

Mortality of Feral Caribbean Fruit Fly (Diptera: Tephritidae) Immatures in Coated Guavas

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ABSTRACT Guavas from a commercial field near Homestead, FL, that were naturally infested with Caribbean fruit flies, *Anastrepha suspensa* (Loew), were coated with Nature Seal 2000, Nature Seal containing 4% hydroxypropyl cellulose, or Pac-Rite TFC 213 (a carnauba wax). Precoating infestation rates ranged from 0 to 3.2 larvae per guava, and the mean Caribbean fruit fly survival in guavas coated with Nature Seal (4%), Nature Seal 2000, or Pac-Rite TFC 213 was 9, 46, and 68%, respectively, compared with uncoated controls. Mean days to 50% emergence was 18.2 d for larvae in guavas coated with Nature Seal (4%); this was significantly longer (95% CL) than the mean to 50% emergence for larvae in uncoated guavas (13.4 d) or those in guavas coated with Pac-Rite TFC 213 (13.2 d). Carbon dioxide levels were generally higher and oxygen levels generally lower in Nature Seal-coated guavas compared with uncoated guavas. Coatings can lower Caribbean fruit fly survival rates in guavas and might become a component of a systems approach to allow export of guavas from Florida to parts of the world that require fruit fly treatment.

KEY WORDS *Anastrepha suspensa*, fruit coating, postharvest treatment, systems approach, carbon dioxide, oxygen

THE CARIBBEAN FRUIT fly, *Anastrepha suspensa* (Loew), infests guava, *Psidium guajava* L., fruit in southern Florida. Guavas infested with Caribbean fruit fly are commonly shipped to markets along the eastern coast of the United States. Caribbean fruit fly control in guavas is difficult. Only 3 insecticides are registered for use on guavas in the United States: Pyrellin (pyrethrin + rotenone), malathion, and *Bacillus thuringiensis* Berliner. The first 2 are effective against Caribbean fruit fly adults, but will not kill eggs or larvae inside the fruit. A 7-d waiting period is required before harvesting guavas from orchards sprayed with malathion.

Another problem with guava marketing is the short shelf life of the fruit. Coatings delayed ripening of guavas (McGuire and Hallman 1995). Hallman et al. (1994) found increased Caribbean fruit fly mortality in coated grapefruits, mangoes, and carambolas compared with noncoated fruits. The objective of this study was to determine if coatings, used to prolong the shelf life of guavas, would also reduce Caribbean fruit fly survival inside the fruits.

Methods and Materials

Number 1 guavas from a field west of Homestead, FL, were obtained from J. R. Brooks & Son on 8 occasions between 18 August 1993 and 16 February 1994. The guavas were divided randomly into 4 equal groups, 3 of which were coated by hand rubbing with Nature Seal 2000 (containing 2% hydroxypropyl cellulose; EcoScience Produce Systems, Orlando, FL), Nature Seal (containing 4% hydroxypropyl cellulose), and Pac-Rite TFC 213 (a carnauba wax; American Machinery, Orlando, FL). On 7 of the 8 fruit collection dates, guavas were coated the day after harvest (Table 1). The guavas coated on 18 August 1993, 8 September 1993, and 6 October 1993 were stored in a cooler at 12°C between harvest and several hours before coating (usually <1 d). This temperature is not considered to cause Caribbean fruit fly mortality because no significant mortality occurred in mangoes stored at 13°C for 11 d (Hallman et al. 1994).

Guavas harvested on the rest of the dates were kept at ≈24°C after harvest, and all guavas were kept at that temperature after coating. After the coatings dried (a few hours), the guavas were placed in plastic trays on steel racks to allow surviving larvae to emerge from the fruit and drop into bins with sand where the larvae pupated. Larvae and pupae were sifted from the sand daily to determine if the proportional emergence rate of larvae from coated guavas was different from the

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Table 1. Guava harvest and coating dates, sample sizes, and Caribbean fruit fly infestation levels

Harvest date	Coating date	Guavas per treatment	Mean guava wt, g	Larvae per guava in control
16 Aug. 1993	18 Aug. 1993	94	93	3.19
7 Sept. 1993	8 Sept. 1993	79	107	0.00
13 Sept. 1993	14 Sept. 1993	51	110	0.17
20 Sept. 1993	21 Sept. 1993	100	76	0.03
5 Oct. 1993	6 Oct. 1993	137	85	0.01
22 Nov. 1993	23 Nov. 1993	121	75	0.69
13 Dec. 1993	14 Dec. 1993	89	74	0.73
15 Feb. 1994	16 Feb. 1994	137	120	0.09

rate in uncoated guavas, and to estimate the life stage of the Caribbean fruit fly when the guavas were coated. At 24°C, the Caribbean fruit fly egg hatches in ≈ 3 d and the larval period lasts ≈ 8 d (Prescott and Baranowski 1971).

Guava fruit were sampled for internal gas through a 1.5-cm-diameter port inserted 1 cm into the side. The port consisted of a stainless steel metal tube fitted with a rubber septa. The fruit surface/sample port interface was coated with stop-cock grease to make a gas-tight seal. Internal gas was sampled from fruit periodically by syringe and injected into a gas chromatograph (Model 8500, Perkin-Elmer, Norwalk, CT) for carbon dioxide and oxygen analysis as described by Nisperos-Carriedo et al. (1990). Three to 5 guavas were sampled per treatment.

Analysis of variance and the Ryan-Einot-Gabriel-Welsch multiple *F* test were used to determine differences between treatments. This mean comparison test is recommended for experimental designs with equal cell sizes and where control of the maximum experimentwise error rate is desired. It is considered the most powerful step-down mean separation test that uses the *F* statistic (SAS Institute 1989).

Results

Caribbean fruit fly infestation levels in the guavas ranged from 0 to 3.2 larvae per guava (Table 1). Those dates with infestation levels < 0.09 larva per guava were not used in the analysis of survival of Caribbean fruit fly immatures in coated and uncoated guavas because not much confidence could be put in data at very low infestation levels, given the sample sizes used (51–137 guavas per treatment). Significant differences existed among the various treatments (Table 2), with only 9% of the larvae emerging from Nature Seal (4%)-coated guavas compared with uncoated guavas. Caribbean fruit fly mortality was correlated with shelf life of coated guavas (McGuire and Hallman 1995); guavas coated with Nature Seal (4%) took the longest to ripen (12.2 d), followed by Nature Seal 2000 (11.2 d), Pac-Rite TFC 213 (10.4 d), and the control (8.3 d). Mean days to 50% emergence of larvae

Table 2. Survival of Caribbean fruit fly in coated guavas

Coating	Mean survival (%)	Mean days to 50% emergence of larvae from guavas
Nature Seal (4%)	9a	18.2a
Nature Seal 2000	46ab	15.6ab
Pac-Rite TFC 213	68bc	13.2b
None (control)	100c	13.4b

Means in each column followed by same letter are not significantly different at the 95% CL (Ryan-Einot-Gabriel-Welsch multiple range test [SAS Institute 1989]). *F* probability for 1st and 2nd columns = 0.0023 and 0.037, respectively; *df* = 3, 12 for both.

from the guavas was significantly greater for Nature Seal (4%)-coated guavas than Pac-Rite-coated or uncoated guavas (Table 2).

Internal carbon dioxide and oxygen concentrations in guavas are presented in Table 3. Carbon dioxide levels were generally higher and oxygen levels generally lower in Nature Seal-coated than noncoated guavas. Carbon dioxide production increases as climacteric fruits (for example, guavas) ripen. Thus, carbon dioxide levels rose in control fruits which were ripening faster than coated fruits. Likewise, oxygen demand for this accelerated respiration increased. Therefore, differences in oxygen and carbon dioxide levels between coated and uncoated guavas were not great.

Discussion

The ability of coatings to reduce Caribbean fruit fly survival in guavas offers means to controlling the pest inside of guavas other than with pesticides, and might contribute to the development of a quarantine treatment for guavas. Immersion of guavas in 46.1°C water for 35 min was approved as a quarantine treatment for Caribbean fruit fly-infested guavas shipped from Florida to California only for infestation levels $\leq 1\%$. Coatings could reduce the survival of Caribbean fruit fly immatures in guavas and contribute to the efficacy of a quarantine treatment. Coatings differed significantly in preventing Caribbean fruit fly emergence, which suggests the possibility of developing coatings that would maximize insect death. The positive relationship between reduction in Caribbean fruit fly emergence from guavas and delay of guava ripen-

Table 3. Percentage of carbon dioxide and oxygen \pm SEM inside coated and uncoated guavas 3 and 10 d after coating

Coating	Carbon dioxide		Oxygen	
	3 d	10 d	3 d	10 d
None	3.9 \pm 1.0	11.8 \pm 3.2	12.6 \pm 1.8	8.9 \pm 3.3
Nature Seal				
2000	6.0 \pm 2.2	15.8 \pm 7.6	9.9 \pm 5.3	9.4 \pm 4.0
Nature Seal (4%)	5.2 \pm 1.5	16.5 \pm 4.2	9.8 \pm 2.5	5.8 \pm 2.8

ing strengthens the hypothesis that the toxic action of coatings against interior fruit pests is similar to modified atmospheres, in which reduced oxygen and increased carbon dioxide levels delay fruit ripening and reduce insect survival (Hallman et al. 1994).

The mean number of days to 50% emergence of Caribbean fruit fly larvae from the control guavas (13.4 d) was excessive considering the developmental time of the insect at 24°C (≈ 11 d from newly oviposited egg to pupation) and the probability that many of the immatures were beyond the newly laid egg stage when the guavas were collected. We have also observed that fully developed 3rd-instar Caribbean fruit flies often remained in relatively sound mangoes and grapefruits for a time before emerging. Time to 50% Caribbean fruit fly larval emergence from coated guavas was delayed compared with the larvae in uncoated guavas. This difference reflects a greater effect of coatings against later instars, delayed development, or delayed emergence in coated guavas.

Hallman et al. (1994) suggested that increased concentrations of certain volatiles, such as methanol or ethanol, may have contributed to reduced emergence of Caribbean fruit fly larvae from coated grapefruits. In addition, delayed ripening might result in a less favorable environment (firmer tissue, less sugar) for larval development inside of the fruit. Greany (1989) reviewed several articles where tephritid larval survival was reduced on unripe fruit compared with ripe fruit.

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