LOW PRESSURE/LOW TEMPERATURE TREATMENTS: INSECT EFFICACY AND APPLE QUALITY

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Because U.S. apples, pears and cherries may be infested with codling moth, *Cydia pomonella*, an important quarantine pest, they require fumigation with methyl bromide before export to certain markets. Whereas quarantine and pre-shipment (QPS) treatments are currently allowable under the Montreal Protocol, there is growing concern that the QPS exemption will eventually be lost. Consequently, alternative treatment protocols are being considered. Low pressure treatments, coupled with low temperatures and carefully regulated humidity, have been shown to prevent product deterioration caused by fungal decay, and prevent shriveling and fruit ripening during storage. This project looks at using these treatments to disinfest pome fruits of the various life stages of the codling moth.

Methods: A lab scale low pressure and low temperature (LPLT) system was used, consisting of two 0.152 m^3 insulated aluminum chambers (VivaFresh™ Model RDC-0005, Atlas Technologies, Port Townsend, WA) and a two-stage rotary vacuum pump regulated by an inline vacuum regulator coupled with a sub-atmospheric regulator. Chamber pressure was monitored with a digital pressure gauge. A rotameter adjusted the air exchange rate, and ingoing air was humidified in order to keep the humidity near saturation (98-99%). Data from temperature, humidity and pressure sensors were sent to a computer control and recording system. The chambers were held in cold rooms set at the desired treatment temperature (10-13°C). Efficacy studies were done using lab-reared codling moth eggs, 7 d old larvae, 14 d old larvae and pupae. Tests were done at 10 mm Hg and 10°C in two chambers; one where samples of each life stage were removed after 6, 8, 10 and 12 days, and the second where samples were removed only after 12 days. Additional dose response studies were done with 5th instar (14 day old) larvae at 12 mm Hg and 13°C in an attempt to reduce the treatment time. Red Chief 'Red Delicious' apples were used for quality evaluations. The weight loss, color, firmness, titratable acidity (TA) and soluble solids content (SSC) of the apples were evaluated after treatment at 10 mm Hg and 10°C for 6, 9, 12 and 15 days, and compared to apples stored at ambient temperatures and at 0°C.

Results: There was little difference noted between codling moth mortality after 12 days of intermittent exposure and 12 days of continuous exposure (Fig. 1). Eggs were found to be the least tolerant to 10 mm Hg and 10°C (Fig. 1). Subsequent probit analysis of the remaining life stages showed that there was no significant difference between 5th instar larvae and pupae, but that 2nd-3rd instar larvae were significantly less tolerant (Table 1). Because 5th instar larvae had the highest LT values, they were selected for further studies. Dose response results for 5th instar larvae exposed to 12 mm Hg pressure and 13°C (Table 2) show that lethal times were considerably reduced from those treatments at 10 mm Hg and 10°C. In particular, probit 9 for 5th instar larvae treated at the higher temperature was 14.7 (13.3-16.7) days, much lower than the 20.5 (16.9-28.9) days needed for probit 9 at the lower temperature.

Table 3 shows the quality parameters for 'Red Delicious' apples before and after treatment. There were no significant differences for the L* values before and after each treatment, although after 15 days of exposure L* values for both 0°C storage and LPLT storage were significantly lower than ambient storage. Chroma values decreased after LPLT treatments, and LPLT storage values were significantly lower than both 0°C storage and ambient storage, after 15 days of treatment. The fruit firmness of treated 'Red Delicious' apples was significantly reduced after ambient storage, and was significantly lower than both 0°C and LPLT treatments, probably due to severe water loss. There were no changes in fruit firmness after 15 days of treatment for either 0°C or LPLT storage. There were no significant changes in titratable acidity for any of the treatments. Soluble solids content varied significantly between exposures, but all values were within acceptable levels. Weight loss (data not shown) was the greatest when apples were kept at room temperature, with more than 6% weight loss after 15 days. Weight loss was much less in LPLT treatments compared with that at room temperature. Weight loss in LPLT treatments after 15 days was slightly higher than that for 0°C storage. Generally weight loss during LPLT treatments was minimized, since the incoming air was humidified.

Conclusions: Large larvae and pupae were found to be the stage most tolerant to LPLT treatments. Increasing temperature to 13°C reduced the exposures needed to reach quarantine security, but 17 day treatments would still be needed. Apple quality was maintained after 15 days of LPLT storage, especially when compared to ambient storage. Additional quality work and confirmatory tests at 12mm Hg and 13°C is needed to determine if the method is acceptable.

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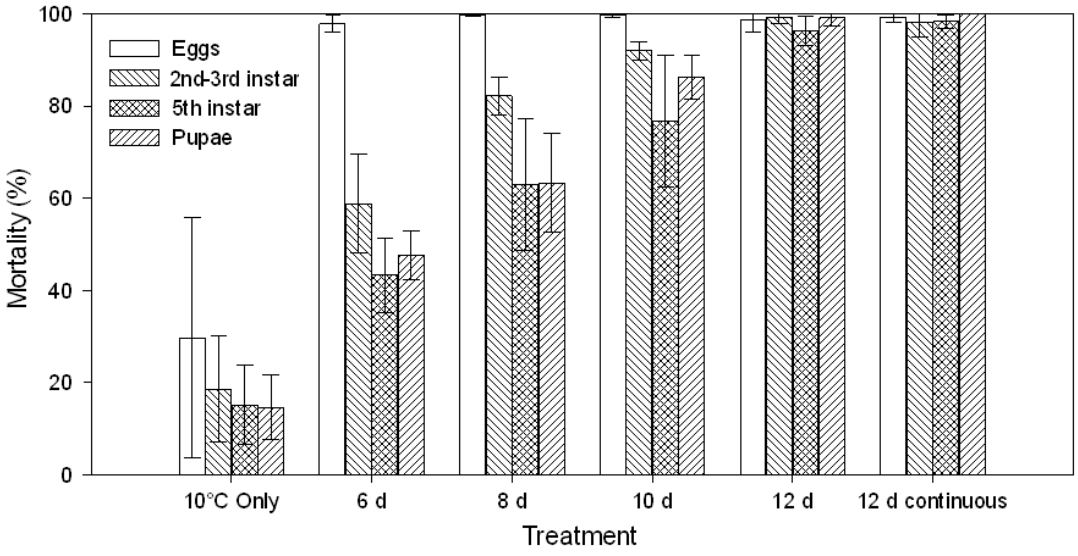

Fig. 1. The mortality of codling moth at four life stages (eggs, 2nd-3rd instar larvae, 5th instar larvae and pupae) under different treatment methods and exposure times.

Table 1. Lethal times (LT, days) for different life stages of codling moth exposed to 10 mm Hg pressure, 10°C, and near saturated humidity

Stage	n	Slope ± SE	LT (95% Confidence Interval)	
			LT_{50}	LT_{95}
2nd-3rd instar	555	0.319 ± 0.042	5.2 (4.2-5.9) a	10.4 (9.7-11.5) a
5th instar	585	0.290 ± 0.033	6.7 (5.2-7.6) b	12.4 (11.0-15.4) b
Pupae	545	0.337 ± 0.038	6.5 (5.7-7.1) b	11.4 (10.6-12.8) b

Values in the same column with different letters are significantly different ($P < 0.05$; lethal dose ratio test).

Table 2. Lethal times (LT, days) for 5th instar codling moth larvae exposed to 12 mm Hg pressure, 13°C and near saturated relative humidity.

Mortality level	Dose	95% CI	
		Lower	Upper
LT_{50}	3.7	3.2	4.1
LT_{95}	8.2	7.8	8.9
$LT_{99.9968}$	14.7	13.3	16.7
Regression parameters			
n	1078	χ^2	15.23
Slope ± SE	0.366 ± 0.034	Heterogeneity	0.952

Table 3. Quality parameters of 'Red Delicious' apples under different treatments and exposure times over three replicates.*

Parameter	Treatment	Ambient	0°C	LPLT
Color-L*	Control	70.9±8.4 a, A	68.9±9.2 a, A	68.8±7.0 a, A
	15 days	73.9±9.9 a, A	68.1±9.9 a, B	67.2±8.4 a, B
Color-Chroma	Control	37.6±5.4 a, A	38.0±5.4 a, A	39.0±3.6 a, A
	15 days	35.6±5.5 a, A	39.6±6.5 a, B	32.0±5.6 b, C
Firmness (N)	Control	72.7±6.4 a, A	72.7±6.4 a, A	72.7±6.4 a, A
	15 days	59.4±5.5 b, A	70.1±8.5 a, B	70.0±8.9 a, B
Titratable Acid	Control	0.26±0.05 a, A	0.26±0.05 a, A	0.26±0.05 a, A
	15 days	0.23±0.05 a, A	0.27±0.05 a, A	0.24±0.03 a, A
Soluble Solids Content	Control	12.6±0.5 a, A	12.6±0.5 a, A	12.6±0.5 a, A
	15 days	13.0±0.8 a, A	13.1±0.6 b, A	12.9±0.3 a, A

* Values in the same column with different lower case letters were significantly different for different treatment time ($P<0.05$) for each quality parameter.
Values in the same row with different upper case letters were significantly different ($P<0.05$) among different treatments for each quality parameter.