Characterization and Optimization of Indoor Environmental Quality on Grey Oyster (*Pleurotus pulmonarius*) Mushroom Cultivation

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MD TARIQUL ISLAM

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LIST OF ABBREVIATIONS

RH	Relative Humidity
MC	Moisture Contents
TWFFB	Total weight of Fresh Fruitbodies
DWFB	Dry Weight of Fruitbodies
PPI	Percentages of Primordial Initiation
NBPI	Number of Bags of Primordial Initiation
TNB	Total Numbers of Bag
PMF	Percentages of Mature Fruitbodies
NBMF	Number of Bags of Mature Fruitbodies
PDP	Percentages of Dead Primordia
BE	Bio-Efficiency
TWFB	Total Weight of Fruitbodies from each Bags
TWS	Total Weight of Substrate of each Bags
H1	Humidifier 1
H2	Humidifier 2
H3	Humidifier 3
H4	Humidifier 4
I	Interval
Kg	Kilogram
Cm	Centimetre
M	Meter
BSA	Bovine Serum Albumin
ML	Millilitre

DF	During Fruiting
DPI	During Primordial Initiation
IW	Individual Weight
NFB	Numbers of Fruitbodies
CD	Cap Diameter
SH	Stalk Height
MD	Mean Difference
LSD	Least Significant Difference
ANOVA	Analysis of Variance
MOA	Ministry of Agriculture Malaysia
P.	*Pleurotus*
spp.	*Species*
FAO	Food and Agriculture Organization
Min	Minute
RPM	Rotation per minute
L	Litre

Pencirian dan Pengoptimuman Kualiti Persekitaran Dalaman Terhadap Penanaman Cendawan Tiram Kelabu (*Pleurotus pulmunorius*)

ABSTRAK

Berdasarkan pemerhatian terhadap peningkatan permintaan cendawan, pengusaha cendawan menghadapi rintangan yang lebih mencabar disebabkan perubahan keadaan persekitaran yang tidak menentu. Mengawal dan memantau kualiti persekitaran di dalam penanaman cendawan adalah faktor penting untuk pengeluaran cendawan yang tinggi. Oleh itu, kajian ini dilakukan untuk memeriksa kesesuaian dan perkembangan pertumbuhan *P.pulmunarious* di dalam persekitaran dalaman. Untuk ini, rekabentuk kajian dijalankan dengan dua prosedur berbeza iaitu pencirian dan pengoptimuman persekitaran dalaman. Pencirian dijalankan dengan lima keadaan persekitaran yang berbeza iaitu Sistem 1 sehingga Sistem 5. Substrat untuk cendawn berlambang telah disediakan dengan mencampurkan habut kayu, dedak dan kapur pertanian untuk semua system penanaman dan behih telah disuntik. Dengan menggunakan substrat yang dipenuhi miselium, eksperimen tanaman cendawan telah dijalankan menggunakan Sistem 1 sehingga Sistem 5. Sistem 1 adalah persekitaran dalaman secara semula jadi manakala Sistem 2 hingga Sistem 5 menggunakan kaedah persekitaran dalaman berkelembapan dengan atau tanpa pengudaraan. Purata suhu dalaman paling rendah dan kelembapan tertinggi adalah pada Sistem 3 yang mana menunjukkan perbezaan ketara dengan semua sistem yang lain. Morfologi tertinggi dan kandungan kelembapan jana buah luar biasa juga ditemui di Sistem 3. Morfologi keseluruhan dan kandungan kelembapan jana buah di Sistem 3 telah menunjukkan perbezaan yang ketara berbanding dengan hasil dari sistem lain. Sebanyak 98.4% permulaan primodia dan 98.6% jana buah matang dengan 1.4% primodia mati ditemui di Sistem 3. Bacaan primodial terendah iaitu sebanyak 30.2% ditemui di Sistem 1. Bacaan terendah jana buah sebanyak 43.1% dan 42.4 %, dan bacaan tertinggi primodia mati adalah 56.9% dan 57.6% masing-masing ditemui di Sistem 4 dan Sistem 5. Bio-kecekapan (73.6%) tertinggi telah dicapai dalam penanaman Sistem 3. Prosedur pengoptimuman telah dijalankan oleh dua keadaan persekitaran berbeza iaitu Sistem 6 dan 7. Sistem 6 dijalankan seperti Sistem 3 dengan menambah jumlah alat kelembapan, pengudaraan dan jumlah beg substrat. Untuk ini, alat kelembapan dan pengudaraan nafas telah digunakan dengan satu gabungan dan lima aplikasi individu untuk mengoptimumkan tempoh pelembapan dan prosedur penanaman. Manakala Sistem 7 menjalankan penanaman secara luaran untuk perbandingan hasil kajian. Konfigurasi optima ditemui sebagai aplikasi selama 15 minit rawatan kelembapan dengan diikuti selang masa selama 15 minit bagi setiap alat kelembapan. Suhu yang paling rendah dan kelembapan paling tinggi didapati dalam Sistem 6. Morfologi dan kandungan kelembapan jana buah didapati paling tinggi di Sistem 6, dimana jumlah hasil sebanyak 261.8 kg yang mana 140.3 kg lebih tinggi daripade Sistem 7. Bacaan suhu menunjukkan hubungan negatif yang ketara dan kelembapan menunjukkan hubungan positif yang ketara dengan morfologi dan kandungan kelembapan di dalam jana buah. Sebaliknya, kandungan kelembapan, bilangan jana buah, diameter topi jana buah dan ketinggian tangkai telah menunjukkan hubungan positif yang ketara kepada berat setiap jana buah. Protein, karbohidrat, dan kandungan lipid didapati sama separti dalam keadaan penanaman biasa dan tidak ada perbezaan yang signifikan didapati dalam sistem penanaman. Hasil kajian ini, memainkan peranan utama untuk penanaman cendawan tertutup dengan menyediakan garis panduan tertentu untuk mengawal faktor-faktor persekitaran, pembangunan sistem penanaman yang lebih baik, meningkatkan morfologi cendawan, kualiti dan hasil, risiko rendah pencemaran dan akhir sekali bagi memastikan pengeluaran berterusan cendawan bebas dari cuaca untuk sepanjang tahun.

Characterization and Optimization of Indoor Environmental Quality on Grey Oyster (*Pleurotus pulmonarius*) Mushroom Cultivation

ABSTRACT

In view of increasing demand, mushroom cultivators are facing more challenges and difficulties to grow mushroom due to inconsistent environmental conditions. Controlling and monitoring of environmental quality in mushroom cultivation is an important factor for high mushroom production. Therefore, this study was initiated to examine the suitability and growing performance of *P. pulmonarius* in indoor environmental condition. For this, the experimental design was followed by two different procedures as characterization and optimization of the indoor environment. Characterization procedure was conducted by mushroom cultivation in five different environmental conditions including from System 1 to System 5. The substrate for mushroom growing was prepared by mixing of sawdust, rice bran and agricultural lime for the all cultivation systems and spawn was inoculated. After completing mycelium colonization the experimental mushroom cultivations were conducted by System 1 to System 5. System 1 was the natural indoor environment whereas from System 2 to System 5 were the indoor humidifying environment with or without ventilation. The lowest mean indoor temperature and the highest mean humidity was found in System 3 which showed significant results with all other systems. The highest morphology and outstanding moisture containing fruitbodies were also found in System 3. The highest 98.4% primordial initiation and 98.6% mature fruitbodies formation with the lowest 1.4% dead primordia were found in System 3. The lowest 30.2% primordial initiation was found in System 1. The lowest 43.1% and 42.4% mature fruitbodies and the highest 56.9% and 57.6% dead primordia were found in System 4 and 5 respectively. The highest bio-efficiency (73.6%) of yield was achieved in the cultivation of System 3. The optimization procedure was conducted under two different environmental conditions as named System 6 and System 7. System 6 was followed by the procedure of System 3 with additional numbers of the humidifier, ventilation, and substrate bags. For this, the humidifiers and ventilations were applied by one combined and five individual treatments to optimize the humidifying duration and cultivation procedure. On the other hand, outdoor cultivation was conducted as System 7 for comparison study. The optimized configuration was found as the application of 15 mins humidifying treatment and followed by 15 mins interval period for each humidifier. The lowest temperature and highest humidity were found in System 6.The morphology and moisture contents of fruitbodies were found significantly high in System 6, where the total yield was found 261.8 kg which was 140.3 kg higher than System 7. The temperature showed significant negative correlation and the humidity showed significant positive correlation with the morphology and moisture contents of fruitbodies. On the other hand, moisture contents, numbers of fruitbodies, cap diameter and stalk height had shown significant positive correlation with individual weight. The protein, carbohydrate, and lipid contents were found similar to conventional cultivation and no significant different was found among the cultivation systems. The outcomes of the present research may play a key role in indoor mushroom cultivation by specific guideline to control environmental factors, develop better cultivation system, improve mushrooms morphology, quality, and yield, low risk of contamination and finally ensure continuous weather independent mushroom production throughout the years.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Mushroom cultivation in Malaysia is getting important due to it's outstanding nutritional and medicinal properties which are 100% vegetarian food and is good for the patient of diabetes and joint pains. The demand of mushrooms especially the grey oyster mushroom (*Pleurotus pulmonarius*) is greater than their production. It's easy to consume and offers high income to local growers due to its ability to grow and fruiting in subtropical and tropical region. *P. pulmonarius* also known as *P. sajor-caju*, is a valuable edible mushroom, commonly called the grey oyster mushroom (Avin, 2014).

In Malaysia, the mushroom has been cultivated since the early 1970s and now mushroom is declared as an industrial crop. As an industrial crop, the mushroom has been included in National Agro-Food Policy Malaysia 2011-2020. The objective of this policy is to ensure sufficient mushroom supplies and to increase the income of cultivators. The most strategies of this policy are to increase production and productivity and control the quality of production. In the policy, the estimated target of mushroom production has to increase by 16 % in every year, from 15 thousand metric tons in 2010 to 67 thousand metric tons in 2020. Where the export value projected to increase about RM300 million in 2020 at the rate of 16.1 % per year (Ministry of Agriculture Malaysia, 2011).

Typically, the number of mushroom growers in different states of Malaysia are fluctuating, because of unstable production and market changes. However, the total number of growers in Malaysia has reportedly increased in every year. In 2007, the total cultivators were 339 which are reached 428 in 2014. Johor, Selangor, and Pahang states are leading in mushroom producers, probably because of the higher demand especially from Chinese Malaysian population (Rosmiza, Davies, Jabil, & Mazdi, 2016). But most of them (about 80%) are small growers and produce below 50 kg per hectare of fresh mushrooms in a day. The medium scale (produce 50-500 kg per day) growers constitute 17% and big scale industries (producing more than 500kg per day) are around 3% only (Haimid, Rahim, & Dardak, 2013).

Although the numbers of mushroom growers in Malaysia are increasing but a lot of mushrooms have to import into Malaysia from other countries mainly from China, Thailand, Hong Kong and Taiwan which is still increasing. According to the report of Rosmiza et al. (2016), mushroom export has increased by about 19% in a year from RM12 million in 2000 to RM67 million in 2008. But the exports slightly dropped from 8302.96 metric tons in 2008 to 3190.26 metric tons in 2013. On the other hand, the import has increased from more than 21 thousand tons in 2004 to 24.5 thousand tons in 2013. This increment of import being partly due to less production, increasing population and a reported higher concern towards health (Mohd-Syauqi, Tapsir, Alam, Hasnul, & Mohd-Zaffrie, 2014).

Together with increasing numbers of mushroom growers, they are not able to produce more mushroom as demand. According to the Ministry of Agriculture 2010 (Haimid et al., 2013), in local market daily demand for fresh mushroom is 50,000 kg while the supply is only 24,000 kg. The most important fact is that the mushroom growers are facing more challenges and difficulties to grow mushrooms due to the inconsistent environmental conditions. The environment is considering the most important physical factor for mushroom production and quality. Referring to the

Agriculture and Food Development Authority Malaysia (2013), the production deficit of mushroom in the year 2009 was approximately 11,000 tons than the previous year. This deficit happened mainly due to the inconsistent environmental conditions of Malaysia by high temperature and low humidity.

This reduction of mushroom production is mainly due to the variation of environmental conditions because most of the mushroom cultivators depend on the outdoor cultivation. So, they are unable to control the inconsistent weather of high temperature and low humidity. They just depend on the natural weather of Malaysia that can reduce the production, morphology, and quality. Even, sometimes this type of mushroom have more risk for pest infection that can be an unhygienic food to the consumers (Fletcher & Gaze, 2007; Singh & Sharma, 2016).

The geography of Malaysia deals with the tropical climate, a country located in Southeast Asia. Malaysia is situated in the equatorial doldrums' area, has a geographic coordinate that reads 2° 30' North latitude and 112° 30' East longitude**.** Malaysia has tropical weather, influenced by monsoonal climate because of its latitude and longitude (Figure 1.1). Tropical climate here gives hot summer that is accompanied with low humidity level. So, the weather of Malaysia is generally hot and sunny throughout the year especially during February to October. During the hot season, the temperature may rise up to 41˚C which may cause very low relative humidity.

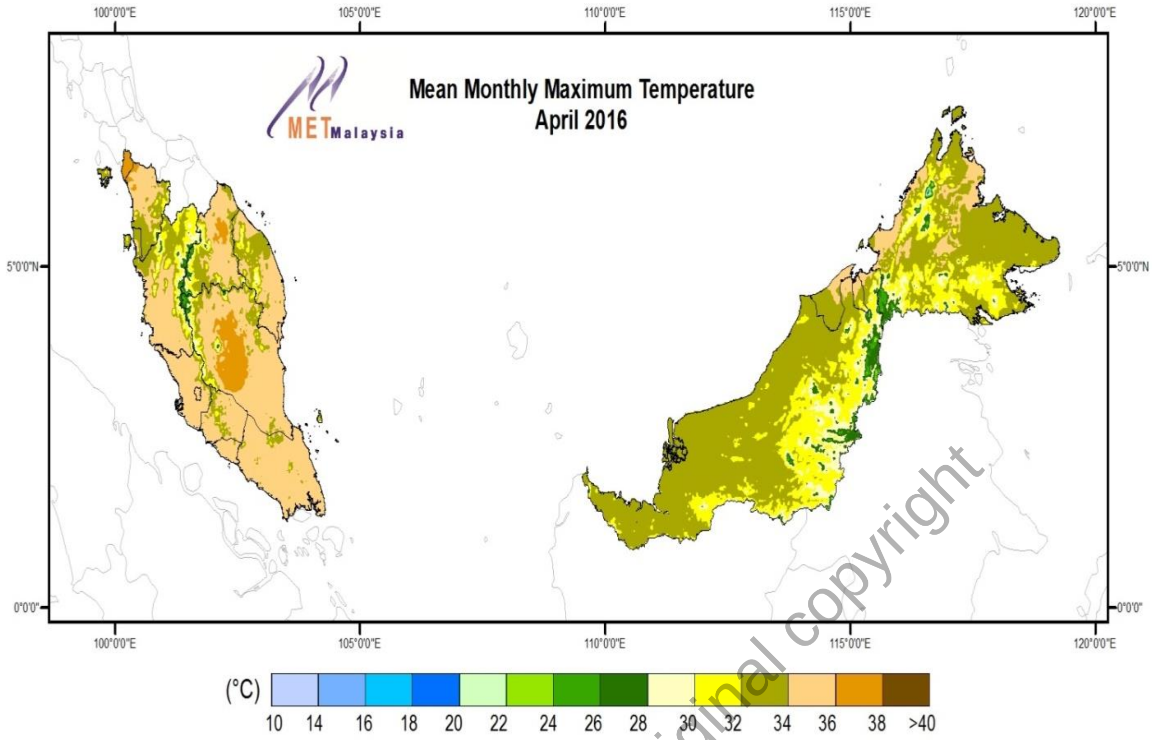

Figure 1.1: Geographic Map of Malaysia with latitude and longitude direction presenting the temperature in April 2016 (Malaysian Metrological Department, 2016).

In the annual report of Malaysian Metrological Department (2015), the maximum 31.2 to 34.1 ˚C and minimum 22.3 to 24.4 ˚C temperatures was varied throughout the year whereas the maximum relative humidity at day was varied 60-67% and 94-96% at night. Moreover, the temperature and humidity in both indoor and outdoor environment are shown inversely proportional to each other. The indoor humidity is lower than outdoor at night since at night the indoor temperature was found higher than the outdoor environment (Wafi, Ismail, & Ahmed, 2011). The highest outdoor temperature of this running year 2016 was recorded 39.3 ˚C in April which caused the lowest relative humidity (Malaysian Metrological Department 2016, Figure 1.1). Whereby, *Pleurotus* species able to grow in 25-30 ˚C temperature and 80-90% humidity (Newsham, 2012; Sher, Al-Yemeni, Bahkali, & Sher, 2010; Uddin et al., 2011).

So, the environment seems to be very important factors for induction of primordial initiation and fruitbodies formation. The appropriate environment is not only crucial for production, but also influences the ideal morphology and quality. Inappropriate temperature and humidity inhabit the mushroom growth and can even wilt and die. Most studies focusing on the relationship of mushroom cultivation with spawn, substrate and nutritional value. Some studies had performed on the environment to find out suitable species for the suitable season in the multi-seasonal country. Some studies also investigated the mushroom production in the artificially controlled indoor environment to find out the optimum ranges of humidity, temperature, carbon-dioxide and light intensity for maximum bio-efficiency (Jang et al., 2003; Seung, Byun, You, & Park, 1984; Yang et al., 2013). For controlling the environment, most of the studies used the air conditioner, evaporative cooler, growth chamber and other different cooling systems which are expensive, high operation costing and not suitable for large or commercial cultivation.

As the temperature and humidity of Malaysia weather is far from the optimal condition for oyster mushroom cultivation. With the traditional or conventional method used by most cultivators, is difficult to achieve the maximum yield as required. Moreover, it is important to know the characteristics of indoor environment for mushroom cultivation in Malaysia. Therefore, this study was conducted to develop a design and optimization procedure to control the indoor environment for the maximum growing performance that leads to ensure continuous mushroom production throughout the year independence of weather and climate change. Moreover, this study is very much relevance to the 2011-2020 Malaysia Agro-food Policy which one of the objectives is to enhance mushroom production.