RESPONSE OF CODLING MOTH AND NAVEL ORANGEWORM LIFE STAGES TO VACUUM

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California tree nuts and fresh fruits often require quarantine or phytosanitary treatments to disinfest product of field pests such as codling moth, *Cydia pomonella*, and navel orangeworm, *Amyelois transitella*. Currently, the rapid treatment time possible with methyl bromide makes this the treatment of choice. Vacuum treatments that apply reduced pressures of more than 27 in. Hg in flexible containers have been used to treat a variety of durable products. The mode of action for these treatments appears to be similar to low oxygen treatments, although the treatments times are often substantially lower for vacuum treatments. As part of a project to test the efficacy of vacuum treatments to disinfest dried fruits and nuts, the relative tolerance of different life stages of codling moth and navel orangeworm was determined in the laboratory.

Methods and Materials

A vacuum of 28.6 in. Hg (33.5 mm Hg) was applied to test insects in 1L vacuum flasks. Using in-line valves and quick-connects, we connected 5 flasks in series so that individual flasks could be isolated and removed without disturbing those remaining. A vacuum pump was used to reduce the pressure in the series of flasks to the treatment level, as measured with a large Hg manometer. After the initial treatment level was reached, the manometer was isolated and removed from the system, and the vacuum level was monitored with a dial pressure gauge throughout the remainder of the test. At each treatment time, a single flask was removed from the system. One of the flasks was isolated from the others before the vacuum was drawn to serve as an untreated control.

The codling moth stages tested were eggs, fifth instar non-diapausing larvae, fifth instar diapausing larvae, and pupae. The navel orangeworm stages tested were eggs, fifth instar larvae, and pupae (no diapausing stage is known to exist in navel orangeworm). Test insects were treated within 8 ml glass vials with screen lids. Either five test larvae, five test pupae, or paper strips with a total of 50 eggs were placed in each vial. A single vial of eggs and 10 vials of all other stages were placed in each flask, and one flask was used for each treatment, for a total of 50 test insects of each stage in each treatment.

During the treatment, the flasks were held in a constant temperature chamber. Codling moth was treated at 25°C for 12, 24, 48, and 72 hours, and at 35°C for 2, 4, 8, and 16 hours. Navel orangeworm was treated at 25°C for 6, 12, 24, and 48 hours. Test insects were removed from the flasks soon after treatment. Within 24-48 hours after treatment, larvae were evaluated as alive or dead based on movement. Adult emergence and egg hatch were used to evaluate mortality of test pupae and eggs, respectively. Final treatment mortality was corrected for control mortality using Abbott's formula.

Results

At both 25°C (Table 1) and 35°C (Table 2) the stage of codling moth most tolerant to vacuum was the diapausing larva. After 72 hours at 25°C, mortality of diapausing codling moth larvae was only 4.7%, while all other stages were 99% or above. Mortality occurred much faster at 35°C, with 69% of diapausing codling moth larvae killed after 16 hours. At 35°C all codling moth pupae and eggs were killed after 8 hours of vacuum, while non-diapausing larvae were completely killed after 16 hours.

At 25°C, the stage of navel orangeworm most tolerant to vacuum appears to be fifth instar larva (Table 3). After 48 hours of exposure, mortality of fifth instar larvae was only 30%, in contrast to 100% for pupae and 87% for eggs. In nearly all cases, mortality of fifth-instar larvae, pupae and eggs of navel orangeworm is lower than that for similar stages of codling moth at comparable treatment times, indicating that this species is the more tolerant of the two. However, diapausing codling moth larvae were more tolerant than the most tolerant stage of the navel orangeworm.

Conclusions

To develop postharvest treatment schedules for any methyl bromide alternative, the most tolerant pest and life stage that may be present in a particular commodity must be identified. While navel orangeworm is a serious pest of California walnuts, almonds and pistachios, codling moth is found only in walnuts. Consequently, the differences in the tolerance of the two species makes it advisable to determine treatment schedules for both fifth instar navel orangeworm larvae and diapausing codling moth larvae.

Although more work is needed to determine the actual potential of vacuum treatments for dried fruits and tree nuts, the perceived advantages include the lack of pesticide residue or emissions, relatively low capital expenditures and energy costs, and treatment times that are expected to be shorter than proposed modified atmosphere treatments. Disadvantages include treatment times that will be longer than methyl bromide treatments, problems with treating bins in flexible containers, and difficulty applying the method to the product volumes of large processors.

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Table 1. Percent mortality of codling moth exposed to 28.6 in. Hg at 25°C

Exposure (hrs)	Non diapausing larvae	Diapausing larvae	Pupae	Eggs
12	2.7	0.8	45.3	19.6
24	13.3	0.0	97.9	89.6
48	90.6	0.0	100.0	99.6
72	100.0	4.7	100.0	99.6

Values are corrected for control mortality, and are means of 3 replicates

Table 2. Percent mortality of codling moth exposed to 28.6 in. Hg at 35°C

Exposure (hrs)	Non diapausing larvae	Diapausing larvae	Pupae	Eggs
2	5.2	0.0	16.9	27.1
4	22.1	0.0	34.3	72.0
8	62.9	0.0	100.0	100.0
16	100.0	68.8	100.0	100.0

Values are corrected for control mortality, and are means of 2 replicates

Table 3. Percent mortality of navel orangeworm exposed to 28.6 in. Hg at 25°C

Exposure (hrs)	Larvae	Pupae	Eggs
6	3.3	1.5	31.1
12	5.1	6.2	50.5
24	8.0	67.4	49.3
48	30.0	100.0	83.8

Values are corrected for control mortality, and are means of 3 replicates