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Carbaryl Insecticide Decomposition after Application on Oyster and Jew's Ear Mushrooms Cultivations

Jarongsak Pumnuan[1,*], Ammorn Insung[1], Sudjai Phutphat[2]

[1]*Department of Plant Production Technology, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*
[2]*Faculty of Science, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand*

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ABSTRACT

One of the major problems in the cultivation of oyster and Jew's ear mushrooms is the damage from various insect and mite pests. Farmers occasionally used pesticides to control the pests, resulting in contamination of the product. The purpose of this study was to evaluate the decomposition of carbaryl insecticide found in oyster and Jew's ear mushrooms. The carbaryl residue, in both mushrooms and on the associated growing bags, was then investigated. The carbaryl insecticide, at different concentrations (0, 850 (recommendation) and 1,700 ppm) was sprayed 2 times: 3 days before, and during the first cap opening. The samples were collected after final spraying on days 0, 1, 3 and 6. The samples were extracted and analyzed for carbaryl residues by GC-MS. The results showed that the oyster and Jew's ear mushrooms sprayed with the 850 ppm carbaryl had residue concentrations of less than 0.45 ppm on the 3rd day. Additionally, the growing bags presented carbaryl residues on day 0 with 1.86 and 0.13 ppm for oyster and Jew's ear mushrooms, respectively. The experiment of 1,700 ppm carbaryl treatment resulted in residues on the 6th day that were less than 0.63 ppm. The contaminations observed in the oyster and Jew's ear growing bags on day 0 were 3.75 and 0.80 ppm, respectively. Our study would recommend that in cases where carbaryl insecticide use in mushroom cultures is imperative, carbaryl application at the recommendation dose should be made 3 days before the harvesting period, in the interest of consumers safety.

Keywords: Residue; Direct spray; Mushroom bag; GC-MS

1. Introduction

Mushroom farming has become more popular in many areas in Thailand. It is reported that Phetchaburi province is the biggest area of mushroom cultivation in Thailand. Mushroom production per

***Corresponding author:** jarongsak.pu@kmitl.ac.th
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year was estimated to be at 10,000 tons [1]. The most cultivated mushroom species were oyster (*Pleurotus ostreatus*) and Jew's ear mushrooms (*Auricularia* spp.) [2]. Those mushrooms are produced by bag cultivation, which involves growing mushroom mycelia on substrate in plastic bags. It was reported that the principal pests in mushroom production are fly pests including three dipteran families: Sciaridae, Phoridae, and Cecidomyiidae; and mites: gamasids, pyemotids, tarsonemids, and tyroglyphids, as well as other pests such as nematodes, mice, spring tails, thrips, beetles, and sowbugs [3]. It was also reported that farmers sometimes used insecticides (carbaryl, methomyl and cypermethrin) for controlling serious insect pests (*Cyllodes* sp., *Drosophila* sp. and *Dasyses* sp.) and mushroom mites (*Luciaphorus perniciosus* and *Formicomotes heteromorphus*) by using the direct spray method [2]. These chemical pesticides when used extensively on mushroom farms, result in the contamination of products. From a previous report, it was presented that nearly 55 fresh and dried mushroom samples from a German market in 2009 were contaminated with pesticide [4]. Prasopsuk and coworkers [5] reported pesticide residues in mushrooms from upper northeastern Thailand in 2011-2013, observing that most samples were contaminated with chlopyrifos, cypermrthrin, methomyl and carbaryl, and >10% of those samples had residue above the maximum residue limit (MRL). Furthermore, both farmers and customers are occasionally affected by the use of these chemical insecticides, and they can also be harmful to non-target organisms and the environment while also resulting in the buildup of resistance to insecticides. Mushroom growers in Thailand still lack guidelines and good management strategies to obtain good quality, clean and safe mushrooms suitable for consumption [6].

The pesticide degradation process includes photodecomposition, micro-biological decomposition, chemical decomposition, and plant detoxication. Pesticide transfer and degradation determine its persistence or retention, efficacy for pest control, and potential for soil and water contamination [7]. Although organo-phosphate and carbamate insecticides tend to degrade quickly in the environment, there is the possibility that high residue levels could be found in fresh mushrooms due to the closed system of mushroom farming, decreasing the rate of degradation. The use of insecticides during the cap opening period may result in consumer receiving mushrooms with high amounts of residue because mushroom products are harvested daily.

The objective of this study was to evaluate the decomposition of carbaryl insecticide applied in oyster and Jew's ear mushroom cultivations. The mushroom farming was prepared, insecticide spray was simulated, and the insecticide residues in the mushrooms and mushroom bags were studied.

2. Materials and Methods

2.1 Mushroom spawn preparation

The mushroom spawns of oyster and Jew's ear mushrooms were gathered from Nongyaplong mushroom cultivation community, Nongyaplong district, Phetchburi province, Thailand. After the mycelia had grown to about 70% of the mushroom bag (the bags contents became ~70% white in color), they were moved to a laboratory at the Department of Plant Production Technology, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Thailand. Then, the mushroom spawn of oyster and Jew's ear mushrooms were incubated until the bags' contents were totally white in color, the visual cue that indicates to growers that the bag is ready for cultivation.

2.2 Mushroom cultivations

The cultivations of oyster and Jew's ear mushrooms were done inside the mushroom farming house (size 2×3×2 m, curved roof) to hold the black plastic nets. Three hundred mushroom bags were placed in each house per replication. Watering was done inside the mushroom house five or more times per day to maintain a relative humidity of about 80% RH, while being careful to water only the outsides of the mushroom bags. These mushroom cultivations were carried out at the department's field.

Shelves or A-frame racks were erected inside the mushroom farming house for oyster mushroom cultivation. The mushroom bags were placed on both sides of the A-frame rack. To stimulate mushroom growth, the cotton plugs from each of the plastic bags were removed. The mushroom bags were not opened completely; the cotton plugs were simply pulled out. For Jew's ear mushroom cultivation, 5 mushroom bags were bound with nylon line and hung to the ceiling inside the house. The plastic bags were cut into a wound line (10 cm/line, 4 lines/bags) to stimulate mushroom growth, and watering was done the same as it was for oyster mushroom cultivation.

2.3 Carbaryl insecticide application

The experiment included 3 treatments including control (no insecticide treated), carbaryl (85% WP) insecticide at the recommended dose (850 ppm) [8] and double dose (1,700 ppm), applied 2 times over 3 days before and during the first cap opening. The insecticide treatments were applied by direct spray at 1 L/house. A half Kg of opened mushroom caps and 3 mushroom bags were randomly collected from each house after chemical spraying at 0 (2 hr after), 1, 3 and 6 days. The mushroom bags were punctured (size 2x2x2 cm) 3 cm from the top of the bag and then 3 pieces of growing material were taken off. The samples of each replication were from 3 mushroom bags. The samples for each day were taken to analyze the residue immediately.

2.4 Carbaryl residue analysis

The sample extraction, partitioning and cleanup methods used for residue detection, using gas chromatography-mass spectrometry GC-MS, were adapted from a previous study [9]. Extracts were analyzed with a Hewlett-Packard (Hewlett-. Packard, Little Falls, DE, USA), Model: Agilent technologies, Series: GC/MS-G1530N/G2579A, and mass-selective detector (MSD). This GC-MS was equipped with a capillary column HP5MS (30 m x 0.25 mm i.d. and 0.25 µm film thickness). Direct injection with 0.2 µl as split mode (split ratio, 100:1 v/v) was used. Helium was used as the carrier with an ionizing voltage of 70 eV, mass ranged 50-500 m/z. Temperatures of the injector and the detector were similarly maintained at 250°C. Standard carbaryl was received from the Agricultural Production Sciences Research and Development Division, Department of Agriculture, Thailand.

3. Results and Discussion

The evaluation of decomposition of carbaryl insecticide after application on oyster and Jew's ear mushrooms showed that oyster and Jew's ear mushrooms sprayed with carbaryl insecticide at recommended dose presented residues on day 0 of 40.52 and 49.60 ppm, respectively; day 3 presented residues of 0.37 and 0.45 ppm, respectively. The residue appearing in the mushroom bags on day 0 were 1.86 (oyster) and 0.13 (Jew's ear) ppm, while after that, residue was not detectable. As for the treatment using double the recommended dose, higher concentrations of carbaryl insecticide residue were found in both oyster and Jew's ear mushrooms, on day 0 with 90.36 and 94.21 ppm, and particularly on 6 day with 0.35 and 0.63 ppm, respectively. Further, mushroom bags had carbaryl insecticide residue on day 0 with 3.75 and 0.80 ppm, but 6 days after treatment, residue was not detectable. In addition to this, carbaryl insecticide residue in all samples of control groups was not found (Table 1). The measurements of residue in both oyster and Jew's ear mushrooms, as well as the associated growing bags, indicate that the rate of carbaryl decomposition is exponential. The equations representing carbaryl residue amount over time in oyster and Jew's ear mushrooms after double dose applications are as follows: $y = 444.77e^{-1.907(x+1)}$ and $y = 690.98e^{-1.547(x+1)}$, respectively (Figs. 2A, 2C). The equations for those treated at the recommended dose are as follows: $y = 395.01e^{-2.348(x+1)}$ and $y = 738.64e^{-2.352(x+1)}$, respectively (Figs. 2B, 2D).

The insecticide decomposition in mushrooms and mushroom bags observed in this study showed that there was no effect from photodecomposition, microbiological decomposition, chemical decomposition or plant detoxication, as Porto et al. [7] also previously observed. The degradation rates increased with increasing levels of organic carbon and moisture in the soil [10]. Our study revealed that, in both mushrooms, very high amounts of chemical residue were detected due to the use of the direct spray method on the mushrooms. Lower levels of carbaryl appeared in the mushrooms in the following days, resulting from the fact that the emerging mushrooms did not receive any additional insecticide, as well as the fact that the mushroom bags did not have any chemical contamination. Likewise, the characteristic morphology of Jew's ear mushroom buds resulted in them being located outside the mushroom bags leading to greater exposure to chemical spray compared to oyster mushrooms, of which the buds emerge inside the mushroom bags. Additionally, cutting the plastic Jew's ear mushroom bag caused some wounds that allowed for greater chemical penetration, resulting in the higher amount of chemical residue in the Jew's mushroom bags compared to those of the oyster mushrooms.

Normally, chemical application is not allowed for mushroom cultivation. So, there are only a few studies on pesticide residues in mushrooms. However, some reports have shown that consumption of mushrooms also poses the risk of consuming insecticide chemicals. Prasopsuk et al. [5] reported that of the mushrooms certified as using Good Agricultural Practice for Food Crop in upper Northeast, Thailand during the years 2011 to 2013, 75% of the samples were contaminated with chlopyrifos, cypermrthrin, methomyl or carbaryl, and higher than 16.7% of the contaminated samples had an amount of residue that exceeded the MRL. Anurakpongsatorn et al. [11] surveyed insecticide contamination in mushrooms from markets in the Bangkok area and found carbaryl insecticide in the abalone and oyster mushrooms. Our study would recommend that for the safety of consumers, the final application of chemicals should occur at least 3 days before harvest.

Table 1. The quantity of carbaryl insecticide residues that appeared in oyster and Jew's ear mushrooms, and mushroom bags at various periods after application.

Dose of spraying (ppm)	Day of collection (after spraying)	Quantity of residues (ppm)			
		Oyster mushroom		Jew's ear mushroom	
		Mushroom	Mushroom bag	Mushroom	Mushroom bag
double recommendation dose (1,700 ppm)	0	90.36±6.61	3.75±1.70	94.21±5.59	0.80±0.13
	1	8.48±2.97	0.75±0.27	33.89±6.90	ND
	3	0.76±0.29	0.58±0.31	21.62±3.00	ND
	6	0.35±0.14	ND	0.63±0.44	ND
Recommendation dose (850 ppm)	0	40.52±6.47	1.86±0.42	49.60±12.14	0.13±0.12
	1	3.13±0.71	ND	13.44±6.23	ND
	3	0.37±0.10	ND	0.45±0.15	ND
	6	ND	ND	ND	ND
Control (0 ppm)	0	ND	ND	ND	ND
	1	ND	ND	ND	ND
	3	ND	ND	ND	ND
	6	ND	ND	ND	ND

ND = Not detectable at quantity less than 002.0ppm, % recovery = .%8.87.

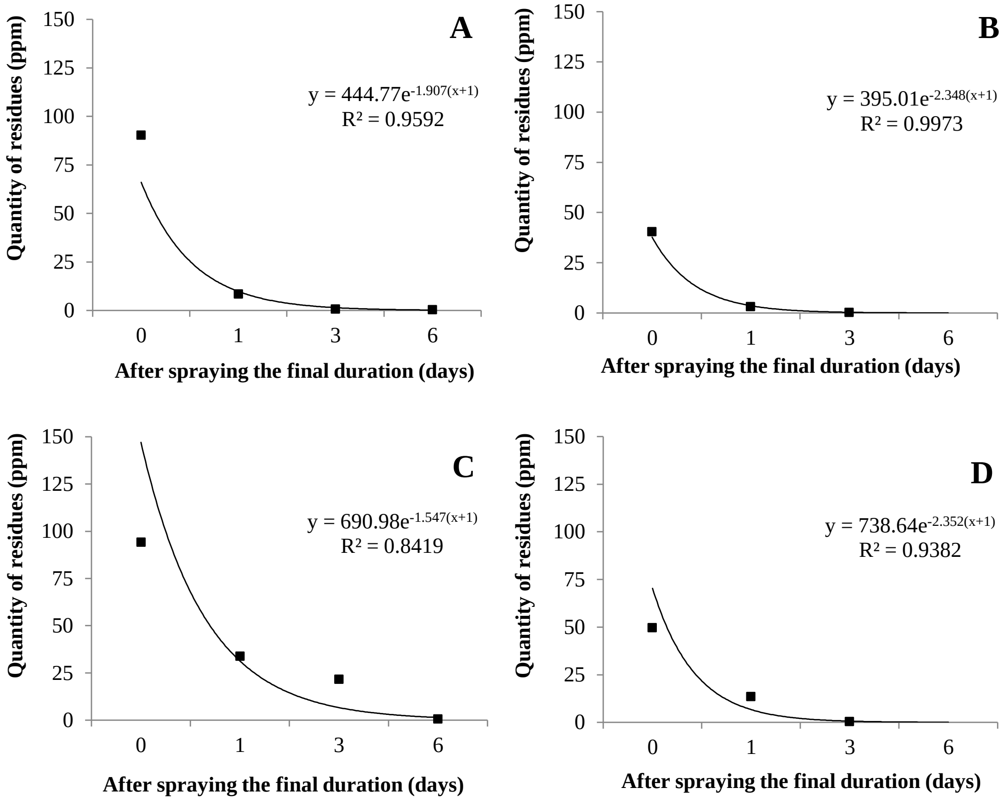

Fig. 1. The quantity of carbaryl insecticide residues that appeared in oyster and Jew's ear mushrooms in various periods after the spraying at recommendation dose (RD) and double recommended dose (DRD) presented by exponential graph, A: Oyster mushroom applied DRD, B: Oyster mushroom applied RD, C: Jew's ear mushroom applied DRD, C: Jew's ear mushroom applied RD.

4. Conclusion

Carbaryl residue in oyster and Jew's ear mushrooms, and in their growing bags were evaluated. The results showed that oyster and Jew's ear mushrooms sprayed with this insecticide at the recommended dose showed residue levels on the 3rd day at amouts of <0.45 ppm. When the application of carbaryl was done at double the recommended dose, it resulted in residues on the 6th day at amounts of <0.63 ppm. Additionally, mushroom bags applied with carbaryl insecticide presented residue levels on the 1st day after treatment that were undetectable.

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