EFFICACY OF TEMPERATURE TREATMENTS FOR INSECT DISINFESTATION OF DRIED FRUITS AND NUTS

J. A. Johnson, H. R. Bolin, G. Fuller, A. A. Rhodes and J. F. Thompson

ABSTRACT

In order to determine the potential of various temperature treatments for disinfesting dried fruits and nuts of postharvest insect pests, exposure times for 50, 95 and 99% mortality in navel orangeworm eggs and pupae and Indianmeal moth pupae were estimated. For navel orangeworm eggs, 99% mortality was achieved with exposure times of 194 minutes at 45°C and 14 minutes at 49°C. Navel orangeworm pupae reacted differently to temperatures; 99% mortalities were produced at 37 minutes at 46°C and 12 minutes at 49°C. Indianmeal moth pupae were less heat tolerant, similar mortalities were obtained at 42 minutes at only 42°C and 13 minutes at 46°C. Freezing points for various stages of the Indianmeal moth were also determined. Pupae and diapausing larvae were the most freeze tolerant, with freezing points of -25°C and -23°C, respectively. The freezing point for non-diapausing larvae was -15°C. The protocol for studies on the effect of high temperatures on product quality was established and experiments were begun. Information on the engineering and economic aspects of both high and low temperature treatments was gathered and an analysis begun.

OBJECTIVES

The purpose of the study is the development of temperature treatments as alternatives to fumigation for insect disinfestation of postharvest dried fruits and nuts. In accomplishing this goal the following objectives have been set.

(a) Determine the temperature extremes and associated exposure times required to kill various stages of the Indianmeal moth (IMM), the navel orangeworm (NOW) and the driedfruit beetle (DFB).

(b) Compare control efficacy of different heat application methods against the above insects in infested raisins, prunes and walnuts.

(c) Evaluate the effect of the above treatments on product quality.

(d) Estimate and compare the costs and feasibility of the above treatments to currently used fumigants and other alternatives.

PROCEDURES

The mortality of pupae of the IMM, and eggs and pupae of the NOW exposed to temperatures ranging from 42 to 49°C for different times was determined. Treatments were applied in a water bath capable of maintaining constant temperatures with ±0.2°C accuracy. For IMM pupae, both direct hot water immersion and indirect immersion in small watertight cells were used to predict the efficacy of different heating methods. For NOW eggs and pupae, only direct immersion was used. Data were analyzed to plot thermal death rate curves and predict LT_{50}s, LT_{95}s and LT_{99}s for each temperature.

Freezing points for IMM pupae, non-diapausing larvae and diapausing larvae were determined by cooling test insects at constant rates in dewar flasks containing liquid nitrogen. Freezing events were observable as sudden increases in insect surface temperatures as detected by thermocouples.

To determine the effect of high temperatures on product quality, various protocols for each commodity have been established. These protocols are outlined in the flow charts in Fig. 6. In addition, researchers have begun to gather the necessary information for analysis of the economic feasibility of temperature treatments for raisins, prunes and walnuts. Initial focus is on commodity treatments most likely to be economically feasible: in-transit heat treatments using modified "grain-driers", in-storage heating, and cold-storage at above freezing temperatures (to suppress insect activity and reproduction).

RESULTS

Percent mortalities from direct hot water immersion of IMM and NOW pupae plotted against exposure time for each treatment temperature are given in Figs. 1 and 2. Exposure times that would provide 50, 95 and 99% mortality (LT_{50}, LT_{95}, and LT_{99}) were estimated using simple regression analysis, and are presented in Table 1. For both insects, a single degree change in temperature resulted in considerable differences in LT values. NOW pupae proved to be more heat resistant than IMM pupae. The LT_{99} for NOW at 46°C was nearly three times that for IMM. To obtain NOW LT_{99}s that were comparable to those of IMM at 46°C, the temperature had to be raised to 49°C.

In order to compare the effectiveness of the different heating methods used for IMM pupae, the logs of the LT_{50}s for each method were plotted against temperature. LT_{50}s of female IMM pupae immersed in water-tight cells were very similar to those from direct immersion tests. Male IMM pupae in cells appeared to be more heat tolerant, with higher LT_{50}s for the same temperatures (Fig. 3). Actually, because males were smaller than females and were thus more insulated by air in the narrow cells, males experienced a slower heating rate than females. The difference in heating rate accounts for the apparent difference in mortalities, because a slower heating rate increases the exposure times necessary for the desired mortality.

Percent mortalities for NOW eggs directly immersed in hot water were plotted against exposure times for each temperature in Fig. 4. Again, simple regression analysis gave fairly accurate estimations of LT_{50}s, LT_{95}s and LT_{99}s, and are presented in Table 2. At lower temperatures, NOW eggs were fairly heat tolerant; 194 minutes were required to produce 99% mortality at 45°C. At 49°C, the same mortality is obtained at 14 minutes. To compare the heat tolerance of NOW eggs with NOW pupae, logs of the LT_{50}s for each stage were plotted against temperature (Fig. 5). Eggs proved much more heat tolerant than pupae at lower temperatures, but this difference decreased as temperatures increased, with eggs less tolerant than pupae at 49°C.

IMM larvae and pupae were capable of surviving exposure to temperatures well below 0°C. IMM pupae proved most freeze resistant, the average temperature at which IMM pupae froze was -24.9°C. Diapausing larvae, the natural overwintering stage of the insect, had an average freezing point of -22.5°C. Non-diapausing larvae, with an average freezing point of only -15.1°C, were much less freeze tolerant than either diapausing larvae or pupae.

The economic analysis of high temperature disinfestations was begun, and will be based on the current cost of driers for products such as pistachio nuts, walnuts, and dried prunes. Five separate types of driers that are used for these commodities have been identified and data on their energy use and capital costs have been collected. The complete financial analysis of high temperature disinfestation will probably be based on using these driers in their off season. These driers are idle for 10 to 11 months per year and would be available for use. Also, they will probably require very little modification in order to be used for disinfestation because they are already set up to handle the crops that we are considering.

Low temperature disinfestation costs will be based on forced air cooling and storage operations which are commonly used in California's fresh fruit and vegetable industry. The off season for many of these facilities is six to nine months and we may assume that existing installations can be used for disinfestation in our financial analysis. We have collected some capital cost and energy use information for recently constructed facilities.

Studies on product quality have been initiated; but results from storage tests are not available at this time.

CONCLUSIONS

The results from the efficacy tests indicate that temperatures of as low as 46°C for as little as 13 minutes would effectively control IMM pupae. Both NOW eggs and pupae were more heat resistant; 49°C for 14 and 12 minutes would be needed to control eggs and pupae, respectively. When both insects are present, a treatment temperature of 50°C for 15 minutes should insure complete control. Before final recommendations can be made, the thermal death points for larval and adult stages of both NOW and IMM, along with eggs of the IMM and all stages of the DFB, need to be determined.

The comparison of heating methods indicates that minor differences in heating rate can dramatically effect efficacy. This must be taken into consideration when treatment temperatures and exposures are predicted for different heat treatments. More work needs to be done on the effect of heating rate and transient temperatures on insect mortality.

The freezing point determinations indicate that the pupal stage of the IMM is the most freeze tolerant. This information will be useful when large-scale low temperature disinfestation of commodities are conducted. Freezing points for NOW and DFB must also be determined in order to identify the most resistant species.

Preliminary engineering and economic studies indicate that modifications of existing dehydration procedures may provide the most economical heat disinfestation of candidate commodities. The use of existing low temperature facilities for disinfestation may also prove acceptable.

Fig. 1 Thermal Death Points for IMM Pupae Direct Immersion

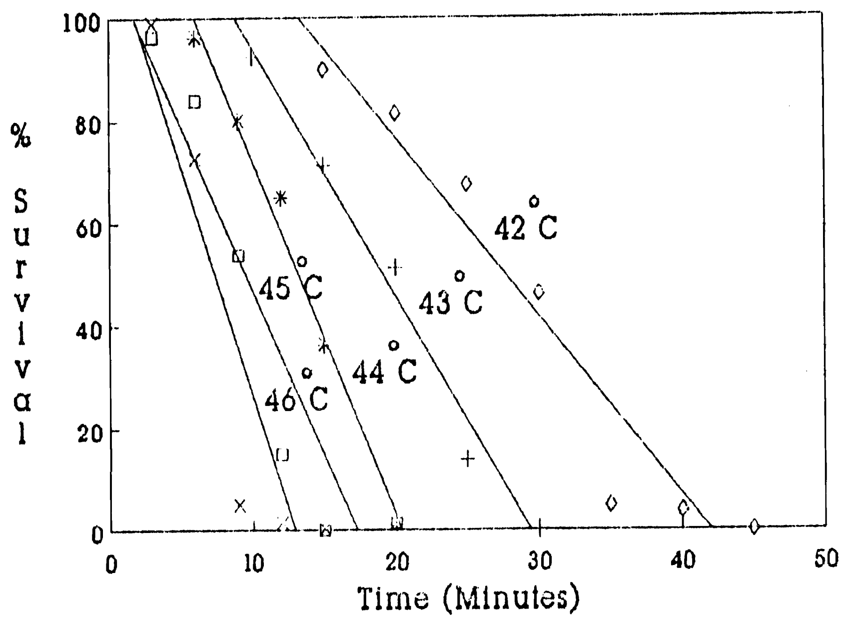


Fig. 2 Thermal Death Points for NOW Pupae Direct Immersion

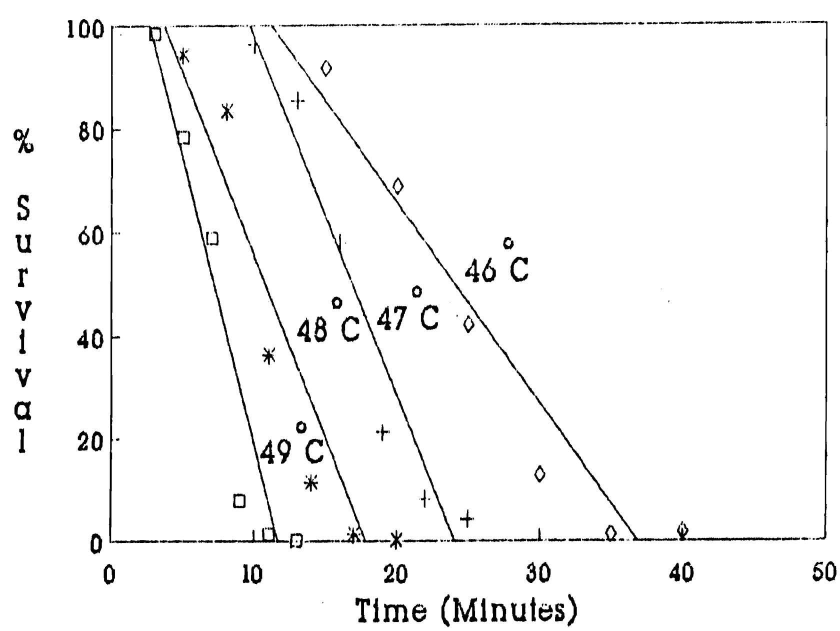


Table 1 Lethal Times for IMM and NOW Pupae

Temp (°C)	IMM LT_{50}	IMM LT_{95}	IMM LT_{99}	NOW LT_{50}	NOW LT_{95}	NOW LT_{99}
	(minutes)					
42	27.7	40.6	41.8	-	-	-
43	19.1	28.4	29.2	-	-	-
44	13.2	19.7	20.3	-	-	-
45	9.5	16.5	17.2	-	-	-
46	7.4	12.4	12.9	24.0	35.6	36.6
47	-	-	-	16.9	23.4	23.9
48	-	-	-	10.8	17.1	17.7
49	-	-	-	7.2	11.3	11.6

Fig. 3 Direct Immersion vs Dry Heat for IMM Pupae

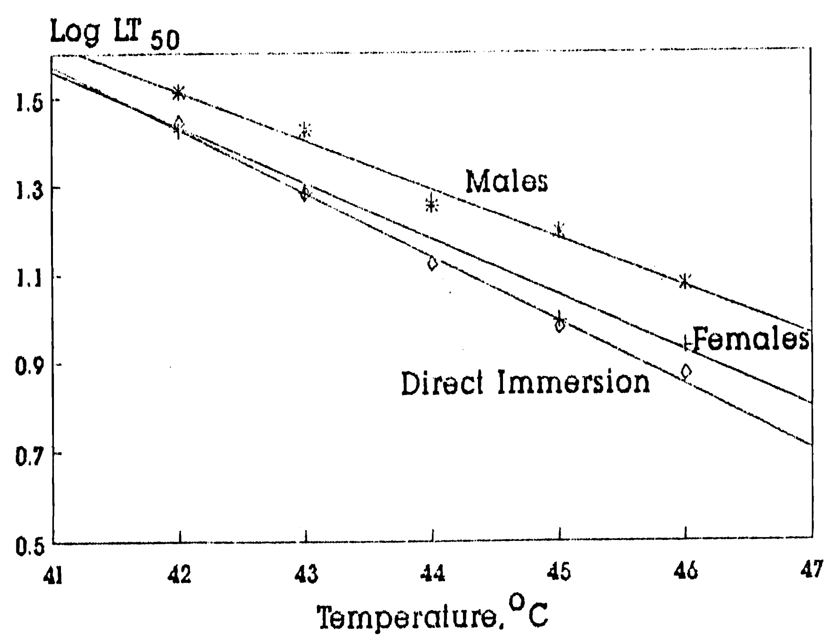


Fig. 4 Thermal Death Points for NOW Eggs

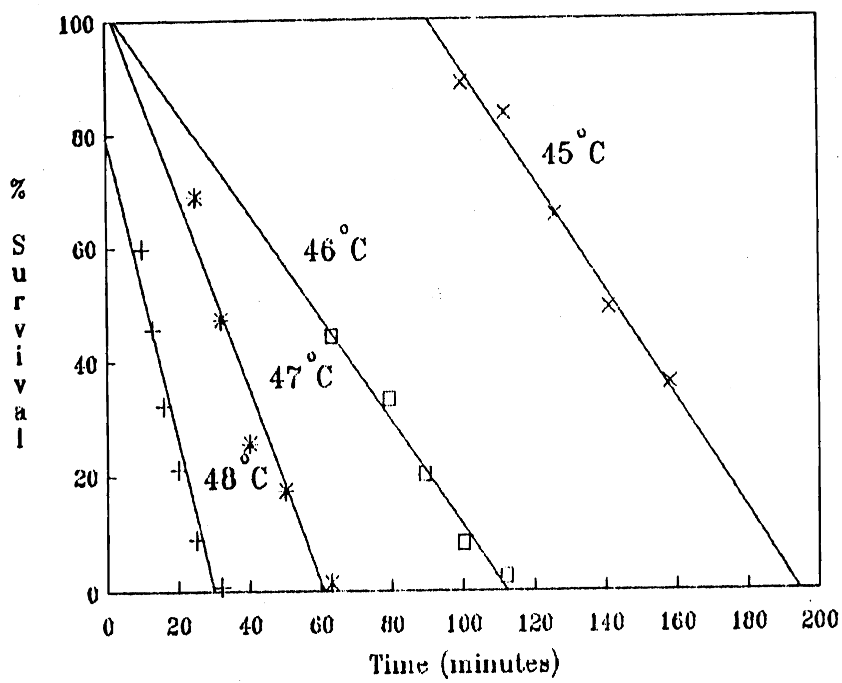


Fig. 5 Thermal LT_{50} for NOW Eggs vs Pupae

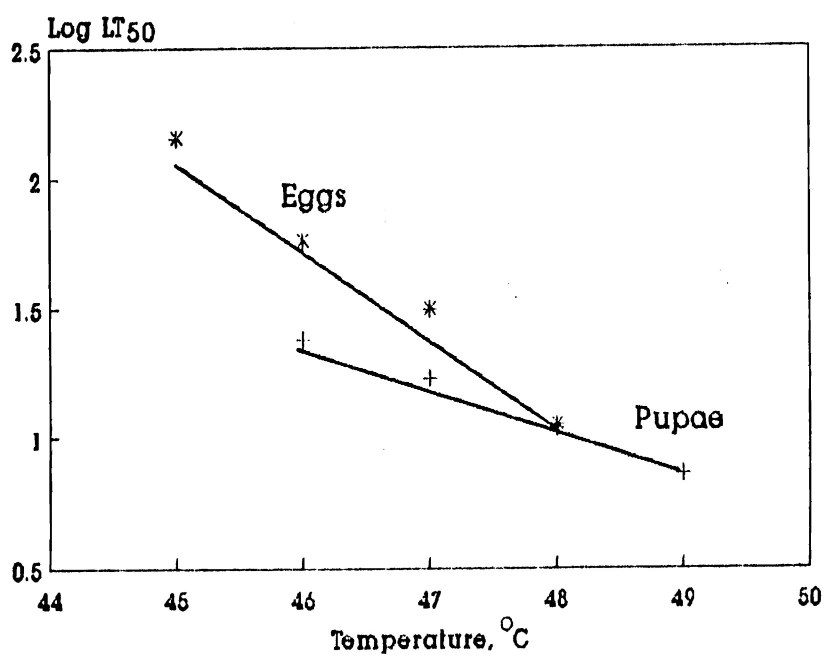
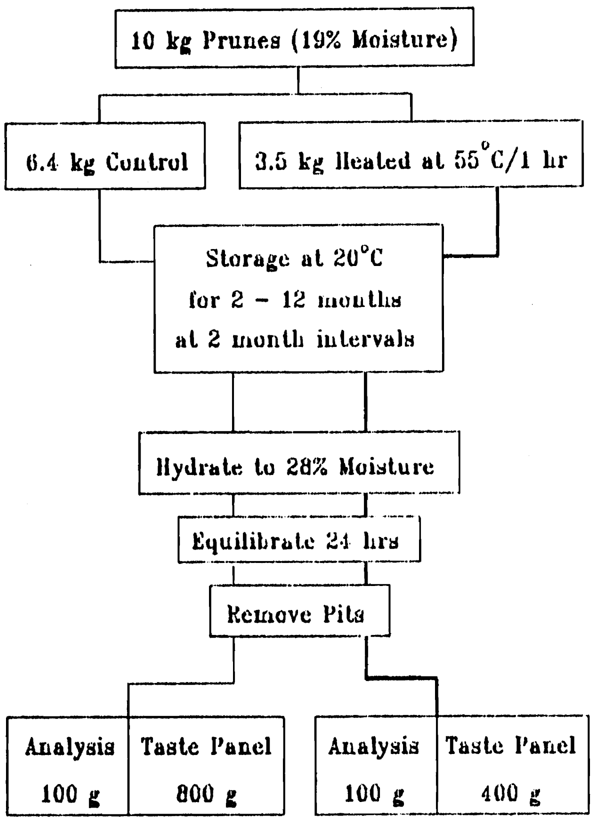


Table 2 Lethal Times for NOW Eggs

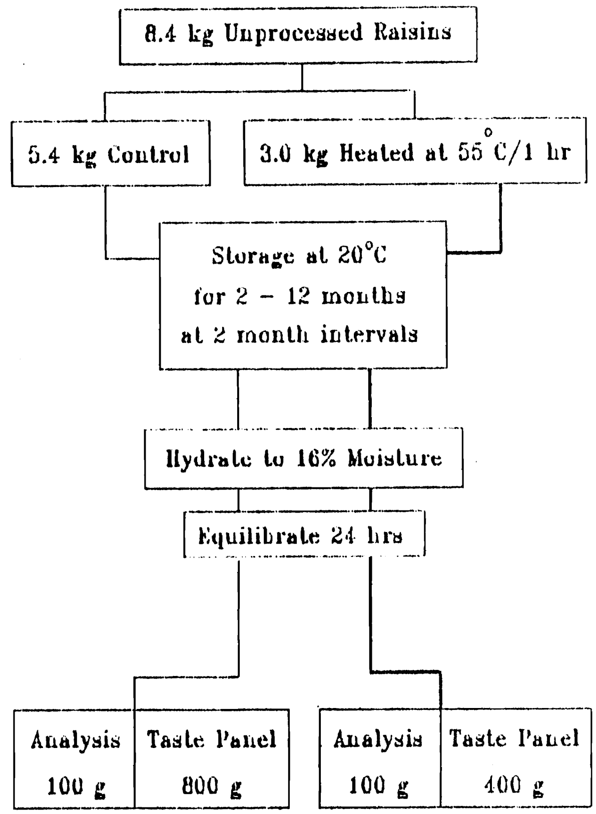
Temp (°C)	LT_{50}	LT_{95} (minutes)	LT_{99}
45	143.0	189.9	194.1
46	57.4	106.9	111.3
47	31.4	57.8	60.2
48	11.1	28.1	29.6
49	5.0	10.9	14.2

Fig. 6 Product Quality Evaluations for Temperature Treatments

Procedures for Quality Evaluations for Prunes



Procedures for Quality Evaluations of Raisins



Procedures for Quality Evaluations for Walnuts