HIGH TEMPERATURE CONTROLLED ATMOSPHERE FOR DISINFESTING GRAPEFRUIT OF MEXICAN FRUIT FLY

Krista C. Shellie and Robert L. Mangan

Mexican fruit fly, (*Anastrepha ludens (*Loew), is a quarantine pest on citrus and other tropical and subtropical fruits (Norrbom, and Kim, 1988), and can potentially limit where and how harvested fruit can be marketed. Commodity treatments approved by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS) for grapefruit against *Anastrespha* species include methyl bromide fumigation, cold, vapor heat, and high temperature forced air (U.S. Department of Agriculture, 1993). Methyl bromide fumigation, cold storage, and vapor heat treatments can damage the market quality of grapefruit. The high temperature forced air treatment for grapefruit requires approximately 4 hours to complete, and does not alter fruit market quality when the treatment is applied on a research scale. High temperature forced air was approved by APHIS in 1993, yet it has not been used commercially to disinfest grapefruit.

The observed lethal effect of modified atmospheric gases on insects and the beneficial effect of modified atmospheric gases on postharvest fruit quality prompted investigation of controlled atmospheres for disinfesting fresh commodities of quarantined insect pests (Fleurat-Lessard, 1990; Carpenter and Potter, 1994; Hallman, 1994). The efficacy of controlled atmosphere storage at ambient or refrigerated temperatures has been investigated for some internal feeding insects, such as Caribbean fruit fly (*Anastrepha suspensa* (Loew) (Benschoter, 1987); codling moth (*Cydia pomonella* (Loew) (Soderstrom et al., 1990); and sweet potato weevil (*Cylas formicarius elegantulus* (Summers) (Delate et al., 1990). Results from these studies, suggest that elevated carbon dioxide levels enhance mortality to a greater extent than does reduced oxygen levels. The temperature at which the insect is exposed to a controlled atmosphere was found to influence insect mortality, with higher temperatures usually being more lethal than lower temperatures. The insecticidal potential of controlled atmosphere storage at temperatures greater than 30C has not been studied (Ke and Kader, 1992). The objective of this research was to evaluate whether a controlled atmosphere established inside a high temperature forced air chamber could enhance mortality of the most heat resistant life stage of *A. ludens* and thereby reduce the amount of time grapefruit infested with Mexican fruit fly need to be exposed to a heat treatment.

Grapefruit weighing between 430-450 g were artificially infested with 50 lab reared, non-feeding, 8 or 9 day old, third-instar *A. ludens* larvae and exposed to an identical, 2 hour temperature stress in the presence or absence of a controlled atmosphere. The imposed temperature stress was equivalent to 46C moist forced-air with dewpoint temperature maintained 2C below the fruit surface temperature and air forced through the chamber at 2 m sec^{-1} (Shellie and Mangan, 1995). A modified atmosphere was passively generated inside the grapefruit by immersing the fruit in a temperature programmed water bath that simulated the 46C forced air temperature stress. A controlled atmosphere was also actively established by continuously injecting 4% oxygen + 18% carbon dioxide into a heated forced-air chamber. Artificially infested grapefruit not exposed to a heat treatment were used as controls. Larvae were removed from control and heat-treated grapefruit 12 hours after treatment, placed into vermiculite, and evaluated daily until they died or pupated. Larval mortality of treated fruit was adjusting for mortality in control fruit. The concentration of oxygen and carbon dioxide inside the fruit during treatment was measured at 30 minute intervals by inserting a louer lock needle into the fruit center prior to treatment, extracting a 1 ml gas sample from the fruit during treatment, and injecting the extracted sample into an HP 5890 gas chromatograph equipped with an Alltech CTR1 column and thermal conductivity detector. Each of the heat treatments were replicated 8 times with 2 fruit per replication.

The center temperatures of grapefruit exposed to forced air and forced controlled atmosphere were nearly identical (Fig. 1). The center temperature of fruit immersed in the temperature programmed water baths exceeded that of fruit exposed to forced air or forced controlled atmosphere by 1 to 2C for the first 60 minutes of treatment. Larvae were exposed to a maximum fruit center temperature of 41C in all heat

treatments. Fruit center temperatures increased at an average rate of 2C every 10 minutes (Fig. 1).

The concentration of carbon dioxide and oxygen inside the grapefruit prior to the heat treatment was about 2 and 20%, respectively. Larvae were exposed to a different concentration of oxygen and carbon dioxide inside the grapefruit during each of the heat treatments (Fig. 2). Carbon dioxide increased and oxygen decreased most dramatically in fruit exposed to the heated controlled atmosphere. After 30 minutes, the levels of carbon dioxide and oxygen in fruit exposed to the heated controlled atmosphere had nearly reached equilibrium with that of the controlled atmosphere. Fruit immersed in water had significantly higher levels of carbon dioxide and reduced levels of oxygen after 30 minutes than fruit exposed to forced air.

Most imprtantly, the percent mortality of larvae from grapefruit exposed to a heated controlled atmosphere was significantly higher than that of larvae from grapefruit exposed to heated air (Table 1). Results from this research suggest that reducing oxygen and or increasing the level of carbon dioxide during heating enhances mortality of *A. ludens* and could potentially reduce the amount of time a commodity has to be exposed to heat to meet quarantine security.

Our research unit is currently investigating the relative tolerance of *A. ludens* to modified levels of oxygen, carbon dioxide, and combinations thereof during heating and during cold storage, and the duration of exposure required to obtain quarantine security. We are also simultaneously researching the physiological response of the fruit to ensure that potential treatments do not impair fruit market quality. Over the last five years our unit has developed nondamaging high temperature forced air treatments for tangerines, oranges, and grapefruit that provide quarantine security against *A. ludens*.

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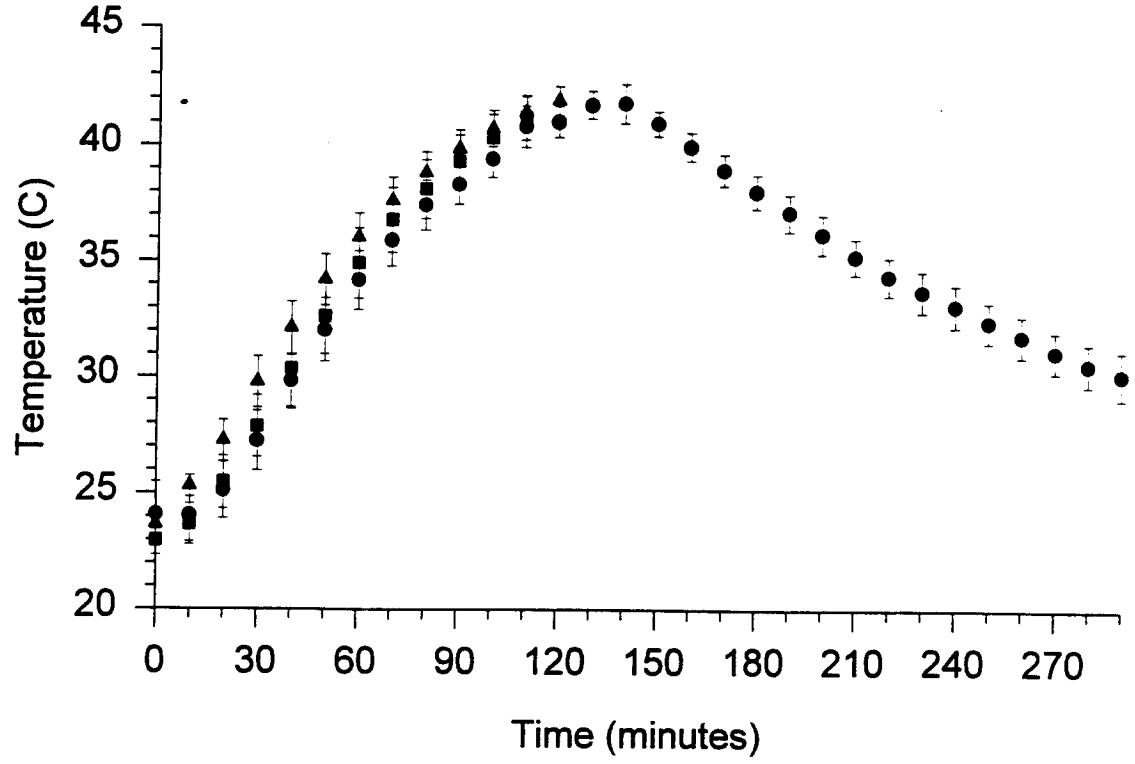

Figure 1. Grapefruit center temperature during a 2 hour exposure to a 46C moist, forced air temperature stress. ■ 4% Oxygen + 18% CO2 ▲ Water immersion ● Air

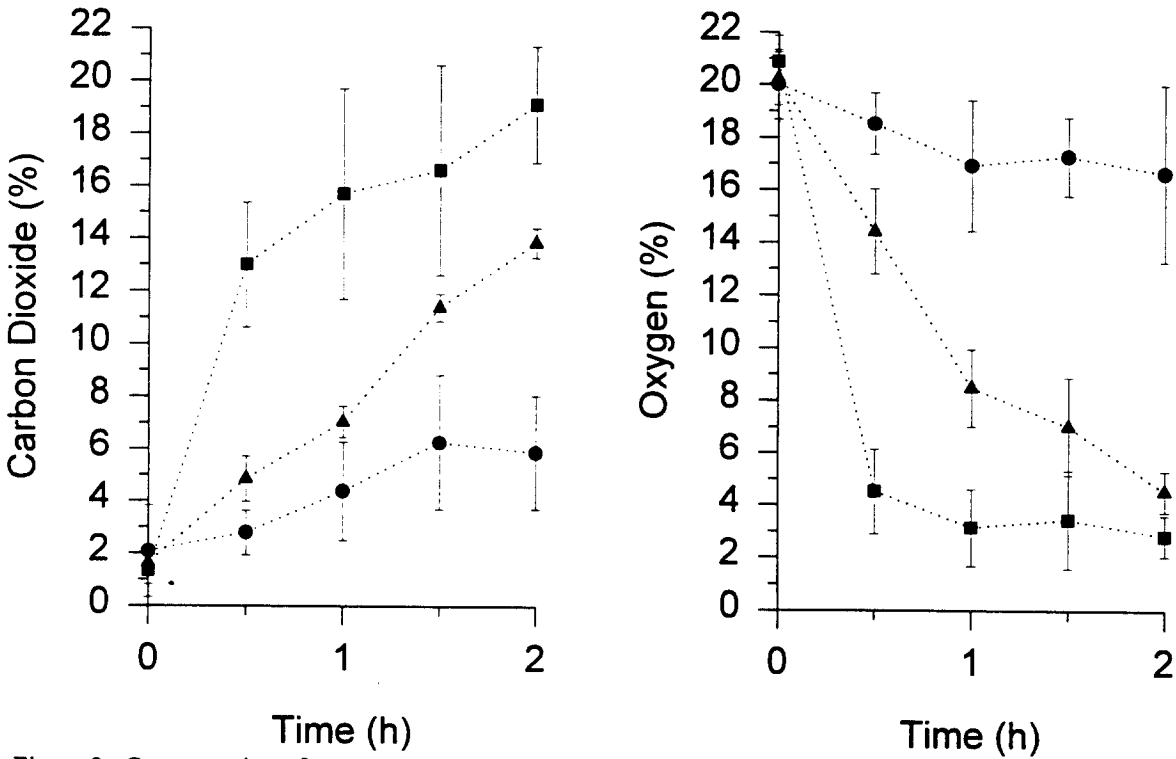

Figure 2. Concentration of oxygen and carbon dioxide inside grapefruit during an imposed 46C forced air temperature stress. ■ 4% Oxygen + 18% CO2 ▲ Water immersion ● Air

Table 1. Mortality of *A. ludens* from artificially infested grapefruit exposed to a 2 hour heat treatment in the presence or absence of a modified atmosphere.

Source	**df**	**Mean Square**[a]
Treatment	2	1093.00*
Error[b]	21	3357.15
		Means[c]
Treatment		**Mortality (%)**
4% O2 + 18% CO2		19.56 a
Water immersion		11.04 ab
Air		8.38 b

[a]*Significant at P≤0.05. [b]Treatment x replication. [c]Mean separation by Duncan's multiple range test at P≤0.05.