VACUUM TREATMENTS FOR TREE NUTS

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In order to meet consumer demands and export requirements, California tree nuts (walnuts, almonds and pistachios) must be free of insect infestation. Processors have long relied on fumigants such as methyl bromide and phosphine to disinfest their product of field pests such as codling moth (*Cydia pomonella*, Lepidoptera: Tortricidae) and navel orangeworm (*Amyelois transitella*, Lepidoptera: Pyralidae), as well as storage pests such as Indianmeal moth (*Plodia interpunctella*, Lepidoptera: Pyralidae). Vacuum treatments have been considered as alternatives to chemical fumigation, but required expensive vacuum chambers to obtain the low pressures needed. Recently, inexpensive vacuum treatments were made possible by treating product in flexible, portable containers. We are evaluating vacuum treatments for control of postharvest nut pests.

Laboratory Studies: Because preliminary studies showed that the presence of commodity may affect the efficacy of vacuum treatments, we developed a laboratory bioassay using cylindrical stainless steel vacuum chambers partially filled with nuts. Using this method, we estimated the exposure times necessary for 95% mortality (LT_{95}) of test insects at 50 mm Hg at 25 and 30°C for navel orangeworm (NOW) eggs and larvae, codling moth (CM) eggs, diapausing larvae and non-diapausing larvae, and Indianmeal moth (IMM) eggs and diapausing larvae. Pupae of all three moth species were found to be very sensitive to the treatments and were not included in the study.

Results of the bioassays are given in Table 1. Mortality from vacuum treatments is believed to be largely due to a lack of oxygen, and treatments are therefore temperature dependent. This is evident in the lower LT_{95}s found at 30°C. NOW eggs were found to be the most tolerant stage at both treatment temperatures, while CM larvae were the most sensitive. The tolerance of diapausing larvae was similar to eggs for both IMM and CM. While treatment times for vacuum are longer than those for methyl bromide, they are comparable to exposures needed for phosphine.

Field Studies: We completed two series of field tests treating almonds in 5 ton GrainPro Cocoons. The first was done under winter conditions, using shelled almonds in wooden bins (Table 2). Test insects were diapausing CM, diapausing IMM, NOW larvae, IMM eggs and NOW eggs. Diapausing CM were included because of their importance to inshell walnut exports, even though they are not a pest of almonds. In all three tests average temperatures were low, less than or equal to 10.5°C (51°F), and the vacuum levels reached were less than the target

level of 50 mm Hg. At these low temperatures 13 days of exposure were needed before high mortality levels of diapausing CM were obtained. Also due to low treatment temperatures, there was no survival of cold-sensitive NOW and IMM eggs in untreated controls in the second and third tests.

The second series of tests was done under summer conditions using inshell almonds in 50 lb poly bags (Table 3). Average temperatures were much higher, with peak temperatures sometimes exceeding 40°C (104°F). Test insects were diapausing CM, diapausing IMM, IMM eggs and NOW eggs. In the first test all insects were killed after 48 hours of exposure. After 30 hours of exposure during the second test, very low survival was seen in NOW eggs, while all other insects were completely killed. In the third test insects were exposed to vacuum for only 24 hours, and there was considerable survival of both diapausing larvae, and relatively high mortality of both NOW and IMM eggs.

Conclusions: Insect eggs are often found to be the most tolerant of vacuum treatments. Our studies indicate that the response of diapausing larvae is comparable to that of eggs. Of the insects included in our study, navel orangeworm appears to be the most tolerant, particularly the egg stage. Because vacuum treatments are temperature dependent, the utility of this treatment is reduced under cold conditions, when exposures required are too long to be practical. Under warmer conditions, however, effective control may be obtained after relatively short exposure times that are comparable to phosphine fumigation, particularly since no aeration is needed after treatment. Cost of the method is limited to capital expense for the flexible containers and vacuum pump, electrical power and labor costs.

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Table 1. Estimated exposures (hours) needed for 95% mortality (LT95) of common California dried fruit and nut pests.

Target stage	Slope ± S.E.	Intercept ± S. E.	LT_{95}	95% CI	
				lower	upper
		25°C			
NOW eggs	0.09 ± 0.003	-1.59 ± 0.066	36.9	33.6	41.4
NOW larvae	0.18 ± 0.009	-3.37 ± 0.188	28.2	25.0	34.5
IMM eggs	0.10 ± 0.003	-1.74 ± 0.065	33.4	31.3	36.1
Diapausing IMM	0.13 ± 0.006	-2.88 ± 0.135	35.4	32.8	38.9
CM eggs	0.08 ± 0.003	-0.44 ± 0.047	27.6	24.2	32.3
Diapausing CM	0.12 ± 0.005	-1.96 ± 0.097	30.0	24.7	41.1
CM larvae	0.24 ± 0.019	-2.63 ± 0.253	17.6	16.3	19.5
		30°C			
NOW eggs	0.14 ± 0.005	-2.03 ± 0.085	26.1	22.2	33.9
NOW larvae	0.40 ± 0.020	-3.60 ± 0.195	13.2	12.1	15.4
IMM eggs	0.18 ± 0.007	-1.78 ± 0.087	18.7	17.1	21.0
Diapausing IMM	0.29 ± 0.015	-3.44 ± 0.197	17.5	14.7	27.1
CM eggs	0.11 ± 0.005	-0.63 ± 0.060	21.1	18.5	24.9
Diapausing CM	0.26 ± 0.015	-2.32 ± 0.164	15.2	11.5	49.5
CM larvae	0.33 ± 0.020	-2.01 ± 0.160	11.0	9.8	12.8

Probit analysis done using SPSS 12.0

Table 2. Mortality (%) of test insects in winter field tests of vacuum cubes treating shelled almonds

	Diapausing CM	Diapausing IMM	NOW larvae	IMM eggs	NOW eggs
7 day exposure at 43.1 mm Hg and 10.5°C average temperature					
Control	1.6	2.4	13.0	17.6	46.2
Vacuum	75.1	96.8	100.0	97.4	99.0
9 day exposure at 38.5 mm Hg and 8.9°C average temperature					
Control	0.5	1.0	0.7	100.0	98.8
Vacuum	1.5	88.3	100.0	100.0	100.0
13 day exposure at 17.7 mm Hg and 6.3°C average temperature					
Control	0.5	2.6	4.0	100.0	100.0
Vacuum	99.5	100.0	100.0	100.0	100.0

Table 3. Mortality (%) of test insects in summer field tests of vacuum cubes treating in-shell almonds

	Diapausing CM	Diapausing IMM	NOW eggs	IMM eggs
48 hour exposure at 50 mm Hg and 29.5°C average temperature				
Control	0.0	3.3	71.4	63.3
Vacuum	100.0	100.0	100.0	100.0
30 hour exposure at 50 mm Hg and 27.0°C average temperature				
Control	0.0	0.0	17.9	2.3
Vacuum	100.0	100.0	98.2	100.0
24 hour exposure at 75 mm Hg and 25.0°C average temperature				
Control	1.5	0.0	16.7	2.7
Vacuum	21.1	25.7	96.8	97.0