VACUUM TREATMENTS FOR CALIFORNIA TREE NUTS

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California walnuts, almonds and pistachios must be free of insect infestation in order to meet consumer demands and export requirements. Fumigants such as methyl bromide have long been used to disinfest tree nuts of field pests such as codling moth (*Cydia pomonella*) and navel orangeworm (*Amyelois transitella*), and storage pests such as Indianmeal moth (*Plodia interpunctella*). The development of flexible, inexpensive, portable containers has made possible the use of vacuum treatments as a non-chemical alternative. Because the mechanism of vacuum treatments is partially dependent on the drying effect of reduced oxygen and low atmospheric pressures, product moistures have an effect on treatment efficacy.

Materials and Methods

Laboratory studies: Treatments were done in cylindrical stainless steel chambers (0.03 m^3) connected in series to a vacuum pump. A capsule vacuum gauge was used to determine when treatment pressure (50 mm hg) for the system was reached; data loggers were used to record the pressure, temperature and relative humidity of individual chambers. Chambers were held in an environmental room at constant temperatures (25 and 30°C). Test insects were non-diapausing and diapausing Indianmeal moth larvae held in stainless steel screen vials. Insects were first treated in empty chambers held at three different relative humidities (ca. 30, 45 and 80% RH maintained with glycerol solutions). Later, test insects were treated in chambers with walnuts at low (5%, about 40%RH) and high (9%, about 70%RH) moisture content. In both experiments 15 larvae/vial and three exposures were used (12, 16 and 20 hours for non-diapausing larvae, and 18, 30, and 42 hours for diapausing larvae). Test insects were weighed before and after treatment to determine moisture loss during treatment. Test insects were held at least 24 hours after treatment before being evaluated for mortality. Untreated controls for all exposures, humidities and walnut moistures were also included.

Field studies: A series of field trials were conducted using airtight rectangular structures made of UV-resistant polyvinyl chloride (5 M/T V-HF Cocoons®). The top and bottom pieces are joined together with a tongue-and-groove zipper. Seventy 50 lb (22.7 kg) polybags of in-shell walnuts filled the treatment Cocoon; 20 polybags on a stack of Styrofoam sheets were used in a second Cocoon as an untreated control. Vacuum pressures were obtained with a 3-hp rotary vacuum pump connected to the Cocoon by a metal-reinforced PVC vacuum hose with a quick disconnect. The pump ran continuously, and the pressure stabilized at ≥60 mm Hg. Treatment vacuum levels were determined with a capsule vacuum gauge, and data loggers were used to record pressure, temperature and relative humidity within the Cocoons. Test insects in stainless steel screen vials were placed within two polybags in the treatment Cocoon, and one polybag in the control Cocoon. As test insects, we used the most tolerant stages determined by earlier lab studies;

Indianmeal moth, codling moth, and navel orangeworm eggs and diapausing Indianmeal moth and codling moth larvae. After each treatment, test insects were retrieved and held for evaluation (24 hours for larvae, one week for eggs).

Results:

Laboratory studies: As relative humidity increased, moisture loss and mortality decreased (Tables 1 and 2) especially at the highest relative humidities. At both treatment temperatures, diapausing Indianmeal moth larvae were far more tolerant to vacuum than nondiapausing larvae, and require roughly twice the exposure to achieve similar mortality. Diapausing larvae were also more resistant to moisture loss. Fig. 1 shows more clearly how longer exposures are needed to obtain comparable moisture loss for diapausing larvae. Mortality was correlated with moisture loss (Fig. 2); 100% mortality was usually reached at 50% moisture loss.

Field studies: Initial tests showed that the underside of the Cocoons was susceptible to damage by rodents. Our current tests found that sand snakes under the walnut polybags created a barrier to mice and help prevent further damage. Treatment pressure levels were successfully maintained between 48 and 60 mm Hg. Data loggers in the treatment bags showed that under continuous vacuum humidity levels remain relatively high (ca. 70%), indicating that longer treatment times may be needed. During summer temperatures, complete mortality was reached after 48 hour exposure to 50 mm Hg, but required longer treatments at higher pressures.

Discussion: The study shows that high humidities in treatment containers, due to the presence of high moisture products, may reduce the efficacy of vacuum treatments by reducing water loss in target insects. Consequently, treatment success should be improved by including product moisture levels in developing treatment schedules. Our study also shows that diapausing Indianmeal moth reduce their moisture loss when compared to nondiapausing larvae. This ability would seem to account in part for the increased tolerance to vacuum found in diapausing larvae. Field studies showed that successful treatments were obtained after 48 hour exposures, but that obtaining target pressures were sometimes difficult due to small leaks in the bags caused by wear. Preventing rodent damage may be very important to overall success.

Conclusions: While more work is needed to refine vacuum treatments for 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 are longer than methyl bromide treatments, problems with treating bins in flexible containers, and difficulty applying the method to the product volumes of large processors. For suitable applications such as smaller producers and organic processors, identifying the potential of product moisture to affect efficacy will improve the success of vacuum treatments and speed its adoption.

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Table 1. Moisture loss and mortality of non-diapausing and diapausing Indianmeal moth under vacuum (50 mm Hg) at different temperatures and humidities

Stage	25°C				30°C			
	Exposure (hours)	30%RH	45%RH	80%RH	Exposure (hours)	30%RH	45%RH	80%RH
				% Moisture Loss				
NDIMM	12	51.4	44.6	24.7	6	45.7	35.7	20.6
	16	58.8	51.7	30.0	8	53.6	44.2	25.0
	20	63.0	57.0	36.3	10	59.2	50.2	29.4
DIMM	18	33.7	30.7	17.3	10	34.7	25.3	12.7
	30	48.2	42.8	24.1	15	44.9	34.7	17.8
	42	54.7	50.4	29.0	20	51.4	43.6	22.6
				% Mortality				
NDIMM	12	98.7	88.5	1.3	6	95.5	44.3	4.9
	16	100.0	98.2	3.1	8	100.0	92.9	8.0
	20	100.0	99.5	15.4	10	99.5	99.5	12.1
DIMM	18	27.9	10.2	0.9	10	54.9	6.2	0.4
	30	95.1	75.1	0.0	15	94.2	43.1	0.9
	42	99.1	92.1	20.2	20	100.0	95.1	4.0

Table 2. Moisture loss and mortality of non-diapausing and diapausing Indianmeal moth under vacuum (50 mm Hg) at different nut moistures and temperatures

Stage	25°C			30°C		
	Exposure (hours)	Low Moisture	High Moisture	Exposure (hours)	Low Moisture	High Moisture
			% Moisture Loss			
NDIMM	12	45.5	23.3	6	41.7	20.3
	16	54.0	31.0	8	50.4	25.3
	20	59.1	35.6	10	56.9	30.6
DIMM	18	32.5	13.1	10	32.4	14.4
	30	42.4	23.3	15	44.5	21.5
	42	50.5	29.0	20	52.4	26.6
			% Mortality			
NDIMM	12	92.0	1.1	6	85.3	5.0
	16	98.6	4.9	8	99.5	4.1
	20	100.0	35.6	10	100	29.3
DIMM	18	18.0	1.3	10	41.8	0.4
	30	70.1	0.8	15	97.4	4.4
	42	96.4	16.5	20	99.5	9.8

Figure 1. Effect of relative humidity on moisture loss during vacuum treatments

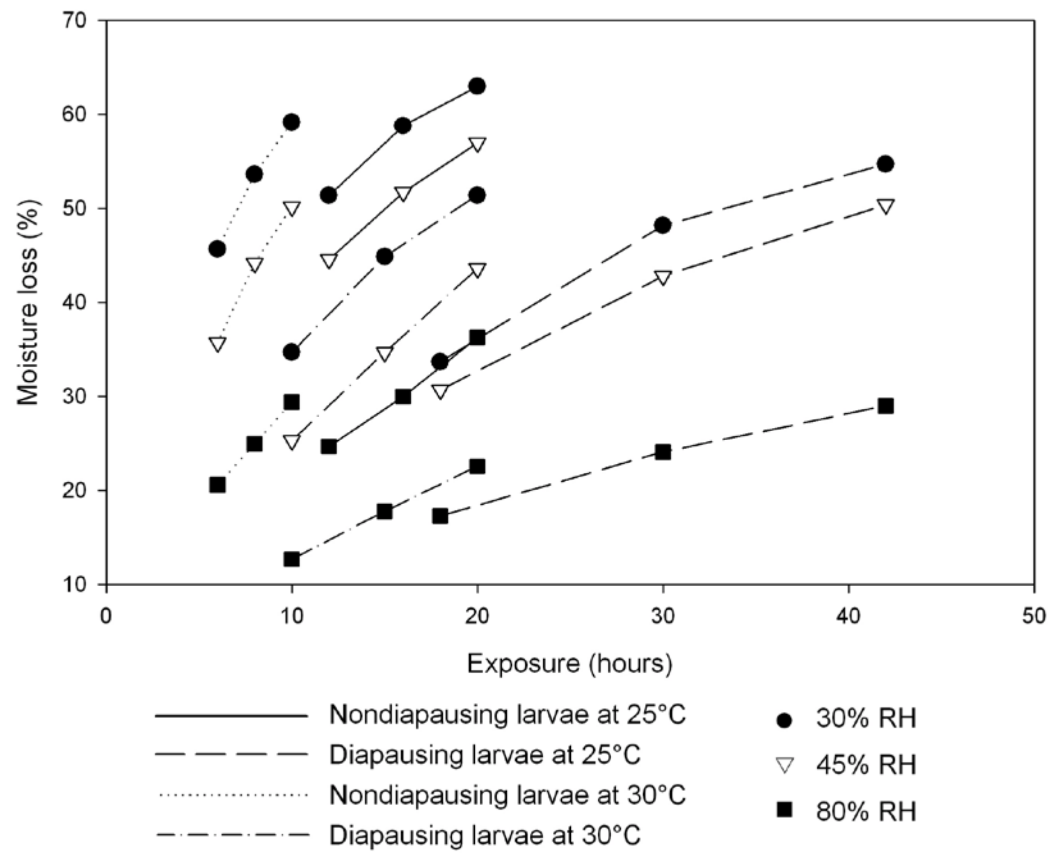

Figure 2. Relationship of moisture loss to mortality during vacuum treatments