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PRELIMINARY INVESTIGATION USING HOT AIR TO DISINFEST GRAPEFRUIT OF CARIBBEAN FRUIT FLY IMMATURES

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Abstract. **A new quarantine method called a hot air treatment is being developed for Florida grapefruit. The treatment disinfests grapefruit of Caribbean fruit fly, *Anastrepha suspensa* (Loew) (Caribfly) immatures by using air heated to a desired temperature and kept at a dewpoint temperature a few degrees below the desired treatment temperature so that water will not condense on fruit surfaces or inside the treatment areas.**

When air at 46°C (from 58 to 90% RH) was delivered at an average velocity of 0.402 cubic meter per sec for 1, 1.25, 1.5, 1.75 or 2 hr to grapefruit (weighing about 460-465 grams per fruit), the projected Probit 9 treatment time to control Caribfly eggs and larvae was 2.95 hr estimated by probit analysis; the average pulp temperature near the center of the grapefruit was about 43.5°C in fruit located at the bottom of the stack and about 45°C in fruit located at the top of the stack; and the market quality of the treated fruit was not damaged.

Florida grown grapefruit [*Citrus paradisi* (Macf.)] are susceptible to infestation by immature stages of the Caribbean fruit fly, *Anastrepha suspensa* (Loew) (Caribfly) (5, 9). Florida grapefruit shipped to Texas, Arizona California Hawaii, and Japan must be treated with approved quarantine treatments that kill all Caribfly infestations. Approved postharvest treatments to disinfest grapefruit of Caribfly immatures are cold temperature storage (1), methyl bromide fumigation (2), and gamma irradiation (10). Hot water (8) and hot air are other alternative treatments under investigation as potential quarantine treatments.

Herein, I report on a hot air treatment to disinfest grapefruit infested with Caribfly eggs and larvae.

Materials and Methods

'Marsh' white grapefruit was transported from a packing house in central Florida to Miami and used for tests. The fruit was individually weighed using a Sartorius electronic balance (Model U5000D) (Sartorius Corporation, 140 Wilbur Place, Bohemia, Long Island, NY 11716). Fruit was exposed in an outdoor cage to thousands of laboratory-reared and gravid female Caribflies (3) for 1-2 weeks to obtain eggs and larvae for treatment. In grapefruit, eggs hatched in 72 hr at 25-26°C and larvae remained in the fruit from 10 to 30 days (D. L. von Windeguth, personal communication). Fruit was removed from the cage, cleaned, and randomized to ensure equal infestation rates per group of fruit.

The 12 largest grapefruit were used to obtain heat transfer data. For this, an insulated 36 gauge, Type T copper constantan thermocouple wire (TC) was inserted into a grapefruit so that the end piece of the TC rested in the center of the fruit or about 55 mm from the surface. A second TC was inserted in the flavedo <1 mm below the epidermis (surface temperature). A third TC was secured about 2 mm above the peel of a grapefruit (air temperature). The procedures were repeated until 12 grapefruit each contained three TCs. Then sixty grapefruit including those with TCs were placed into each of three containers (55.88 by 35.56 by 30.48 cm lwh) that were stacked in a column. Three grapefruit each with TCs were located at the top and bottom layers of the top container; three with TCs were put in the bottom layer of the middle container, and three grapefruit with TCs were put on the bottom layer of fruit in the bottom container. The largest grapefruit of 12 in the bottom layer was placed in an area previously determined by temperature measurements to be the coldest. Temperatures recorded from this grapefruit provided input to the program that controlled the test. The 36 TCs plus one to monitor dewpoint temperature and one to monitor air temperature at the top of the fruit stack were wired into a computer. Twenty five percent of the untreated and infested grapefruit served as the control to estimate the level of infestation present in the treated fruit. A manuscript is being prepared that describes the hot air treatment appliance and procedures to perform tests.

One-2 days after the fruit was removed from the infestation cage, five groups of about 180 grapefruit per group were treated with air at 46°C each for 1, 1.25, 1.5, 1.75, or 2 hr delivered at an average velocity of 0.402 cubic meters per sec to determine time/temperature mortality relationships for eggs and larvae. About 180 grapefruit were treated for each time period. The treated and untreated fruits were put into separate structures (4) kept in a room at 25.26°C. Containers with sand were placed below each structure to collect mature larvae that left the fruit. Sand was sifted 1-2 times each week for 5 weeks, and the number of recovered larvae and pupae that developed from larvae was recorded. Pupae having a normal appearance were recorded as survivors and used in the analysis. Data were analyzed to the 99% mortality level by computer-program-

Table 1. Time/temperature mortality relationships for eggs and larvae of Caribfly in grapefruit treated with air at 46°C for 1 to 2 hr estimated by probit analysis fiducial limits = 95%).

Time (hr)	Estimated treated larval population	No. larvae recovered	% mortality
1.00	2,585	2,466	4.6035
1.25	2,669	1,435	46.2345
1.50	1,628	816	49.8771
1.75	1,089	318	70.7989
2.00	350	3	99.1429

Slope ± SE = 2.646860 ± 0.804414; Intercept ± SE = 1.194128 ± 1.097848.

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med probit analysis (fiducial limits = 95%) with the probit and *GLM* procedures of the Statistical Analysis System (SAS) (7) and to 99.9968% mortality level to obtain Probit 9 (6). A sample of 300 pupae collected from the control was put into a plastic container covered with gauze and used to determine percent eclosion. Also, fruit phytotoxicity tests were performed. Thirty-six unprocessed and uninfested freshly harvested grapefruit were treated for 3 hr with air at 46°C, and 36 similar fruits that were not treated served as the control. All fruit were stored at 15.6°C for 2 weeks and then examined for firmness, scalding and pitting, and unusual taste and aroma.

Results and Discussion

The preliminary study was based on a total of 820 treated and 403 untreated grapefruits and an estimated treated fly population of 8,321 (Table 1). From the probit equation, the projected treatment time for 99.9968% Probit 9 mortality was 2.95 hr. Percent eclosion of flies from pupae collected as larvae from the untreated fruit was 88. The average temperatures near the center of grapefruit (placed at different layers in the fruit stack) are shown in Fig. 1. Within a 3-hr treatment, average pulp temperature increased from about 24°C to 30-32°C at 1 hr, 39-43°C at 2 hr, and 43-45°C at 3 hr. Surface temperatures of grapefruit measured about 0.05 mm below the peel at different places within the stack are shown in Fig. 2. At 1 hr, average temperatures ranged near 39 to 41°C; at 2 h, 43.5-44.5°C; and at 3 hr, 45-46°C throughout the stack. Temperatures measured at 2 mm above and around the fruit within the stack are shown in Fig 3. At 1 hr, average temperatures ranged near 42 to 44°C; at 2 hr, 44.5-45.5°C; and at 3 hr, about 46°C throughout the stack.

The quality of the grapefruit treated for 3 hr at 46°C was not damaged, and no significant differences were observed between treated and untreated fruit.

The hot air treatment as described in this study was effective against Caribfly infestations in grapefruit and did not damage the fruit quality. Industry personnel might believe that a 3-hr treatment is lengthy and too costly.

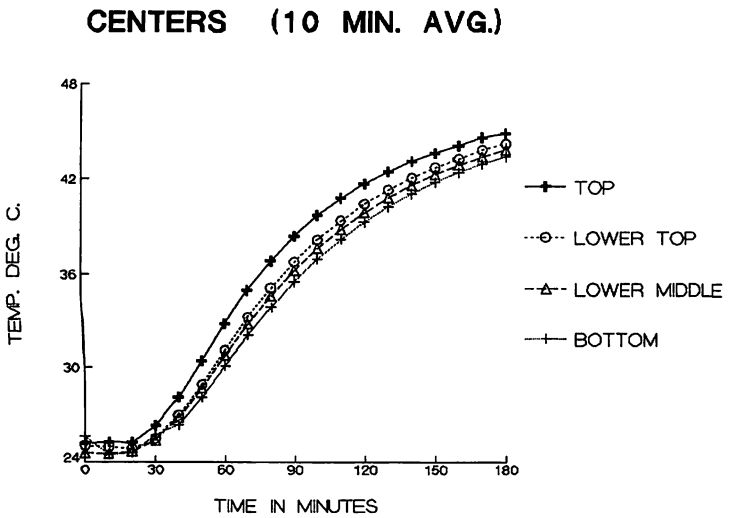

Fig 1. Average pulp temperatures near the centers of grapefruit (weighing about 460-465 grams each) located at the top, middle, and bottom layers of a 55.88 by 35.56 by 93.98 cm (lwh) stack of 180 fruit.

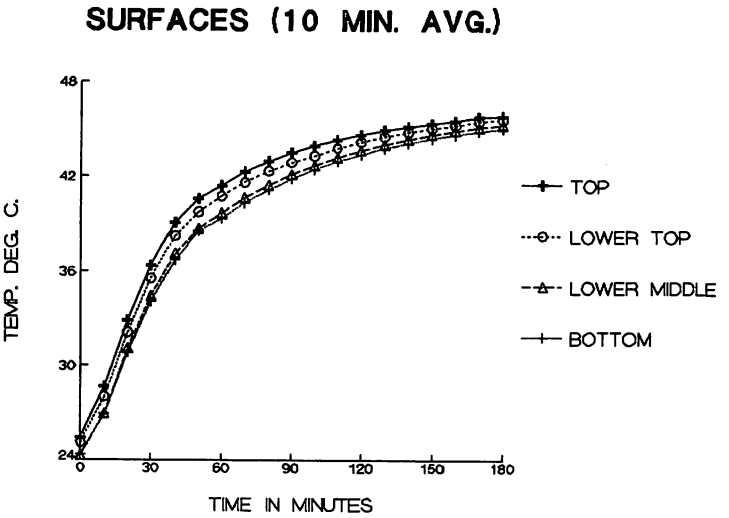

Fig. 2. Average surface temperatures 0.05 mm below the peel of grapefruit (weighing about 460-465 grams each) located at the top, middle, and bottom layers of a 55.88 by 35.56 by 93.98 cm (lwh) stack of 180 fruit.

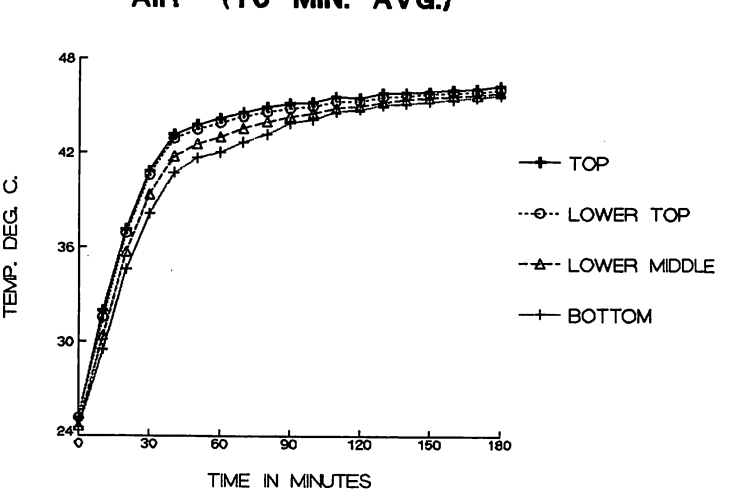

Fig 3. Average temperatures 2 mm above the peel of grapefruit (weighing about 460-465 grams each) located at the top, middle, and bottom layers of a 55.88 by 35.56 by 93.98 cm (lwh) stack of 180 fruit.

Therefore, studies are underway to determine the effect of hot air at 47 to 50°C on killing immatures and on fruit quality. Perhaps hot air treatments at temperatures >46°C and <50°C can be developed which will shorten the exposure time needed to provide quarantine security without damaging the fruit.

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DETECTION, QUARANTINE, AND ERADICATION OF FRUIT FLIES INVADING FLORIDA

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Abstract. **Detection and eradication techniques employed in Florida's first fruit fly eradication program required destruction of all medfly host fruits and vegetables on all infested properties, including destruction of such material in the surrounding 1 mile area. Since this first successful attempt to eradicate a major economic species of fruit fly from Florida, fruit fly detection and eradication techniques have advanced to include a permanent fruit fly detection program utilizing synthetic lures. The synthetic used for medfly is trimedlure. Other synthetic attractants are used for *Dacus* species. Quarantine regulations have evolved from requiring mandatory destruction of host fruit and maintaining a host-free period to certification of regulated articles through treatment and inspection. As techniques were improved it became clear that early detection meant greater savings of dollars and efforts spent on eradication. Early detection enhances the chances of eradicating any pest. This is the aim of Florida's Fruit Fly Detection Program.**

The 1929 Mediterranean Fruit Fly Eradication Campaign

The value of Florida's Fruit Fly Detection Program can be well justified when the history of some of the past fruit fly eradication programs are considered. The first infestation of an economically important fruit fly in Florida occurred on April 6, 1929, when a state nursery inspector became alarmed at the presence of "maggots" in grapefruit which he acquired in the vicinity of Orlando, Florida. Examination of these larvae by entomologists led them to conclude that a fruit fly of the family Tephritidae was involved, possibly *Anastrepha fraterculus* (Wiedemann), which at that time was believed to occur in the West Indies and was commonly referred to as the West Indian fruit fly. Shortly after this a visitor reported an excessive drop of grapefruit had taken place at the H. L. Hamlin 40-acre citrus grove located at Marks and Mills Streets, Orlando. A visit to the citrus grove confirmed the presence of many fruit fly larvae. Upon further observation, adults were seen on the foliage. Some were captured and mailed to Washington and Gainesville, and identified on April 10, 1929, as the Mediterranean fruit fly, (*Ceratitis capitata* (Wiedemann)) (1).

The Chief of the Plant Quarantine and Control Administration and the Plant Commissioner of the State Plant Board approached the problem with one objective—eradication, although this had never been accomplished in any country in which the Mediterranean fruit fly had become established. A plan of approach was agreed upon, and, as might be expected, modifications were made from time to time. Essentially the program embraced the following features:

1. Scouting to determine the extent of its spread in Florida and elsewhere.
2. Division of the State into: (a) Infested Zones, to include any property within 1 mile of an infested grove or area in which infested host fruits or vegetables were located; and (b) Protective Zones, to include an area within 9 miles of the outside boundary of an infested zone.
3. Destruction of all host fruits and vegetables in infested properties as rapidly as found, including the destruction of such material in the surrounding mile (infested) zones.
4. Application of poisoned bait spray throughout both infested and protective zones. The first formula employed consisted of: lead arsenate, crude brown sugar, molasses, and water. (Almost 300,000 pounds of lead arsenate were used.) Later the lead arsenate was replaced by copper carbonate. Complaints were received concerning spray injury, which resulted in the appointment of a committee of successful citrus growers to investigate the claims. To summarize, the committee reported in part as follows: "that the beneficial results of the 'bait spray' far outweigh the damage that has occurred". (Eighth Biennial Report of the Plant Commissioner, pp. 55-56, February 1931).
5. Establishment of a summer host-free period by removing and destroying all summer ripening host fruits and the prohibition of the growing of summer ripening vegetables in both infested and protective zones.