OVICIDAL EFFICACY OF SULFURYL FLOURIDE TO STORED-PRODUCT PESTS OF DRIED FRUIT

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Insects and Mortality. *Plodia interpunctella* (indianmeal moth, IMM), *Tribolium castaneum* (red flour beetle, RFB), and *Carpophilus hemipterus* (dried fruit beetle, DFB) were cultured at 27+/-1 °C and 60+/-5% RH. In general, IMM is grown on a wheat bran diet, RFB on a rice bran diet, and DFB on bananas over a soil media. Rearing specifics (USDA 2009a) and harvesting of eggs is different for each species. IMM eggs are deposited loosely on bran and harvested through a wire mesh screen over a Petri dish. Female RFB egg layers are setup in pre-sifted white flour and then the eggs separated using sieves. Female DBF egg layers are provided an egg-laying platform, consisting of two glass microscope slides separated slightly with two sheets of waxed paper and a smear of agar diet laying-substrate; a rubber band holds the device together. DFB oviposition is highly variable, but the eggs are easily visible and counted through the peripheral edge of the glass slides. Non-exposed (i.e., control) and fumigant-exposed eggs were 0-72, 0-48, 0-36 h old respectively for IMM, RFB, and DFB. Mortality was assessed following treatment after incubation under rearing conditions; IMM and DFB eggs are evaluated after 2-3 d and RFB eggs after 6-7 d. Using a microscope, exposed-egg mortality was diagnosed by the development of white coloration and survivability by vacated egg cases. Control-egg mortality for IMM and DFB is typically < 5% and < 10% for RFB. The target number of eggs per treatment is 100+/-5. Dose-mortality regressions were generated using Probit analysis (Finney, 1971).

Fumigations. Sulfuryl fluoride exposures occurred in Labonco® 1-cu. ft. chambers modified for fumigation (USDA 2009b), as were comparative studies with methyl bromide. Eggs of each species (50-250) were kept in separate gas-permeable storage containers within each chamber; dose-mortality data was acquired in the absence of commodity. Fumigations were conducted at 760 mmHg for 24 h and at 100 mmHg for 4 h.

Chemical Analysis. Gas chromatography retention times and mass spectra were used for chemical verification during fumigation trials. Sulfuryl fluoride doses were quantitatively monitored with a Varian 3800 using a gas sampling port with a 10 μL sample loop, a packed GSQ analytical column (L = 30 m, ID = 4.5 mm) held at 100°C for 10 min, and a PFPD detector at 250°C that received only 10% of the column flow. Quantitative mass spectrometry of methyl bromide and sulfuryl fluoride was with a HP 5890 using 50μL splitless injections (225°C), a megabore GSQ analytical column (L = 60 m, ID = 0.53mm, df = 0.25 μm) at 100°C for 10 min, and a GCD detector in EI mode.

Results and Discussion. Initial dose-mortality investigations identified the egg stage as the most tolerant life stage of IMM, RFB, and DFB. Preliminary data acquired thus far shows that the transition from LD_{50} through $LD_{99,}$ which is used to generate statistical regressions, occurs over a dose range greater than an order of magnitude for RFB, approximately equal to an order of magnitude for IMM, and less than an order of magnitude for DFB. The relationship between the dose required to elicit mortality and the inflection of that mortality is curious and warrants future investigation, particularly with respect to the "tolerant" yet "reactive" response of DFB eggs toward sulfuryl fluoride. As was noticed with *Amyelois transitella* eggs, data indicates that there is more variability in egg mortality with sulfuryl fluoride under vacuum (100 mm Hg) relative to atmospheric pressure (760 mmHg); this suggests that 24 h chamber (or tarpaulin) fumigations are better suited for controlling eggs of these pests with sulfuryl fluoride, particularly if P9 control is desired. If sulfuryl fluoride fumigations are conducted under at ambient temperatures, which are customary for CA dried fruit, it should be noted that cooler temperatures warrant greater doses. Work in the near future will focus on: adding additional fumigations for statistical power, exploring the effect of commodity(e.g. raisins, figs, dates, prunes) on egg mortality, completing temperature profiles (70° and 90°C) and direct data comparison against methyl bromide.

Estimated Lethal Doses of Sulfuryl Fluoride (SF) (mg/L or oz/1000 ft^3) to **Egg Stage** of Stored-Product Pests: Indianmeal moth (IMM), red flour beetle (RFB), and dried fruit beetle (DFB)
LD_x and probit 9 (P9, $LD_{99.9986}$), Upper 95% Confidence Limit (parenthesis)

Temp (°F)	IMM				RFB				DFB			
	LD_{50}	LD_{95}	LD_{99}	LD_{P9}	LD_{50}	LD_{95}	LD_{99}	LD_{P9}	LD_{50}	LD_{95}	LD_{99}	LD_{P9}
Schedule: 24 hr; Normal Atmospheric Pressure												
60	18.5 (20.4)	36.8 (48.2)	48.9 (73.1)	98.3 (206.0)	31.7 (35.8)	81.5 (95.2)	120.6 (151.4)	315.3 (486.3)	214.7 (227.9)	444.0 (491.2)	599.9 (697.6)	1256.4 (1665.7)
70	11.1 (12.2)	25.7 (31.1)	36.4 (47.7)	85.7 (138.2)	29.6 (32.5)	69.2 (77.7)	98.2 (116.8)	232.6 (323.8)	–	–	–	–
80	5.4 (6.2)	14.2 (19.3)	21.3 (32.9)	57.7 (124.8)	27.6 (29.5)	43.7 (48.3)	52.9 (61.2)	84.7 (111.1)	55.0 (59.9)	88.9 (109.3)	108.5 (144.6)	177.0 (291.2)
Schedule: 4 hr; Vacuum (100 mm or 26" Hg)												
60	85.2 (93.6)	181.2 (207.4)	247.7 (303.0)	533.7 (783.9)	141.9 (157.0)	396.7 (480.0)	607.3 (812.3)	1728.4 (3000.2)	846.8 (876.6)	1092.7 (1190.4)	1214.5 (1370.3)	1574.3 (1944.5)
70	60.8 (66.6)	104.9 (129.8)	131.5 (181.8)	229.1 (422.3)	162.5 (178.6)	291.7 (332.6)	371.8 (456.6)	674.5 (1016.6)	–	–	–	–
80	21.9 (27.0)	62.3 (86.5)	96.1 (162.3)	278.4 (802.0)	45.3 (66.3)	204.9 (777.5)	383.1 (4,247.9)	1780.7 (29,023)	–	–	–	–

- Doses will likely change as more tests are run and data collected.
- The egg stage of these stored-product pests will be present in host commodities; data (not shown) indicates that eggs are the target stage for developing a SF treatment schedule.

References.

Finney, D.J. *Probit Analysis*; 3rd ed.; Cambridge university Press: Cambridge, 1971

USDA 2009a http://www.ars.usda.gov//Main/site_main.htm?docid=18134

USDA 2009b http://www.ars.usda.gov/Main/docs.htm?docid=18577