MORTALITY OF MEXICAN FRUIT FLY (DIPTERA: TEPHRITIDAE) IMMATURES IN COATED GRAPEFRUITS

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ABSTRACT

Coatings applied to fruits have been shown to kill tephritid fruit fly immatures inside of the fruits. The present research investigated the efficacy of coatings against distinct life stages of Mexican fruit fly, *Anastrepha ludens* (Loew), and results showed high levels of disinfestation of grapefruits of up to the early third instar (95%) for one commonly used grapefruit coating, Citrus Lustr 402. Emergence was reduced significantly even for late third instars. Leaving one-third of each grapefruit uncoated reduced efficacy considerably. Mixing Citrus Lustr 402 into the diet used to rear Mexican fruit fly did not affect survival indicating that this coating is not toxic to larvae. This research supports the hypothesis that coatings act primarily to modify atmospheres inside the fruits and kill larvae by restricting gaseous exchange. Fruit coating could be incorporated as a component of an integrated systems approach to quarantine security where a series of pest infestation-reducing steps decreases risk to insignificant levels.

Key Words: Fruit wax, quarantine security, systems approach, *Anastrepha ludens*

RESUMEN

Ha sido demostrado que ciertas cubiertas aplicadas a las frutas matan a los inmaduros de las moscas tefrítidas en el interior de las mismas. En la presente investigación se estudió la eficacia de las cubiertas contra diferentes estadios de la mosca mexicana de las frutas, *Anastrepha ludens* (Loew). Los resultados mostraron que la desinfestación de toronjas tratadas con la cubierta comunmente usada alcanza el 95% en el tercer estadio temprano de la mosca. La eficacia se redujo considerablemente al dejar un tercio de cada fruta sin cubrir. La mezcla de Citrus Lustr 402 con la dieta usada para criar la mosca mexicana no afectó la supervivencia, indicando que esa cubierta no es tóxica a las larvas. Esa investigación sostiene la hipótesis de que las cu-

biertas actuan primariamente modificando la atmósfera dentro de las frutas y matan las larvas mediante la restricción del intercambio de gases. La cubierta de las frutas podría ser incorporada a los sistemas integrales de seguridad cuarentenaria donde una serie de pasos para la reducción de la infestación de plagas disminuya el riesgo a niveles insignificantes.

Tephritid fruit flies are major horticultural pests and probably the chief group of quarantined pests worldwide. To prevent inadvertent introduction of fruit fly species into areas of the world where they do not exist but could become established, fruits are subjected to quarantine treatments, shipped from areas certified to be free of the pests, or packed under systems which reduce the risk of infestation to negligible levels (Sharp & Hallman 1994).

Fruit coatings have been shown to kill Caribbean fruit fly, *Anastrepha suspensa* (Loew), immatures in various fruits (Hallman 1996, Hallman & Foos 1996, Hallman et al. 1994, 1995). One-hundred percent Caribbean fruit fly mortality was observed in grapefruits coated with Sta-Fresh 600, a non-drying coating commercially applied to melons in transit and washed off after arrival (Hallman et al. 1994). Apparently, coatings also killed Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), immatures in fruits (Saul et al. 1985, 1987). Coatings probably kill fruit fly immatures inside of fruits largely by creating a modified atmosphere (Hallman 1994).

None of the previous research addressed the effect of coating fruit on different fruit fly stadia. The goals of the research reported herein were to determine if coating grapefruit would kill Mexican fruit fly, *Anastrepha ludens* (Loew), and to determine the mortality levels at different insect life stages. An experiment was also conducted to determine if coatings would kill Mexican fruit fly larvae when mixed in their diet.

Materials and Methods

Mexican fruit flies were from a colony reared on a semi-artificial diet at the U.S. Department of Agriculture, Subtropical Agricultural Research Laboratory in Weslaco, Texas (Spishakoff & Hernandez-Davila 1968). Grapefruit cultivars 'Ruby Red' and 'Rio Red' (mean weight about 450 g) were placed 180-200 fruits at a time in an aluminum screen cage ($228 \times 81 \times 46$ cm) with about 10,000 Mexican fruit fly adults for 24 hours. About half of the flies were females, and all were fed water, sugar, and yeast hydrolysate. After exposure to oviposition, the grapefruits were cleaned with water and light hand scrubbing and held at about 24°C until the Mexican fruit fly immatures reached the desired stage: early egg (1 day), second instar (7-8 days), early third instar (11-14 days), and late third instar (15-18 days). Several grapefruits were cut open and the stage of fruit fly development verified before grapefruits were coated. The experimental design was a randomized complete block with three replicates and 20 grapefruits per replicate-treatment combination, including uncoated controls.

The following coatings were used: Sta-Fresh 590 HS (FMC Corp., Lakeland, FL), Citrus Lustr 402 (ELF Atochem North America, Inc., Monrovia, CA), and Nature Seal 2020 (EcoScience, Orlando, FL). Sta-Fresh 590 HS and Citrus Lustr 402 are commercially-used, high-gloss citrus coatings which contain alkali soluble resins, propylene glycol, fatty vegetable acid soaps, and silicone antifoam. Nature Seal 2020 is a cellulose-based coating which is used on limes. Each grapefruit was hand coated with 0.9-1.0 ml, which is approximately the rate used commercially on grapefruits in southern Texas, and allowed to dry in ambient air.

To determine if complete coating of fruit was necessary to achieve fruit fly mortality, in one test one-third of the surface area of the grapefruits was covered with a single piece of 5.15-cm wide tape before coating and then removed about one-half hour after coating, leaving about one-third of the fruit uncoated in a single patch. This test was conducted on fruits 10-13 days after infestation when most larvae had developed to early third instar. The experimental design was randomized complete block with three replicates and 20 fruits per replicate including the uncoated controls.

All grapefruits were placed individually in 2-liter plastic containers containing about 250 cm^3 of sand which provided a burrowing and pupation site for emerging larvae. About two weeks after larvae began emerging, the fruits were dissected, and all puparia and live and dead larvae were counted.

To test if the coatings were actually toxic to Mexican fruit fly larvae, 1 ml of coating was mixed with 150 ml of diet, placed in 275-ml plastic containers, and infested with 100 early third instars. When the larvae completed feeding they were removed from the diet and placed in 0.5-liter heavy paper containers with 100 cm^3 of vermiculite and held for pupation and adult emergence. This experiment was a randomized complete block with four replicates, including the controls without coating.

All data were analyzed by the SAS ANOVA procedure after normality was tested with the UNIVARIATE procedure (SAS Institute, Inc. 1988). Data which were not normal were transformed by $\log(n + 1)$ and then tested again.

Results and Discussion

Analysis of variance [$\log(n + 1)$] showed significant differences among numbers of Mexican fruit fly larvae emerging from grapefruits coated at different life stages of the insect ($F = 5.14$; $df = 3,6$; $P \leq 5\%$) and between the different coatings used ($F = 20.3$; $df = 3,6$; $P \leq 1\%$) (Table 1). The least number of larvae emerged from grapefruits coated with Citrus Lustr 402. Standard errors of the mean overlapped only in the case of third instars in grapefruits coated with Citrus Lustr 402 and Sta-Fresh 590, indicating no difference between these two coatings for third instars. Survival remained low through the early third instar, but increased greatly among late third instars. The life stage by coating interaction was not significant ($F = 1.74$, $df = 9,18$), indicating that the relative effectiveness of the three coatings was similar among the various Mexican fruit fly life stages.

Table 1. Mean and standard error of the mean (± SEM) for number of Mexican fruit fly larvae emerging from grapefruits coated with three coatings at four life stages.

	Coating[1]		
Stage	Citrus Lustr 402	Sta-Fresh 590	Nature Seal 2020
1-day old egg	0.03 ± 0.03	2.6 ± 1.3	9.0 ± 0.9
2nd instar	0.02 ± 0.02	1.8 ± 1.5	10.7 ± 4.2
Early 3rd instar	1.1 ± 1.1	3.1 ± 2.0	14.7 ± 3.6
Late 3rd instar	6.6 ± 2.6	4.5 ± 2.2	14.9 ± 3.7

[1]Mean number of larvae from uncoated control = 19.0 ± 4.0.

Mixing Citrus Lustr 402 into the diet did not affect survival of early third instar Mexican fruit fly to the adult stage (mean of 81% survival for control versus 80% for diet plus coating)demonstrating that the coating was not directly toxic to the insect.

Mortality of Mexican fruit fly in grapefruits that had about two-thirds of the surface area coated leaving a single, uncoated 5.15 cm wide strip was greatly reduced compared with totally coated fruits. Mean number of insects per grapefruit (± SEM) was 21.1 ± 4.6, 7.8 ± 1.5, and 8.5 ± 0.9 for the control, Citrus Lustr 402, and Sta-Fresh 590, respectively. Grapefruits infested with early third instars and that were two-thirds coated yielded 37-40% of the total Mexican fruit fly larvae emerging from uncoated grapefruits compared with 5.8-16% for completely coated grapefruits. Nevertheless, analysis of variance indicated significant differences between the control and the two partially coated treatments ($F = 7.09$; $df = 2,4$; $P \leq 5\%$).

Conclusions

Application of citrus coatings at commercial rates provided high levels of disinfestation of Mexican fruit fly immatures from grapefruits. Although the level of reduction was inadequate to provide quarantine security, which requires virtually 100% mortality, the data suggest that coatings could be easily incorporated as a component of a quarantine security system consisting of a series of pest mitigating steps to reduce the risk of infestation to a negligible level (Hallman 1995). Partial coating reduced the effect greatly, but still provided some abatement. The coating even provided significant mortality of late third instars, many of which probably could have avoided mortality simply by emerging from the fruit. In this study, Citrus Lustr 402 was markedly better than the other two coatings used in reducing Mexican fruit fly survival in grapefruits. It is arguable that the effect of coatings on fruit fly disinfestation would be more pronounced than these studies indicated because most of the grapefruits that were coated would have been culled due to their substandard condition caused by remaining at room temperature for 7-18 days after infestation while waiting for the insects to reach the desired stage of development before coating. Commercially, fruits would be coated very soon after harvest.

Because the coating itself was not directly toxic to the larvae it seems likely that the mode of action of coatings is simply a modified atmosphere where lowered oxygen and raised carbon dioxide levels kill insects inside of fruits (Hallman et al. 1994).

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