THERMAL TOLERANCE OF NAVEL ORANGEWORM AND INDIANMEAL MOTH

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California produces nearly all of the dried fruits and tree nuts in the United States, resulting in an annual production of more than 1.2 million metric tons of commodity valued at over $1 billion. A major problem in the production, storage and marketing of these commodities is infestation by postharvest pyralid moths such as navel orangeworm (*Amyelois transitella*) and Indianmeal moth (*Plodia interpunctella*). Currently, the dried fruit and tree nut industry relies heavily on fumigation with methyl bromide for postharvest insect control. As such, alternative control methods are needed. Heat treatments using hot forced air or hot water dips have been proposed for a variety of postharvest insect pests, but the lengthy exposure times needed may reduce throughput or may cause product damage. Industrial radiofrequency (RF) and microwave systems, extensively used in the food processing, textile and wood processing industries, may avoid these problems by providing more rapid product heating of 18-36°F/min (10-20°C/min). Knowledge of thermal tolerance for targeted insects is essential in developing heat treatments utilizing these methods. Our study used a heating block system developed at Washington State University, Pullman WA, to study thermal tolerance of navel orangeworm and Indianmeal moth at heating rates comparable to those found in RF or microwave heating.

Materials and Methods

The Washington State University heating block system consisted of top and bottom blocks, heating pads, an insect test chamber, controlled atmosphere circulating channels (not used in the current study), and a data acquisition/control unit. Thermocouples inserted through sensor paths were used to monitor the temperatures of the top and bottom blocks, and the air temperature in the chamber. Heating rates (0.18-36°F/min or 0.1-20 °C/min) and the set-point temperature were controlled by the visual software WorkBench PC 2.0 via a solid-state relay. For the current study, a heating rate of 32.4°F/min (18°C/min) was selected to simulate rapid heating of fruit using RF and microwave energies.

In other studies, we determined that fifth instar larvae were the most heat tolerant stage of the navel orangeworm. Consequently, we used fifth instar navel orangeworm and Indianmeal moth as test insects. We also compared heat tolerance of diapausing and non-diapausing fifth instar Indianmeal moth larvae. We treated 200 insects at a time to temperatures of 111.2-125.6°F (44-52°C) for 0.1-140 minutes. Each treatment was replicated three times. At the end of each exposure, the power to the heating block was turned off and the insects were quickly (within 10 sec) transferred to a plastic container. Because we anticipated that commercial treatments would include rapid post-treatment cooling of product to minimize the effect on product quality, the treated larvae were immediately moved to cold storage at 39°F (4°C) and stored at this temperature for one day. After the cold storage, the larvae were held at 73.4°F (23°C) for one day to minimize the effect of cold stupor before examination. Insects were considered dead if no movement was observed. Moribund and surviving larvae were observed for an additional five days.

The resulting mortality data were used to develop a 0.5th order kinetic model for fifth instar larvae of both species, from which lethal exposure times (LTs) for 95%, 99% and 99.9968% (probit 9) mortality were calculated. Thermal responses of non-diapausing and diapausing Indianmeal moth larvae were compared using *t* tests.

Results

Navel orangeworm proved to be the most heat tolerant of the two species, with LT values for comparable temperatures being approximately 5 times longer for navel orangeworm than for Indianmeal moth (Table 1). Thermal death time (TDT) curves for the two species were essentially parallel (Fig. 1), indicating a similar mechanism for thermal kill for both species.

Thermal mortality of diapausing Indianmeal moth larvae was consistently lower than that for non-diapausing larvae (Table 2), although the difference was only significant for larvae exposed to 114.8°F (46°C) for 10 minutes and to 122°F (50°C) for 2 minutes. Diapausing Indianmeal moth larvae were less heat tolerant than those of navel orangeworm.

Conclusions

Using heating rates comparable to those obtained with RF or microwave heating, we obtained high mortality levels for the most thermal tolerant species, navel orangeworm, after relatively short exposure times (1 minute or less at 120.2°F). In addition to allowing treatment of large volumes of commodity, such rapid heat treatments may also avoid product damage in heat sensitive commodities. Preliminary quality studies with walnuts treated with RF energy for 3 minutes showed no significant increase in peroxide values or fatty acid levels.

Advantages for RF and microwave heat treatments

- Efficacious
- Allows rapid treatment of large volumes of commodity
- Avoids damage to heat sensitive commodities
- May also be useful for rapid drying of some products

Disadvantages for RF and microwave heat treatments

- Will require some capital expenditure for new equipment
- Energy intensive
- May not be useful for products normally stored in bins

Table 1. Comparison of lethal times (LTs) observed and calculated from 0.5th order kinetic models for navel orangeworm and Indianmeal moth fifth-instar larvae.

	Navel orangeworm				Indianmeal moth			
Temp °F (°C)	Observed 100% (min)	LTs calculated from model (min)			Observed 100% (min)	LTs calculated from model (min)		
		LT_{95}	LT_{99}	$LT_{99.9968}$		LT_{95}	LT_{99}	$LT_{99.9968}$
111.2 (44)	-	-	-	-	120	105.9	121.3	133.1
114.8 (46)	140	120.0	137.6	151.1	30	23.6	27.5	30.5
118.4 (48)	50	40.9	46.8	51.3	10	7.6	8.8	9.8
122.0 (50)	15	13.5	15.3	16.8	3	2.2	2.5	2.8
125.6 (52)	6	4.3	5.0	5.6	1	0.9	1.0	1.1
120.2 (54)	1	0.8	0.6	1.0	-	-	-	-

Fig. 1. Thermal-death-time (TDT) curve for fifth-instar navel orangeworm and Indianmeal moth

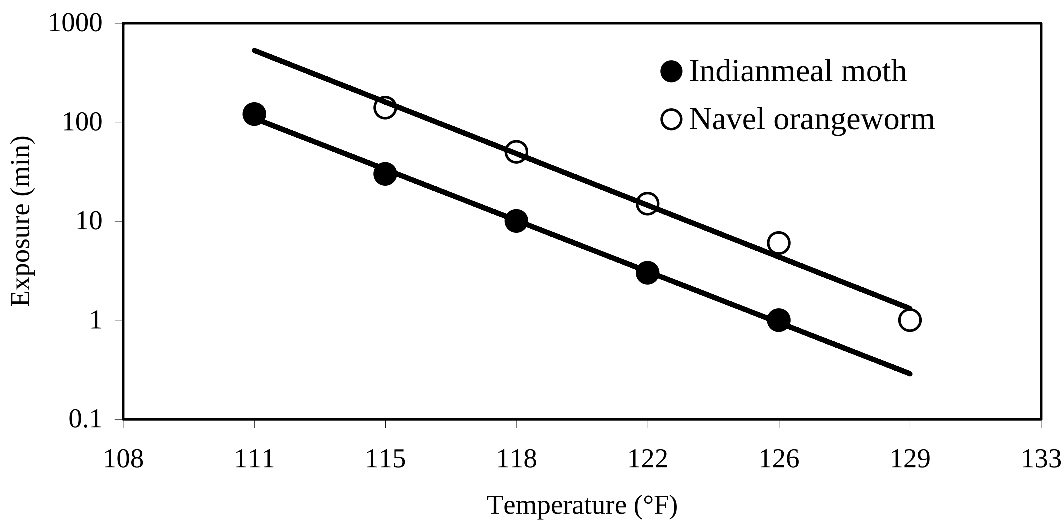

Table 2. Comparative heat tolerance of non-diapausing and diapausing Indianmeal moth fifth instar larvae

Temp °F (°C)	Exposure (min)	% Mortality ± SE	
		Non-diapausing larvae	Diapausing larvae
77.0 (25)	50	1.0 ± 0.58	0.7 ± 0.33
114.8 (46)	10	54.9 ± 9.10 *	9.2 ± 3.06 *
	17	85.1 ± 4.62	79.8 ± 4.64
118.4 (48)	7	95.0 ± 0.58	91.4 ± 7.62
122.0 (50)	2	98.0 ± 1.32 *	83.3 ± 6.41 *

* Values are significantly different at the 5% level