THE EFFICACY OF CONTROLLED ATMOSPHERE COOLSTORAGE IN CONTROLLING LEAFROLLER SPECIES

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SUMMARY

The effect of 30, 90 and 120 days of controlled atmosphere coolstorage on three leafroller species, light brown apple moth (*Epiphyas postvittana*), brown-headed leafroller (*Ctenopseustis obliquana*) and greenheaded leafroller (*Planotortrix excessana*) was investigated by artificially infesting 'Red Delicious' apples. A CA coolstorage period of at least 90 days is proposed as a quarantine treatment for apples exported from New Zealand.

INTRODUCTION

Controlled atmospheres (CA) are used currently for two main purposes: to disinfect stored product insects from grain, and to extend the storage life of fruits and vegetables. The atmospheres and environments used for each purpose differ markedly as grain can tolerate conditions that would severely affect fresh produce.

Two main types of atmospheres are insecticidal to stored grain pests: low oxygen atmospheres and CO₂-rich atmospheres (Bailey and Banks 1975). The time taken to achieve a certain level of insect kill is dependent not only on the composition of the atmosphere but also on the temperature and humidity of the environment. At high storage temperatures e.g., 35 °C, only a few days are required but this is extended to several weeks at less than 15 °C. Low relative humidity (less than 50%) greatly augments the insecticidal effect of controlled atmospheres, and it appears that death under CO₂-rich atmospheres may often be related to water loss from the insect (Jay *et al* 1971).

Controlled atmosphere disinfestation of grain insects is a commercially feasible alternative to current methods that rely on pesticides, and one that is free of residues and pest resistance problems.

Controlled atmospheres using oxygen and carbon dioxide are used in combination with low temperature storage to extend the shelf-life of many fruits and vegetables (Hatton *et al* 1975). However, the insecticidal environment used to disinfest grain (prolonged periods of storage at high temperatures, low humidity, high carbon dioxide levels) is inappropriate to fresh fruits and vegetables. Nevertheless, some research has investigated exposure of insects infesting fruit and vegetables to high levels of CO₂ for short periods of time, and has shown some lethal effects which may have practical application as quarantine treatments.

Exposure of San José scale (*Quadraspidiotus perniciosus*) on apples to 90% CO₂ and less than 1% O₂ for 2 days at 12 °C or greater was completely effective in killing scale without affecting apple quality (Morgan and Gaunce 1975). Storage of apples for at least 16 weeks at 2 °C in controlled atmosphere (3% O₂:3% CO₂) or standard coolstorage has been proposed as a quarantine treatment for *Q. perniciosus* on apple exports from Italy to Germany (Dickler 1975).

There have been few investigations reporting on the effects of CA on lepidopterous pests. Codling moth larvae (*Cydia pomonella*) have survived 132 days in both standard coolstorage (SC) and CA (Glass *et al* 1961); and a minimum period of 60 days SC or CA storage was used to enhance the effects of fumigation with methyl bromide (Moffitt 1971).

This study examined the responses of three leafroller species, light brown apple moth (LBAM), greenheaded leafroller (GHL), and brownheaded leafroller (BHL),

Proc. 38th N.Z. Weed and Pest Control Conf.

artificially placed on 'Red Delicious' apples and held in commercial CA storage. Apples stored for 90 days under CA conditions (compared with SC) return a premium price on the North American market.

METHODS

'Red Delicious' apples were left unsprayed for 13 weeks prior to harvest to minimise chemical residues from field-sprays that could subsequently affect larval establishment. The apples were held in ambient conditions (10-15 °C) for less than 2 weeks prior to being infested with larvae.

All species of leafroller larvae were laboratory reared on artificial diet (Singh 1974). They were selected for infestation when approximately 200 (LBAM) and 300 (BHL, GHL) day-degrees in age above a threshold of 8 °C. Thus mainly second or third instar larvae were used. Those too small or too large and therefore likely to pupate were rejected as they are unlikely to be found on the fruit at harvest.

The larvae were allowed to establish naturally over a period of 3-6 days at 25.0 ± 2 °C on the apples. Approximately 130 larvae were placed in each box of 100 apples. The infested apples were 'pre-conditioned' for 36 hours at 12.0 ± 0.5 °C prior to being placed in standard coolstorage (SC) or CA storage at the New Zealand Apple and Pear Marketing Board (NZAPMB) coolstores, Henderson, Auckland. Infested apples held in SC acted as a control. The controlled atmosphere was nominally 3% oxygen and 3% carbon dioxide. The temperatures (SC and CA stores) and atmospheres (CA store) were recorded daily during the experimental period. In order to prevent leafroller contamination of export fruit in the same coolstores, fine nylon-mesh net bags were placed around each infested carton.

A proportion of each treatment was removed after 30, 90 and 120 days SC and CA storage. A self-contained breathing apparatus was used to remove samples from the CA environment.

An equal proportion of apples from each box was examined by each recorder to reduce bias. Each apple was inspected externally for the presence of larvae before being opened at the calyx to record entries into the core of the fruit.

Recovered larvae were classified as follows: live (able to crawl), moribund (unable to crawl but alive), dead (no movement), squashed (larvae inadvertently crushed by apple movement), or pupated. Squashed larvae and those that had pupated were excluded from the final data. Although moribund larvae are unacceptable for quarantine inspection, they provided additional information in these preliminary trials. Moribund larvae were placed into individual tubes with artificial diet and retained at 25.0 ± 2.0 °C for later re-assessment as live if there was evidence of feeding, or if pupation occurred. The larvae recovered in the net bags were recorded and included in the data.

TABLE 1: The percentage mortality (based on total larvae recovered) of light brown apple moth (LBAM), brownheaded leafroller (BHL) and greenheaded leafroller (GHL) exposed to standard coolstorage (SC) or controlled atmosphere (CA) coolstorage when artificially placed on 'Red Delicious' apples.

Days in storage	Coolstorage treatment	Leafroller species					
		LBAM		BHL		GHL	
		Total larvae	% mortality	Total larvae	% mortality	Total larvae	% mortality
30	SC	179	98.8	99	32.3	92	30.4
30	CA	711	95.6	123	43.9	109	53.2
90	SC	163	100.0	100	100.0	110	90.9
90	CA	737	100.0	180	100.0	132	100.0
120	SC	133	100.0	87	81.6	88	78.4
120	CA	702	100.0	155	100.0	162	100.0

RESULTS AND DISCUSSION

The average oxygen and carbon dioxide levels, and temperatures recorded over 18 weeks in the NZAPMB CA coolstores were 3.8%, 2.8% and 0.9°C respectively. Complete kill of all three leafroller species was achieved at 90 days of commercial CA coolstorage (Table 1). Complete kill of LBAM was also achieved after more than 90 days of SC, in contrast to BHL and GHL which survived 120 days of SC.

These results indicate that a quarantine inspection for leafroller species on apples from New Zealand would be unnecessary if CA storage for at least 90 days was a disinfestation treatment acceptable to the importing country.

ACKNOWLEDGEMENTS

We wish to thank Dr P. Singh, Mr G.K. Clare and the staff of the Rearing Group, Entomology Division, for providing the leafrollers; Mr Ewan Grant-Mackie for assistance in the assessment of leafroller mortality; Mr G. Hammonds (David Oppenheimer and Associates, Vancouver); Messrs I.D. Wilson, D. Soldera (New Zealand Apple and Pear Marketing Board, Wellington) and D. Hamilton (NZAPMB, Henderson); and Dr N.A. Martin and Mr P.R. Dentener for discussions on this report.

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