Volvariella volvacea (Bull.) Singer MUSHROOM PRODUCTION CULTIVATED USING OIL PALM EMPTY FRUIT BUNCH IN AYER HITAM FOREST RESERVE, PUCHONG, SELANGOR, MALAYSIA

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Forest farming of straw mushrooms (*Volvariella volvacea*) could be a potential agroforestry practice that increases crop diversity while conserving forest ecosystem, however, there were some constraints on mushroom cultivation process. To date, specific information for straw mushroom cultivation using oil palm empty fruit bunch as substrate, particularly suitable microclimatic conditions, best practices, composting period and composting parameters are limited. Hence, the objectives of this study were; (i) to determine the effect of microclimate (air temperature, relative humidity, light intensity), and bed pH on *V. volvacea* mushroom production, (ii) to determine the effect of bed orientations, bed conditions (temperature, humidity, pH) and other attributes (i.e., harvesting week, cultivation month and replication) on *V. volvacea* mushroom production, and (iii) to assess the composting period and composting condition of EFB (temperature, pH, moisture content, oxygen level, and carbon monoxide level) on *V. volvacea* mushroom production in lowland dipterocarp forest. Outdoor cultivation method was carried out with four replications from November 2017 until May 2019. The microclimatic conditions (air temperature, relative humidity, light intensity) and bed pH were compared between replications. Generalized linear models (GLMMs) were used to examine the relationship of mushroom production with 7 predictor variables (bed temperature, bed humidity, bed pH, bed orientation, harvesting week, cultivation month and replication). Correlation tests for multi-collinearity among variables were also conducted. One-way ANOVA was done to determine the significant result between composting periods of 9 and 12 days on *V. volvacea* production. Additionally, the change in chemical composition of EFB was analyzed using FT-IR Spectroscopic Analysis. The results revealed that *V. volvacea* production was affected by microclimatic and bed conditions. The highest production of *V. volvacea* was recorded with 49,446 g that requires temperature, relative humidity, light intensity and bed pH at 29.4°C, 79.68%, 505.5 lx and pH 6.92, respectively. Bed orientations and bed pH were insignificant, however bed humidity, bed temperature,

harvesting week, cultivation month and replication significantly influenced *V. volvacea* production. Composting periods of 9 and 12 days did not significantly affect the *V. volvacea* production. The highest production, R2 indicated that the suitable composting parameters were 33.65 - 71.47°C, pH 6.5 - 7, normal MC, oxygen level more than 10% and 0 - 90 rpm carbon monoxide. In conclusion, cultivation of *V. volvacea* is ethnically feasible under a tropical agroforestry system.

Keywords: *Volvariella volvacea*, oil palm empty fruit bunch, substrate, lowland dipterocarp forest, microclimate, outdoor cultivation

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PENGELUARAN CENDAWAN *Volvariella volvacea* (Bull.) Singer MENGGUNAKAN TANDAN KOSONG KELAPA SAWIT DI HUTAN SIMPAN AYER HITAM, PUCHONG, SELANGOR, MALAYSIA

Oleh

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Perhutanan tani untuk cendawan jerami (*Volvariella volvacea*) dapat menjadi amalan agroperhutanan yang berpotensi untuk meningkatkan kepelbagaian tanaman di sambil memelihara ekosistem hutan, namun terdapat beberapa kekangan dalam proses penanaman cendawan. Sehingga kini, maklumat khusus untuk penanaman cendawan menggunakan tandan kosong kelapa sawit sebagai substrat, terutama sekali keadaan iklim mikro, amalan terbaik, tempoh pengkomposan dan parameter pengkomposan adalah terhad. Oleh itu, objektif kajian ini adalah; (i) untuk menentukan kesan iklim mikro (suhu udara, kelembapan relatif, pH, keamatan cahaya dan pH batas terhadap pengeluaran cendawan *V. volvacea*, (ii) untuk menentukan kesan orientasi batas, keadaan batas (suhu, kelembapan, pH) dan atribut lain (minggu penuaian, bulan penanaman dan ulangan) terhadap pengeluaran cendawan *V. volvacea* dan (iii) untuk menilai tempoh pengkomposan EFB (suhu, pH, kandungan kelembapan, paras oksigen dan karbon monoksida) terhadap pengeluaran cendawan *V. Volvacea* di hutan dipterokarpa pamah. Kaedah penanaman luar dijalankan dengan empat ulangan dari November 2017 hingga Mei 2019. Keadaan ilkim mikro (suhu udara, kelembapan relatif, keamatan cahaya) dan pH batas dibandingkan antara ulangan. Model linear umum (GLMMs) digunakan untuk memeriksa hubungan penghasilan cendawan dengan 7 pemboleh ubah ramalan (suhu batas, kelembapan batas, pH batas, orientasi batas, minggu penuaian, bulan penanaman dan ulangan). Ujian hubungkait untuk pelbagai garisan antara pelbagai pemboleh ubah juga dijalankan. ANOVA satu hala dijalankan untuk menentukan hasil signifikan antara tempoh pengkomposan 9 dan 12 hari terhadap pengeluaran *V. volvacea*. Setelah itu, perubahan dalam komposisi kimia EFB dianalisis menggunakan Analisis Spektroskopik FT-IR. Dapatan kajian menunjukkan bahawa pengeluaran *V. volvacea* dipengaruhi oleh keadaan iklim mikro dan keadaan batas. Pengeluaran cendawan tertinggi dicatatkan dengan jumlah 49,446 g dengan memerlukan suhu, kelembapan relatif, keamatan cahaya dan pH batas masing-masing pada 29.4°C, 79.68%, 505.5 lx dan pH 6.92. Sementara itu, orientasi batas dan

pH batas tidak signifikan namun kelembapan batas, suhu batas, minggu penuaian, bulan penanaman dan ulangan mempengaruhi pengeluaran *V. volvacea* secara signifikan. Tempoh pengkomposan 9 dan 12 hari tidak menunjukkan hasil yang signifikan terhadap pengeluaran *V. volvacea*. Pengeluaran cendawan tertinggi, R2 menunjukkan bahawa parameter pengkomposan yang sesuai ialah 33.65 – 71.47°C, pH 6.5 – 7, MC normal, kadar oksigen melebihi 10% dan karbon monoksida 0 – 90 rpm. Kesimpulannya, penanaman *V. volvacea* boleh dilaksanakan secara beretika di bawah sistem agroperhutanan tropika.

Kata kunci: *Volvariella volvacea*, tandan kosong kelapa sawit, substrat, hutan dipterokarpa pamah, iklim mikro, penanaman luar

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AHFR	Ayer Hitam Forest Reserve
AICRP	All India Coordination Research Project
ANOVA	Analysis of Variance
BE	Biological Efficiency
C:N	Carbon nitrogen
CRD	Completely randomized design
EFB	Empty fruit bunch
E-W	East-West
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization of United Nations
FBD	Fruiting body development
FTIR	Fourier Transform Infrared
GLMMs	Generalized Linear Mixed Models
MC	Moisture content
MPOB	Malaysian Palm Oil Board
NAP	National Agrofood Policy
NCP	National Commodity Policy
N-S	North-South
PPF	Palm pressed fiber
SD	Standard deviation
SE	Standard error

CHAPTER 1

INTRODUCTION

1.1 Background of study

The paddy straw mushroom, *Volvariella volvacea* is one of the most popular cultivated mushrooms in Southeast Asia. It is well known for its highly nutritious value, contains a good amount of protein, crude fibre and ash, all make it a healthy diet as well as contains a superior composition of various elements and essential amino acids (Biswas, 2014). There was no other vegetable or cultivated mushroom found that can be served as a table dish within a short time from its planting, but *V. volvacea* can do this as it comes to harvest on 10^{th} day (Thiribhuvanamala et al., 2012). Using paddy straw for the substrate was the oldest and most commonly used technique.

Unlike the commercial production of paddy straw mushrooms in neighboring countries such as China, Indonesia and Thailand, production in Malaysia is still very limited due to a lack of technical know-how for mushroom cultivation. This paddy straw mushroom can be found in tropics and subtropics which grow well on cellulosic agricultural waste (Zikriyani, Saskiawan & Mangunwardoyo, 2018).

Agricultural wastes such as sawdust, cotton waste and paddy straw are suitable for the cultivation of edible mushrooms (Ahlawat & Tewari, 2007). There were also studies on the cultivation of paddy straw mushrooms using oil palm empty fruit bunch (EFB) as raw material (substrate) (Triyono et al., 2019; Sakinah et al., 2019; Rauf, 2017; Ukoima et al., 2009). Usually, EFB waste is commonly applied for incineration process or dumping. Thus, in order to make full use of natural resources produced in Malaysia, EFB is utilized. EFB biomass is also composed of 24% xylan, a sugar polymer made of pentose sugar xylose which can be used as a substrate for the production of a wide variety of compounds (Rahman, 2007). One such compound is xylitol, extensively used in food, pharmaceutical, thin coating applications and alternative sweetener (Parajo et al., 1995; Torget et al., 1991; Pepper and Olinger, 1988).

Besides microclimate factors, the state of compost (substrate) of mushrooms could influence the growth. Composting period (i.e., days or duration) (Triyono et al., 2019; Rauf, 2017) and parameters measured in composting (i.e., temperature, moisture content, pH, oxygen and carbon monoxide) (Gummert et al., 2020) are among the state of compost that has the potential to give impact on *V. volvacea* mushroom production. Recently, Hasim (2019) studied the relationship between conditions of cultivation bed such as bed orientations, bed temperature and bed humidity on *V. volvacea* mushroom production although it was reported that production was not significantly affected by all factors.

1.2 Problem statement

Due to the low rubber prices in Malaysia, rubber smallholders in Kedah have been cultivating *V. volvacea* mushroom since 2015 using oil palm EFB as substrate. Looking at the success in Kedah, the government has suggested cultivating mushrooms in a degraded forest (Star Online, 2018). With the existing information on mushroom cultivation, our smallholders started to grow them. However, the existing information may or may not be helpful in a different scenario of degraded forest areas. The area is shaded under tree canopies, decreasing the air temperature and humidity level in the area. Levels of moisture and temperature are very essential for mushroom growth to the extent that different ranges of moisture and temperature are more suitable for certain types and species of mushroom.

To date, specific information on microclimatic conditions such as air temperature, relative humidity and soil pH throughout the process of mushroom production, i.e., composting, incubation and harvesting, is limited. Not much data is available for smallholders to cultivate mushrooms. Hence, this study helps to contribute towards a better understanding by filling up the gaps in *V. volvacea* mushroom cultivation system. Mushroom bed (growing area) plays an important part in mushroom cultivation. Information regarding mushroom bed such as shape and sizes were documented in some studies, but limited information was found on mushroom bed orientation, specifically in Malaysia.

Meanwhile, some researchers have cultivated mushrooms under the forest canopy to take advantage of the natural and tropical climate. For instance, *V. volvacea* was cultivated under shade trees in India (Gupta et al., 2018; Thakur & Singh, 2014). This study attempts to observe the potential of mushroom cultivation under tree-shaded areas or a forest canopy.

Composting is one of the most important biological processes that involve the decomposition of organic material into compost which is beneficial in mushroom cultivation. It is undeniable that studies on composting have been widely written and documented in studies for decades. Although many composting studies were found, the detail information on composting period and composting parameters (temperature, pH, moisture content, oxygen and carbon monoxide level) is scarcely found in Malaysia. Therefore, the hypothesis for the study is:

1) Microclimatic factors (air temperature, relative humidity) and soil pH could have a significant effect on *V. volvacea* mushroom production in a logged-over forest.
2) Bed orientation (North-South, East-West) could affect the abundance and weight of *V. volvacea* mushroom due to the direction of sunlight taken into the mushroom bed.
3) Most optimum composting period and composting condition such as temperature, moisture content, oxygen as well as carbon monoxide level

during the composting process that might affect *V. volvacea* mushroom production could be determined.

1.3 Objectives

The main objective of this study is to investigate the *V. volvacea* mushroom production cultivated using EFB substrate in lowland dipterocarp forest area as one of the agroforestry initiatives. The specific objectives are as follows;

1) To determine the effect of microclimate (air temperature, relative humidity, light intensity) and bed pH on *V. volvacea* mushroom production.
2) To determine the bed orientations, bed conditions (i.e., bed temperature, humidity, pH) and other attributes (i.e., harvesting week, cultivation month and replication) on *V. volvacea* mushroom production
3) To assess the composting period (i.e., 9 and 12 days) and composting parameters of EFB (i.e., temperature, pH, moisture content, oxygen level, carbon monoxide level) on *V. volvacea* mushroom production.

1.4 Significance of study

Mushroom cultivation has great potential to become one of the agroforestry practices in this country. Due to human activities such as deforestation, land degradation and greenhouse gas emissions, forest is deteriorating. This study promotes optimal utilization of abandoned or degraded forest areas to increase the yield of non-timber forest products. Smallholders in Malaysia could benefit by integrated farming in their ready farm areas to generate more income and not depending on certain crops only, in line with the *Dasar Komoditi Negara 2011-2020*. Cultivation in the forest is also one of the agroforestry approaches that benefit people's economic, environmental, and social need of people. Better protection of ecological systems, increment of soil nutrients and reduction of surface run-off are among the benefits of practicing agroforestry. Nevertheless, mushroom cultivation also helps enhance food security in our country.

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