CONTROLLED ATMOSPHERES TO REDUCE POST HARVEST INSECT DAMAGE TO HORTICULTURAL CROPS

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Introduction

Controlled atmospheres have been utilized for preservation of man's food stores since ancient times [3]. Insect control with controlled atmospheres generally has been with relatively nonperishable commodities, such as grains, dried fruits and nuts. Factors generally addressed in controlled atmosphere research include insect kill-times, environmental effects (temperature and relative humidity) phytotoxicity (including taste and odor alteration), sealing of storages, atmosphere generation equipment and economics. Although much research has been conducted on these subjects, little information is available on the effects of controlled atmospheres on many insect pests and on the reaction of many host crops to the atmospheres needed to kill insects.

To more fully understand the interactions of insects, their normal habitat and controlled atmospheres, two insect pests of tree nuts were investigated. Indianmeal moth (IMM), *Plodia interpunctella* (Hübner), is the most important insect pest of stored-products, e.g. nuts and dried fruits, and is well adapted to storage environments. A second type of storage-pest is the navel orangeworm (NOW), *Amyelois transitella* (Walker), which normally infests nuts in the field, enters storage with the commodity but is not as well adapted to storage conditions as the Indianmeal moth.

Currently, stone fruits are restricted from entering some foreign markets due to possible insect infestations. The Codling moth, *Cydia pomonella* (L.), which may infest nectarines, peaches and plums, must be controlled to receive clearance for export of these fruits. Research on codling moth reported by Gaunce et al. [2], indicated that carbon dioxide in high concentrations killed codling moth larvae. Their investigation of possible phytotoxicity caused by such atmospheres indicated a potential for using carbon dioxide on some apple cultivars.

Controlled Atmosphere Effects on Codling Moth

Laboratory tests were conducted to investigate the effects of high carbon dioxide (60%) and low oxygen (0.5%) atmospheres, applied at 25°C and at relative humidities of 60 and 95%, on the time required for codling moth mortality. The low oxygen atmosphere simulated that of an exothermic generator and contained 10% carbon dioxide with the balance nitrogen. To date, adult codling moths and eggs have been tested under the conditions indicated in Tables 1 and 2. Adult moths were killed faster when exposured to the high CO_2 atmospheres than they were when exposed to atmospheres low in O_2. The lower relative humidity also reduced the time required to kill insects exposed to enriched CO_2 atmospheres.

Table 1. Percent mortality of adult codling moths exposed to modified atmospheres at 25°C (77°F).

Atmosphere	Mortality at indicated Exposure time (hrs.)						
	12	18	24	30	36	48	60
	%						
60% CO_2 - 60% RH	7	55	82	95	100	100	--
60% CO_2 - 95% RH	1	--	54	88	97	100	--
Low O_2* - 60% RH	1	5	22	5	63	91	100

*0.5% O_2, 10% CO_2, 89.5% N_2

Eggs were killed in about the same time when exposed to either the carbon dioxide or low-oxygen atmospheres (Table 2). The time to obtain 100% mortality was reduced by 12 hours for both atmospheres when the RH was 60%, rather than 95%.

Table 2. Adjusted[1/] percent mortality of codling moth eggs exposed to modified atmospheres at 25°C (77°F).

Atmosphere	Mortality at Indicated Exposure Time (Hrs.)					
	12	24	36	48	60	72
	%					
60% CO_2 - 60% RH	61	80	96	97	100	100
60% CO_2 [2/] - 95% RH	63	79	95	98	99	100
Low O_2 [2/] - 60% RH	54	67	87	99	100	100
Low O_2 [2/] - 95% RH	52	61	82	94	99	100

1/ Adjusted by Abbotts formula [1].
2/ *0.5% O_2, 10% CO_2, 89.5% N_2

Controlled Atmosphere Effects on Indianmeal Moth and Navel Orangeworm

Pupae of IMM and NOW were exposed to all combinations of 0.5, 1 and 2% oxygen (with 10% CO_2 and a balance of N_2) at 15.6, 21.1, or 26.7°C and at 40 or 60% relative humidity. The lethal time to kill 95% (LT95) of each insect population was determined for each atmosphere combination. Temperature effects were similar for IMM and NOW (Figure 1 A,B).

Insect mortality data were analyzed for insect response to oxygen concentration, temperature, and level of relative humidity. Both IMM and NOW responded similarly to temperature changes, and the effect could be accounted for by a hyperbolic relationship of time versus temperature. The LT95 data were calculated in "degree-hours" which is similar to degree-day calculations. The degree-hour required for insect kill was estimated at each relative humidity and each oxygen concentration tested (Table 3). Mortality of Indianmeal moth required 588 to 1034 degree-hour, depending upon the oxygen level. Mortality of navel orangeworm required either 913 or 1488 degree-hour, depending upon the relative humidity. Analyses of the effects of oxygen and relative humidity showed that IMM was more sensitive to changes in oxygen concentration than NOW (Table 3), while NOW was more sensitive to changes in relative humidity than IMM.

Table 3. Mortality of Indianmeal moth and navel orangeworm pupae exposed to low-oxygen atmospheres.

Oxygen Atmosphere*	Mortality of indicated insect at 40 or 60% relative humidity			
	Indianmeal moth		Navel orangeworm	
	40%	60%	40%	60%
%	- - - Calculated Degree Hours** - -			
0.5	588	588	913	1488
1.0	718	718	913	1488
2.0	1034	1034	913	1488

* plus 10% CO_2 and the balance N_2
** estimated time required for LD95 at given humidities and oxygen concentrations.

Time mortality data were used to determine the lower threshold temperature (the temperature below which the atmosphere would be ineffective) for each combination of relative humidity and oxygen concentration. The lower threshold temperature ranged from 8.8° to 10.9°C for IMM moth and 7.3° to 8.9°C for NOW (Table 4).

Table 4. Lower threshold temperature (°C)

Oxygen Atmosphere*	Temperature below which atmosphere was ineffective against indicated insect at 40 or 60% relative humidity			
	Indianmeal moth		Navel orangeworm	
	40%	60%	40%	60%
%	°C			
0.5	10.2	10.9	7.3	6.6
1.0	9.7	10.6	8.1	7.8
2.0	8.8	10.1	8.8	8.9

*plus 10% CO_2 and balance N_2

Conclusions

Low-oxygen and carbon-dioxide enriched atmospheres were shown to control adults and eggs of codling moth *in vitro*. Exposure times needed for control were shorter with the lower than with the higher relative humidities tested for both insect stages.

Two different types of insects, one a storage pest (Indianmeal moth) and the other, a field infesting pest (navel orangeworm), were found to respond differently to relative humidity and to oxygen concentration. The field infesting insect responded to changes in relative humidity while the storage pest responded to reduced oxygen levels. This observation suggests that the insect involved with field infestations has adapted to food with a high moisture content, while the storage pest has adapted to food with a low moisture content and consequently is more affected by reduced oxygen atmospheres within storages.

Literature Cited

1. Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

2. Gaunce, A. P., C. V. G. Morgan and M. Meheriuk. 1982. Control of tree fruit insects with modified atmospheres. pp. 383-385. In: Controlled Atmospheres for Storage and Transport of Perishable Agricultural Commodities. Eds. D. G. Richardson and M. Meheriuk. Oregon State University, School of Agriculture Symposium Series No. 1. Timber Press, Beaverton, Oregon.

3. Sigaut, Francois. 1980. Significance of underground storage in traditional systems of grain production. pp. 3-13. In: Controlled Atmosphere Storage of Grains. Ed. J. Shejbal Elsevier, New York.

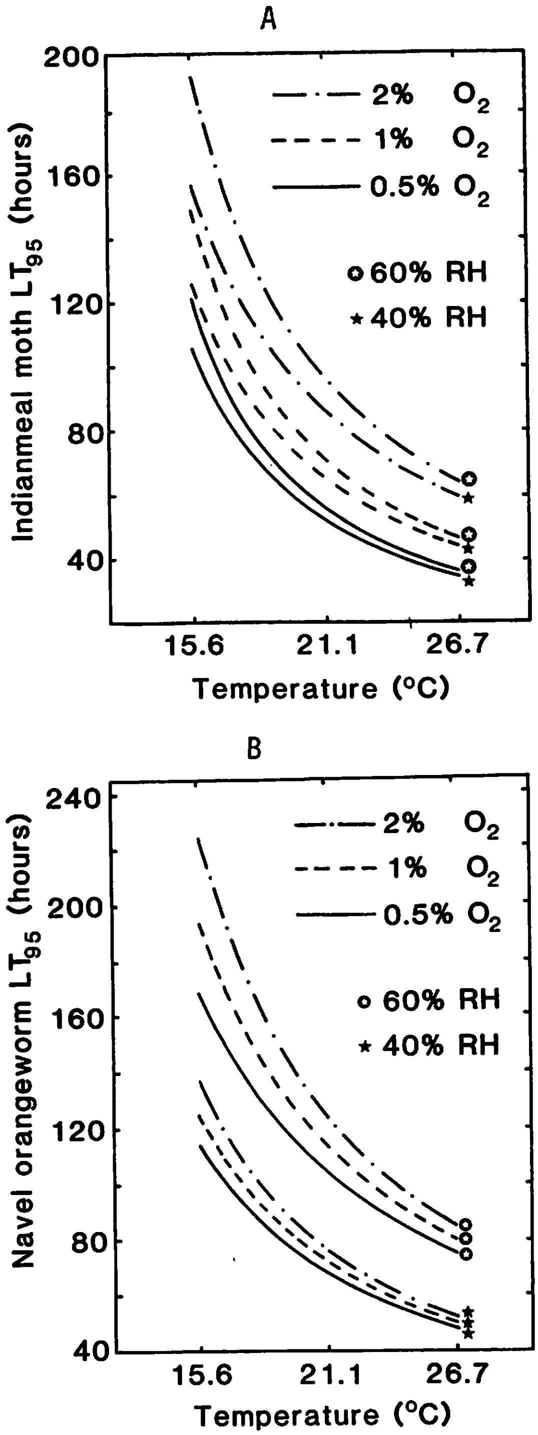

Fig. 1: Interactive effects of three environmental factors on insect mortality (oxygen atmospheres contained 10% CO_2 and the balance N_2 simulating a generated atmosphere).