EFFECT OF PRODUCT MOISTURE ON EFFICACY OF VACUUM TREATMENTS FOR TREE NUTS

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California tree nuts (walnuts, almonds and pistachios) must be free of insect infestation in order to meet consumer demands and export requirements. Processors have long relied on fumigants such as methyl bromide 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). Recently, 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 low atmospheric pressures, product moisture may have an effect on treatment efficacy.

Materials and Methods: Treatments were done in cylindrical stainless steel chambers (0.03 m^3) connected in series to a vacuum pump. A dial vacuum gauge was used to determine when treatment pressure (50 mm hg) for the system was reached, and data loggers were used to record the pressure, temperature and relative humidity of individual chambers. The chambers were held in an environmental room at 25°C. Test insects were non-diapausing and diapausing Indianmeal moth larvae held in stainless steel screen vials. The first experiment treated test insects in empty chambers held at three different relative humidities (ca. 30, 45 and 80% RH maintained with glycerol solutions). The second experiment treated test insects in chambers with walnuts at low and high moisture levels (5 and 9%, respectively). For both experiments 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.

Results: Figures 1 and 2 are representative relative humidity profiles for experiments with glycerol and walnuts, respectively. Relative humidity levels dropped as the chambers were pumped down, and then quickly returned to target levels once the chamber was sealed. Relative humidity levels for low and high moisture walnuts were about 40 and 70%, respectively.

Both moisture loss and mortality of test insects was strongly affected by humidity levels in both experiments (Tables 1 and 2). As relative humidity increased, moisture loss and mortality decreased. Test insects, both diapausing and nondiapausing, were much more tolerant to the vacuum treatment at the highest relative humidities. As demonstrated in earlier studies, diapausing Indianmeal moth were far more tolerant to vacuum than nondiapausing Indianmeal moth, and require roughly twice the exposure to achieve similar mortality. Diapausing larvae were also more resistant to moisture loss. Figure 3 shows more clearly how longer exposures are needed to obtain comparable moisture loss for diapausing larvae.

Discussion: The mechanism for vacuum treatments is believed to be largely due to reduced oxygen levels. Also, because increased water loss is often found in insects under low oxygen environments, and reduced pressures may also act to increase water loss, dehydration would also seem to play an important part. 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. Treatment success may be improved by including product moisture levels in developing treatment schedules.

Diapausing insects are often cold tolerant, and cold tolerance is often associated with tolerance to desiccation. Our study shows that diapausing Indianmeal moth are able to 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.

Conclusions: Although more work is needed to determine the actual potential of 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 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. For suitable applications such as smaller producers and organic processors, identifying the potential of product moisture to affect efficacy should 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 three different humidities

Stage	Exposure (hours)	Vacuum			Control		
		30%RH	45%RH	80%RH	30%RH	45%RH	80%RH
		% Moisture Loss					
NDIMM	12	51.4	44.6	24.7	8.1	7.5	6.4
	16	58.8	51.7	30.0	7.2	8.5	7.8
	20	63.0	57.0	36.3	11.5	8.5	8.6
DIMM	18	33.7	30.7	17.4	1.5	1.5	1.2
	30	48.2	42.8	22.8	2.0	1.7	1.6
	42	54.7	50.4	30.3	2.6	2.7	2.2
		% Mortality					
NDIMM	12	98.7	88.5	1.3	1.4	1.3	0.9
	16	100.0	98.2	3.1	0.9	0.4	1.8
	20	100.0	99.6	15.3	2.2	2.2	2.7
DIMM	18	27.9	10.2	0.9	0.0	0.0	0.0
	30	95.1	75.1	0.1	0.0	0.0	0.0
	42	99.1	92.1	20.9	0.0	0.0	0.0

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

Stage	Exposure (hours)	Vacuum		Control	
		Low Moisture	High Moisture	Low Moisture	High Moisture
		% Moisture Loss			
NDIMM	12	45.0	26.6	7.8	7.0
	16	56.5	34.9	8.3	8.0
	20	59.3	37.4	9.6	8.5
DIMM	18	29.3	10.9	1.1	0.8
	30	41.7	21.0	1.7	1.1
	42	49.9	27.2	2.3	1.1
		% Mortality			
NDIMM	12	96.0	2.0	0.0	0.0
	16	100.0	8.0	0.0	0.0
	20	100.0	58.0	0.0	2.0
DIMM	18	15.7	0.0	1.3	0.0
	30	76.9	0.7	0.0	1.3
	42	94.7	2.8	0.0	0.0

Figure 1. Relative Humidity Levels with Glycerol Solutions

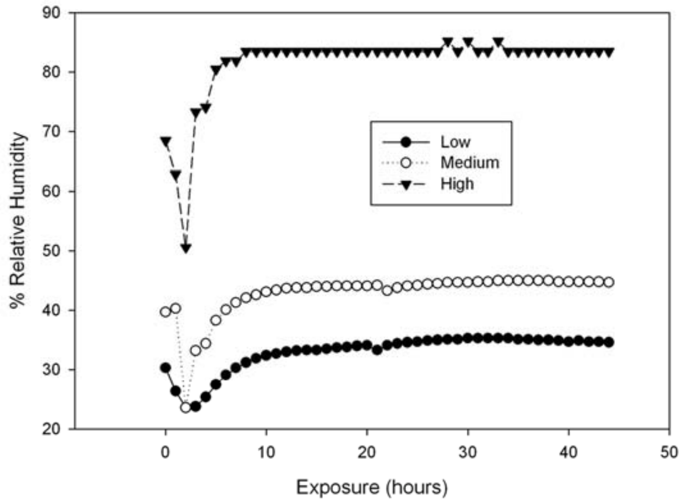

Figure 2. Relative Humidity Levels with Conditioned Walnuts

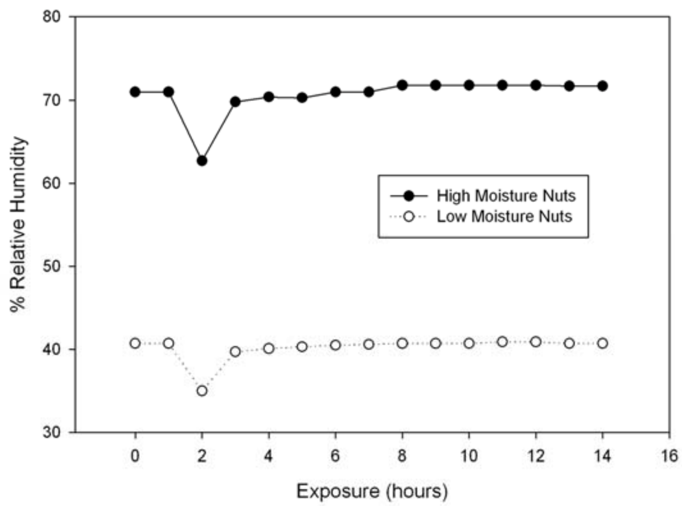

Figure 3. Effect of Relative Humidity on Insect Moisture Loss During Vacuum Treatment