



Research Article

Vermicomposting Mushroom Waste to Enhance Phoenix Oyster Mushroom (*Pleurotus pulmonarius*) Cultivation via Circular Economy

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ABSTRACT

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This research aimed to study the yield of Phoenix oyster mushrooms (*Pleurotus pulmonarius*) using vermicompost derived from spent mushroom substrate. The vermicompost was produced by using spent mushroom compost as both food and habitat for earthworms. Vermicompost was mixed to replace rice bran in ratios of 100%, 75%, 50%, 25%, and a control group without vermicompost. The experiment followed a completely randomized design (CRD). Nutrient analysis of the vermicompost produced from the spent mushroom substrate revealed moisture content of 20.29–36.35%, pH of 7.51–8.24, total nitrogen of 1.21–1.64%, total phosphorus of 0.52–0.77%, total potassium of 4.34–5.23%, and a carbon-to-nitrogen ratio of 15.90–31.40. These values comply with the organic fertilizer standards of the Department of Agriculture of Thailand. Analysis of phoenix oyster mushroom yield using vermicompost as a substrate mixture showed that the 75% vermicompost ratio produced the highest fresh weight and stem length. The number of mushrooms and cap diameter also tended to be highest at this ratio. The yield in terms of fresh weight and cap diameter of Phoenix oyster mushrooms was significantly different from that of mushrooms grown without vermicompost, whereas the number of mushrooms and stem length did not show significant differences across all treatments. These findings suggest that vermicompost enhances mushroom growth compared with the original formula without vermicompost.

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1. Introduction

Currently, increased consumption has led to greater resource use, resulting in the depletion of natural resources due to production processes and the generation of substantial waste. Consequently, the concept of the circular economy has garnered widespread attention and cooperation. Mushrooms are agricultural products with high production potential, including oyster mushrooms (*Pleurotus ostreatus*), Phoenix oyster mushrooms (*Pleurotus pulmonarius*),

jelly ear mushrooms (*Auricularia polytricha*), and straw mushrooms (*Volvariella volvacea*). In 2020, Thailand produced approximately 150,000 tons of mushrooms, valued at over 9 billion baht (266 million USD) (Chinnawong and Longja, n.d.). After mushroom cultivation, a large amount of spent mushroom substrate remained in the area (Nopparatmaitree *et al.*, 2017), posing a disposal problem. One method of disposing of organic waste is vermicomposting, where earthworms break down the waste into nutrient-rich compost. Vermicompost not only reduces organic

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waste but also enhances plant growth and soil health. It consists of fine, brownish-black granules that are light, airy, with good drainage and air circulation. It has a high moisture capacity and contains abundant organic matter. This results from the decomposition of organic waste by earthworms. The activity of microorganisms and digestive juices in the earthworms' intestines converts nutrients from organic debris into forms that plants can utilize.

Previous research has explored the use of various waste materials as components in mushroom cultivation or as a fertilizer for other crops. For instance, empty palm fruit bunches have been used to make straw mushroom substrates, and spent mushroom lumps have been used as a fertilizer in mangosteen orchards. This practice was found to increase the availability of secondary nutrients, supplementing but not entirely replacing chemical fertilizers (Kuntad *et al.*, 2012). Additionally, waste materials such as pineapple pulp, sawdust, and bamboo left over from chopstick production have been successfully utilized in the cultivation of Phoenix oyster mushrooms (Srinak *et al.*, 2012; Pongthornpruek and Kraiwuttinan, 2013). Moreover, the fronds or petioles of oil palm that are cut off and allowed to decompose naturally can be used as a material for growing mushrooms as well (Seephueak *et al.*, 2021). From the above information, therefore, this

research applies the circular economy concept to the Phoenix oyster mushroom farm community enterprise. It utilizes spent Phoenix oyster mushroom compost as food and bedding for earthworms. The resulting vermicompost is then used as an ingredient in Phoenix oyster mushroom compost. This approach comprehensively repurposes agricultural waste to enhance productivity and improve the soil structure and chemical properties, providing essential plant nutrients, reducing reliance on chemical fertilizers, and returning organic matter to the soil. This enhances soil fertility, making it suitable for the next cultivation season.

2. Materials and Methods

2.1 Preparing habitat and food for earthworms

The spent mushroom substrates were sun-dried to eliminate fungi that might grow in the mushroom compost. After that, they were mixed with cow manure in a ratio of 1:1 to be used as bedding and food for African Night Crawler earthworms (*Eudrilus eugeniae*). Vermicompost samples were collected every 15 days for 45 days and analyzed for mineral nutrients, including moisture, pH, total nitrogen (Total N), total phosphorus (Total P_2O_5), total potassium (Total K_2O), and carbon to nitrogen ratio (C/N ratio), and the analytical methods are shown in Table 1.

Table 1 Analytical methods of the vermicompost

Parameters	Method
Total Nitrogen	Total Kjeldahl method
Phosphorous (Total P_2O_5)	Vanadomolybdate (Barton) method
Potassium (Total K_2O)	Atomic Emission Spectrophotometry
C/N ratio	Walkley Black modified acid-dichromate digestion, $FeSO_4$ titration method
pH	pH meter
Moisture content	Oven - drying method

2.2 The productivities of phoenix oyster mushroom with vermicompost

In this study, a Completely Randomized Design (CRD) was employed to evaluate the effects of five different vermicompost formulas derived from spent mushroom compost. The formulas replaced rice bran in varying proportions: 0% (control), 25%, 50%, 75%, and 100% vermicompost. The experiment was conducted over 30 days. Data were collected on fresh weight, number of fruiting bodies, cap diameter, and stem length.

Mushroom compost, the mixing ratio includes 100 kilograms of rubberwood sawdust, 5 kilograms of rice bran, 1 kilogram of rice flour, 0.2 kilograms of magnesium sulfate, 1 kilogram of calcium carbonate, and 60-70% clean water. Vermicompost is used to replace rice bran in different proportions: 0% (control), 25%, 50%, 75%, and 100% vermicompost. After preparing the formula with various ratios, mix all the ingredients together as shown in Figure 1(a) and put them in plastic bags for mushrooms cultivation. Immediately steam the spawns to pasteurize for about 3-4 hours, then let them cool, as shown in Figure 1(b). Transfer the phoenix oyster mushroom spawn cultivated on sorghum seeds, using approximately 10-20 seeds per inoculum, into the cooled substrate mixture under aseptic conditions. Immediately seal the cultivation bags with sterile cotton plugs to prevent contamination. Maintain aseptic conditions in the transfer area and sterilize inoculation tools with alcohol between each use to prevent contamination. Place the inoculated spawn substrates in an incubator with controlled temperature and humidity conditions. After sufficient mycelial colonization of the substrate, fruiting bodies will begin to form within approximately 3-4 days. All experimental replications were conducted within controlled cultivation facilities where temperature, humidity, and light conditions were uniformly maintained across all treatments. Collect mushroom samples daily for 30 days, analyzing the yield by measuring the size and weight of the phoenix oyster mushrooms in term of g/bag.



(a)



(b)

Figure 1 Sample preparation for each experiment; ingredients for each experimental formula (a), incubation stage (b)

2.3 Data analysis

Data were collected on phoenix oyster mushroom growth, including the fresh weight, the number of fruiting bodies, the diameter of the mushroom caps, and the length of stalk. The data were analyzed using SPSS software, and differences between treatments were compared with the Duncan's Multiple Range Test (DMRT) at a 95% confidence level.

3. Results and Discussion

3.1 Properties of vermicompost

The results of the nutrient content in vermicompost produced from spent phoenix oyster mushroom substrate. During the time of the experiment,

it was found that the moisture content was 25.2%, the pH was 7.81, the total nitrogen was 1.43%, the total phosphorus was 0.61%, the total potassium was 4.82%, and the C/N ratio was 26.17%, respectively. All values are in accordance with the organic fertilizer standards of the Department of Agriculture of Thailand. The composition of nitrogen, phosphorus, and potassium in the compost depends on the type of organic waste. Vermicompost is effective due to their fine texture, porosity, ventilation and humidity. These characteristics influence the activity of microorganisms, soil nutrient absorption, and plant growth (Jaitea, 2015).

According to the report of Sriwongchai (2017), it was found that spent mushroom compost has a main component of lignocellulose and contains structures such as cellulose and hemicellulose, which make up more than 50% of its dry weight. The study by Chuphong *et al.* (2012) produced vermicompost from water hyacinth. It was found that waste materials were used as food and bedding for earthworms, including sawdust, dry rice straw, crushed eggshells, and paper. The materials used for mushroom and water hyacinth cultivation were mixed in the ratio of 1:1:1:1:1:3. This experiment found a moisture content of 24.67%, a pH of 8.2, a total nitrogen content of 1.44%, a total phosphorus content of 1.05%, a total potassium content of 2.08%, and a carbon to nitrogen ratio of 25%. In addition, Jianwichayakul and Somniyam (2021) studied vermicompost from water hyacinth. The local earthworms *Polypheretima elongata* (PE) and the commercial earthworm *E. eugeniae* (EE) were grown on food with four different ratios of water hyacinth and cow manure: water hyacinth (control), water hyacinth (WH) to cow manure (CM) at 3:1, 4:1, and 5:1. The

results of the study found that EE produced vermicompost with higher total N and organic matter than PE, but the total P, total K and pH were not different. The ratio of water hyacinth and cow manure is suitable for producing vermicompost. It was found that using a ratio of 4:1 gave the highest yield, but the nutrient content did not differ across all treatments.

3.2 Effects of vermicompost on the quality of phoenix oyster mushrooms

3.2.1 Total weight and number of fruiting bodies of phoenix oyster mushrooms

Regarding the fresh weight, the results showed significant differences between the control and vermicompost formulas. The formula with 75% vermicompost yielded the highest average fresh weight of 43.17 grams, followed by the 100% vermicompost formula, which had an average of 42.09 grams. The use of the 50% and 25% vermicompost formulas resulted in average fresh weights of 40.97 and 40.24 g, respectively. The control (0% vermicompost) had the lowest average fresh weight at 34.26 g/bag (Table 2).

Regarding the number of fruiting bodies, no significant differences were observed between the formulas. The 100% vermicompost formula had the highest average number of flowers at 5.05 basidiocarps/bag. This was followed by the 25% and 75% vermicompost both with an average of 4.90 basidiocarps/bag. The 50% vermicompost formula had an average of 4.84 basidiocarps/bag, while the control group had the lowest average number of flowers at 4.66 basidiocarps/bag. The productivity of the Phoenix oyster mushroom is shown in Table 2.

Table 2 Productivities of phoenix oyster mushroom in the first flush

Vermicompost:Rice bran (v/v)	Fresh weight (g /bag)	Number of fruiting bodies (basidiocarp/bag)
0 : 100	34.26±1.51 ^{b 1/}	4.66±0.09
25 : 75	40.24±1.67 ^a	4.90±0.32
50 : 50	40.97±1.70 ^a	4.84±0.13
75 : 25	43.17±7.08 ^a	4.90±0.17
100: 0	42.09±2.38 ^a	5.05±0.23

Note: ^{1/} Mean values within the same columns followed by different superscript letters are significantly different according to Duncan's multiple range test (P<0.05).

3.2.2 Yields and basidiocarps of phoenix oyster mushroom

The productivity of phoenix oyster mushrooms, in terms of cap diameter, varied significantly between the control and the vermicompost formulas. The 100% vermicompost formula had the largest average cap diameter measuring 41.62 mm, followed by the 50% vermicompost formula at 41.35 mm. The 75% and 25% vermicompost formulas had average diameters of 40.59 and 40.06 mm, respectively. The control, which did not contain

vermicompost, had the smallest average cap diameter at 34.60 mm, as shown in Table 3.

There was no significant difference in the average stalk length of phoenix oyster mushrooms among the formulas. The formula mixed with 75% vermicompost had the highest average stalk length of 43.38 mm, followed by the 25% vermicompost formula with an average stalk length of 42.77 mm. The 100% and 50% vermicompost formulas had average stalk lengths of 42.23 and 41.92 mm., respectively. The lowest stalk length was observed in the control group, which did not contain vermicompost, measuring 41.09 mm, as indicated in Table 3 and Figure 2.

Table 3 Cap diameter and stalk length of phoenix oyster mushroom in different formulations

Vermicompost : Rice bran	Basidiocarp	
	Cap diameter (mm.)	Stalk length (mm.)
0:100	34.60±1.34 ^{b 1/}	41.09±3.09
25 :75	40.06±1.95 ^a	42.77±6.89
50 : 50	41.35±1.78 ^a	41.92±2.11
75 : 25	40.59±1.92 ^a	43.38±7.30
100:0	41.62±1.53 ^a	42.23±1.95

Note: ^{1/} Mean values within the same column followed by different superscript letters are significantly different according to Duncan's new multiple range test (P<0.05).



Figure 2 Productivities of phoenix oyster mushroom in the first flush

The study of the effect of vermicompost on the basidiocarp of phoenix oyster mushrooms, in terms of yield, total number of basidiocarp, cap size and stalk length, is consistent with the study by Tudsas *et al.* (2018), which reported that the use of vermicompost at a ratio of 40% increased the total weight of straw mushrooms (*V. volvacea*). The highest average total yield of straw mushroom was 444.01 grams per pile. The highest average number of basidiocarps was 36.67 flowers per pile. The highest average number of button-shaped basidiocarps was 4.67 per pile.

3.2.3 Production cost and yield analysis

The study analyzed the cost and return of phoenix oyster mushroom (*P. pulmonarius*) cultivation using vermicompost-amended substrates compared to traditional substrates. The total production cost per kilogram of mushrooms was lower with the vermicompost treatment (47-55 THB/kg) than with the traditional substrate (50-60 THB/kg). The use of vermicompost resulted in a yield increase of 15-20%, with vermicompost-amended substrates producing 300-350 kg per 1,000 bags, compared to 250-300 kg per 1,000 bags in the traditional system.

4. Conclusion

This study demonstrates the efficacy of vermicompost derived from spent phoenix oyster mushroom substrate as a nutritionally viable growing medium for subsequent mushroom cultivation. The vermicompost produced exhibited nutrient parameters (moisture content 20.29-36.35%, pH 7.51-8.24, total nitrogen 1.21-1.64%, total phosphorus 0.52-0.77%, total potassium 4.34-5.23%, and C/N ratio 15.90-31.40) that comply with Department of Agriculture organic fertilizer standards. Experimental results indicate that the substrate containing 75% vermicompost yielded optimal production metrics, with specimens exhibiting the highest wet weight (43.17 grams) and longest stalk length (43.38 millimeters). While the fruiting body count remained consistent across treatment groups, the incorporation of vermicompost significantly enhanced overall growth parameters compared to control conditions. The results highlight that integrating

vermicompost into phoenix oyster mushroom production not only enhances yield but also reduces per-unit production costs, leading to greater financial returns. These findings support the economic viability of vermicompost adoption in commercial mushroom farming, contributing to both profitability and sustainability in agribusiness.

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