have already been infected. Chlorine solutions at less than pH 6.5 are more corrosive and volatile, and therefore more difficult to keep in solution. They are also more hazardous to workers (10). Problems with degradation of benomyl will occur when the pH exceeds 8 (3).

A benomyl drench will also control green mold providing benzimidazole-resistant strains are not present (11). Thiabendazole or the experimental fungicide, guazatine (4), would also be suitable fungicides for use in a truck bin drenching system.

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1988 QUALITY OF FLORIDA GRAPEFRUIT ARRIVALS IN JAPAN AND TAIWAN: PROBLEMS AND RECOMMENDATIONS

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Abstract. **Fresh citrus shipments from Florida totaled 71,424,000 cartons during the 1987-1988 season. Of that total, 45,214,000 cartons, or 63.3% were grapefruit. Grapefruit exports totaled 20,675,000 cartons, or 45.7% of the total fresh grapefruit shipments. Japan was by far the largest importer of Florida grapefruit receiving 10.9 million cartons, or 52%, of total exports.**

In late May and early June 1988, Florida grapefruit were examined at port warehouses in Japan and Taiwan. Quality was generally good, with low levels of peel injury and decay. Decay was high in older shipments kept in warehouses for more than 6 weeks after arrival. Fruit from designated fly free zones tended to have more decay and less desirable color than cold treated fruit. Temperature records on board one vessel from boarding to discharging of cargo were examined indicating that the quarantine requirements of cold treatment were exceeded. Other observations on arrivals in Taiwan and Japan are presented along with suggestions for quality control.

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A HOT WATER/COLD STORAGE QUARANTINE TREATMENT FOR GRAPEFRUIT INFESTED WITH THE CARIBBEAN FRUIT FLY

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Additional index words. commodity treatment, *Anastrepha suspensa*, Tephritidae.

Abstract. **Grapefruit (*Citrus paradisi* Macf.) were infested with immature stages of the Caribbean fruit fly, *Anastrepha suspensa* (Loew) (Diptera: Tephritidae). After infestation fruit were immersed in hot water at 43.3°C (110°F) from 45 to 90 min and then placed in a cooler at 1.1°C (34°F) for 7 days. Fruit were held to evaluate larval mortality in response to the treatments. Probit analysis of mortality data predicted that hot water immersion (43.3°C) of 100 minutes followed by seven days of cold treatment (1.1°C) or a hot water immersion (43.3°C) of 175 minutes by itself would produce Probit 9 (99.9968% mortality) quarantine security.**

In the mid 1960s the Caribbean fruit fly, *Anastrepha suspensa* (Loew), infested parts of Florida and soon spread over most of the state (13, 14). In the early 1970s, shipments of grapefruit from Florida to Japan were found to

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have fruit fly larvae in them. Fumigation techniques were developed for quarantine purposes using ethylene dibromide (EDB) (1). In the early 1980s EDB was banned by the EPA as a potential carcinogen (10), and after several extensions this chemical's use was discontinued. EDB had major advantages over other quarantine treatments in that it was quick, thorough, and had minimal phytotoxicity problems. The United States Dept. of Agriculture, Animal-Plant Health Inspection Service-Plant Protection Quarantine (USDA-APHIS-PPQ) treatment manual give schedules for cold treatments based on unpublished work done in the 1930s (5), so the citrus industry substituted cold treatments for the banned fumigant. Benschoter (3, 4) conducted work on cold storage as a quarantine treatment for fruit infested with *A. suspensa*.

The USDA-APHIS-PPQ quarantine manual also lists two quarantine schedules for citrus using vapor heat and methyl bromide fumigation (15). Cold treatment provides probit 9 quarantine security with a minimum of phytotoxicity problems, but it is a long term treatment and requires up to three weeks. It fits in well with slower surface shipping but not with rapid movement of produce to market. Cold storage at low temperatures also may also require pre-conditioning of the fruit to avoid chilling injury (8). Research on hot water immersion of grapefruit as well as vapor heat, dry heat, gamma irradiation and other treatments have been conducted to provide rapid effective quarantine treatments for grapefruit with a minimum of phytotoxicity (11). Phytotoxicity has been found to be a potential problem with some heat treatments (9).

The current research evaluates the combination of a heat treatment with a cold storage treatment. A combination of the hot water plus cold storage treatments may provide a faster treatment and avoid phytotoxicity problems.

Materials and Methods

Grapefruit (*Citrus paradisi* Macf.) (size 36 Marsh white) were placed in an outdoor fly cage containing approximately 200,000 laboratory reared Caribbean fruit flies (6). The grapefruit were kept in the cage for seven days and then held for another seven days to ensure that mature third instar larvae were present. The fruit were randomized and divided into groups of 30 fruit. Three groups of fruit (total of 90 fruit) were used as a control to estimate the larval infestation present. These fruit were immediately placed in holding towers. The emerging larvae crawled or fell into buckets filled with sand where they pupated. The sand was sifted and larvae were counted several times a week for up to four weeks or when no more larvae emerged from the fruit.

The remaining fruit were divided into four groups with 60 fruit in each group. Each group was immersed in hot water at 43.3°C (110°F) for one of 4 different times; 45 min, 60 min, 75 min, and 90 min. All of the fruit were allowed to cool in ambient air (approximately 25 to 27°C) for 24 hours, then one half of each treatment (30 fruit) was placed in a walk in cooler at 1.1°C (34°F). The other half of the fruit was immediately placed in holding towers for larval emergence. The fruit in the cooler remained there for 7 days, then was placed in towers over buckets of sand and held there for larval emergence.

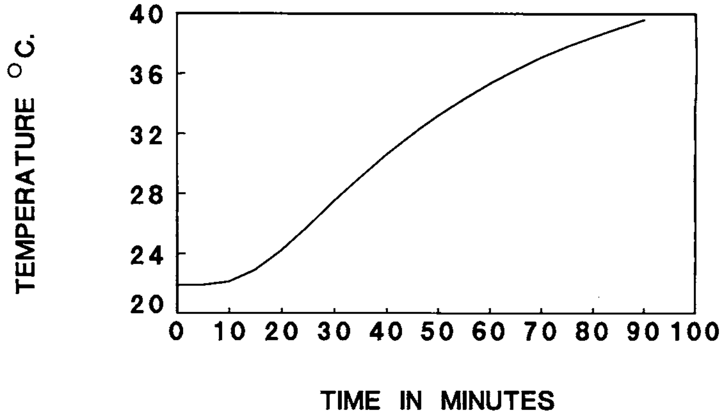

Fig. 1. Core temperature of grapefruit immersed in hot water at 43.3°C (110°F).

The experiment was replicated 3 times and the data combined for analysis. Analysis of insect recovery data was done using SAS probit analysis (7). Temperatures were monitored during heating and cooling phases of the treatment with 36 gauge copper-constantan thermocouple wires placed at the center of sample fruit and recorded with a data logger (Fluke Model 2200B).

Results and Discussion

The temperature at the center of the fruit during the hot water immersion increased until it reached the temperature of the surrounding hot water (43.3°F) in 12 to 130 minutes (Fig. 1). Ordinarily no larvae will survive a treatment of this severity (12). To find the survivors indicated by Probit 9 (99.9968% mortality) one must treat in excess of 30,000 insects (2).

The use of the cold storage caused an increase in the larval mortality for a given hot water immersion time (Fig. 2). Following 60 minutes of hot water immersion, the cold treatment killed almost 100% of the fruit flies, while the hot water immersion alone required another 30 minutes of treatment to reach the same result.

Probit analysis was used to predict a treatment time needed to produce a given level of quarantine security. Probit analysis estimated LD50s (dose required to kill 50% of the population) for the two treatments that were not

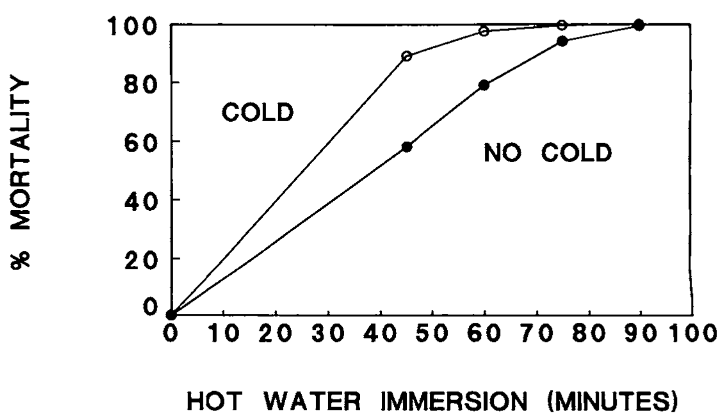

Fig. 2. The effect of combining hot water immersion (43.3°C) and cold storage (1.1°C) of grapefruit versus hot water immersion alone on larval mortality.

Table 1. Probit analysis on log10 of time (minutes) of hot water dip.

Treatment	43.3°C hot water dip no cold treatment	43.3°C hot water dip one week at 1.1°C
LD50	42.8 minutes	29.3 minutes
LD90	67.3 minutes	45.9 minutes
LD99	97.2 minutes	66.3 minutes
Probit 9 (LD99.9968)	175.5 minutes	100.2 minutes

highly divergent (Table 1). As the dosage (length of hot water immersion) is increased from one required to achieve LD99 to the dosage required to achieve Probit 9, the time gap widened between the two treatments. There was a difference of 75 minutes between the two treatments at Probit 9. Combining a cold treatment with the hot water immersion cut the hot water immersion time required to reach Probit 9 almost in half. This may allow a hot water immersion treatment which will not harm the grapefruit, yet allow the treatment to be completed in less time than the current standard cold storage quarantine treatments.

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PHYTOTOXICITY TO GRAPEFRUIT EXPOSED TO HOT WATER IMMERSION TREATMENT

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Abstract. **The effect of immersing grapefruit (*Citrus paradisi* Macf.), cv. Marsh, for 4.5 hr in 43.5°C (110°F) water is reported to provide effective quarantine protection against the Caribbean fruit fly (*Anastrepha suspensa* Loew). Exposure of freshly harvested grapefruit to this hot water, time/temperature regime was phytotoxic to the peel. Phytotoxicity was expressed as peel discoloration, puffiness, and decreased resistance of peel to penicillium infection after treatment and storage. Fruit subjected to the hot water treatment increased 1% in volume during the treatment compared to little or no change for those in ambient water or nonimmersed control fruit. After 2 weeks' storage at 10°C (50°F), hot water-treated fruit had about 45% decay compared to 6% and 1% in fruit immersed in ambient water or nonimmersed fruit, respectively. Hot water-immersed fruit were significantly more deteriorated than those of other treatments based on condition of the stem scar, appearance of the peel, and fruit firmness. Based on observations of late-season fruit in 3 separate tests during the 1987/88 season, we concluded that a 4-hr hot water treatment at 43.5°C was too phytotoxic to serve as a quarantine treatment.**

Grapefruit (*Citrus paradisi* Macf.) exported from Florida to certain countries, such as Japan, must be certified as free from the Caribbean fruit fly (*Anastrepha suspensa*). Certification may be accomplished by harvesting fruit from certified fly-free zones, or by subjecting fruit to the approved cold treatment procedure (1). Since November 30, 1987, when ethylene dibromide (EDB) fumigation of grapefruit was suspended by the Japanese government, investigations for alternative methods to control the Caribbean fruit fly have intensified.

Currently, hot water treatment is approved as a quarantine treatment for the control of the West Indian (*A. obiqua*) and Caribbean fruit flies in mango (cv. Francis) imported into the United States from Haiti (1). For papayas, the combination of hot water and EDB fumigation or a double hot water treatment are approved quarantine procedures (1). The Plant Protection and Quarantine Treatment Manual also lists a vapor heat treatment for the