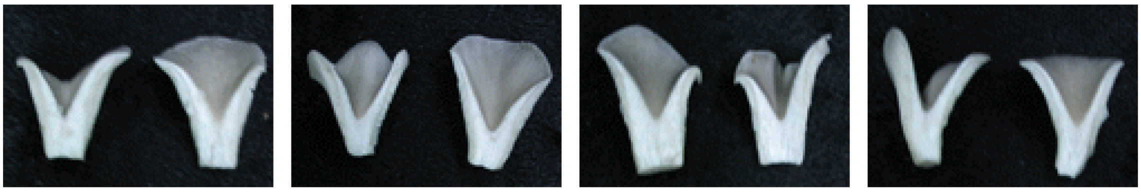

Fig. 4. Morphological properties of pileus according to air velocity.

horizontal direction, because the moisture content of the fruit body stipe is reduced, the phenomenon appears that the increase of stipe or the fruit body is curved-grown. And also, he has reported that the growth of mushroom is influenced by the wind direction, and in this experiment, it is matched to show other results with the cultivation room experiment and the chamber experiment, and after this, it is judged that the thorough review for the wind direction should be performed.

In the beech mushroom, if the wind reached to the fruit body in the air velocity of 0.4m/s from the horizontal direction, he has reported the growth was bad (Akira, 1991), and also it has reported that the range of the air flow rate should be 0.05~0.25 m/s (Bowman, 1987). Sung *et al*(1998) had reported about the course that promotes the generation of mushrooms by inhibiting the vegetative growth from the surface mycelia of the medium and converting the generative growth, by evaporating the moisture of the medium by adjusting the air velocity at the time of cultivation of *Flammulina Velutipes*, and Takatsuji (2001) had reported that *F. Velutipes* were cultivated by treating the air velocity of 0.8m/s in the inhibition process. In addition, it had reported that in the cultivation of shiitake mushroom, the increase of the air velocity increased the oxygen supply and influenced on the vegetative growth of mushrooms or the formation of fruit bodies, and the rising of the air velocity inhibited the growth because the moisture content of fruit bodies were reduced by increasing the moisture transpiration of fruit bodies (Lee, 2001), and it has reported that if the air velocity more than 6 hours in comparison with the case of no air velocity was composed, the growth and quality of shiitake mushrooms were good (Son, Choi, 2000). Thus, it is considered that there is the difference in the suitable air velocity for growth according to the kinds of mushrooms, and it has reported that in the case of oyster mushrooms, if the air velocity is faster, the deformity mushroom of a trumpet type was generated owing to that the form of the mushroom turned over to one side (Rural development administration, 2004), and also in this experiments, the deformity mushrooms of a trumpet type were generated in the air velocity of 0.6m/s or more. According to above results, the suitable air velocity for the growth of oyster mushroom is determined as 0.3m/s or less, and it is considered that the optimal air velocity should be maintained by installing an inverter (velocity converter), etc. so that the air velocity having an effect on the fruit bodies are not generated to 0.3m/s or more when the unit cooler or the ventilation fan in the cultivation room were operated.

ACKNOWLEDGEMENT

This work was supported by the the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) under Grant number (2017R1D1A3B03034601)

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