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POTENTIAL FOR GAMMA RADIATION AS A QUARANTINE TREATMENT FOR CARIBBEAN FRUIT FLY IN CITRUS

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ABSTRACT

The potential for using gamma radiation as a quarantine treatment for the control of the Caribbean fruit fly [Anastrepha suspensa (Loew)] in citrus is being investigated by the Agricultural Research Service of the United States Department of Agriculture and the Florida Department of Citrus in cooperation with the United States Department of Energy and private industry.

In dosage-mortality tests, pupae were recovered from infested grapefruit held at 25°C for 6 weeks following irradiation at 0.15 and 0.30 kGy. No insects were recovered from grapefruit irradiated at 0.60 and 0.90 kGy. Two adults emerged from the recovered pupae, one male at 0.15 kGy and one female at 0.30 kGy; both adults died without reproducing. Based on the number of pupae recovered, fly mortality was 98.9% at 0.15 kGy, 99.94% at 0.30 kGy, and 100% at 0.60 and 0.90 kGy. In phytotoxicity tests, noninfested grapefruit were held for 4 weeks at 10 or 16°C followed by 2 weeks at 21°C and examined for radiation injury. Injury was minimal at 0.30 kGy and the grapefruit had acceptable taste, no adverse chemical changes and met Grade A standards when examined by Florida inspectors. Injury to the rind and off-flavors in juice and sections were often severe at higher dosages (0.60 and 0.90 kGy). Grapefruit irradiated at 0.60 and 0.90 kGy showed rind breakdown and scald after storage. Scald was the dominant injury in October and December tests, and rind breakdown was the dominant injury in February, April and May tests. Generally, injured areas developed decay during holding at 21°C.

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ABSTRACT

The potential for using gamma radiation as a quarantine treatment for the control of the Caribbean fruit fly (*Anastrepha suspensa* (Loew)) in citrus is being investigated by the Agricultural Research Service of the United States Department of Agriculture and the Florida Department of Citrus in cooperation with the United States Department of Energy and private industry.

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Immature stages of the Caribbean fruit fly, Anastrepha suspensa (Loew), can infest grapefruit (Citrus paradisi Macf.) grown in Florida, although the fruit is not a primary host (Weems, 1966). Ethylene dibromide (EDB) is currently the main quarantine treatment for control of the fruit fly in grapefruit shipped to Japan and citrus-growing areas in the United States. Possible withdrawal of registration of EDB has stimulated research into possible alternatives, such as gamma radiation. Use of radiation as a possible quarantine treatment for fruit flies was suggested first by Balock et al. (1956). Early work on irradiation of citrus (Dennison et al., 1966) showed that dosages of 1.0 kGy and higher caused peel injury sufficient to render the grapefruit unacceptable for successful marketing. Initial studies by Burditt et al. (1981) using low dose irradiation (less than 1.0 kGy) showed increased peel pitting, scald and decay in grapefruit irradiated at from 0.25 to 0.60 kGy. The present investigation represents an expansion of that initial research aimed at gaining additional information on the sensitivity to injury by gamma radiation of grapefruit picked at various times during the season and developing the necessary dosage-mortality data required for quarantine purposes. The research involved cooperation between USDA/ARS laboratories in Miami, Winter Haven and Orlando, Florida, the Florida Department of Citrus, and the U. S. Department of Energy. Four main areas of research were explored -- phytotoxic effects of gamma radiation, effects on quality and flavor, radiation dosage effects on insect mortality, and dosimetry measurements with both individual and palletized cartons of grapefruit.

Phytotoxicity. Following irradiation, the grapefruit were held at 10 or

16°C for 4 weeks to simulate a typical shipment from Florida to Japan and were then examined for injury and decay. The fruit were held for another 2 weeks at 21°C and reexamined for injury and decay. The results of these examinations, as reported by Hatton et al. (1982), showed that scald, which appeared as a superficial browning of the rind, was the predominant injury in early-season fruit picked in October and December (Table 1). Rind breakdown, which included both pitting (dark, sunken surface lesions generally around the equatorial plane of the fruit) and aging (tissue wilt, shrivel and collapse around the stem button -- area may turn brown and oil glands collapse) was the predominant injury in mid- and late-season fruit picked in February, April and May. Injury increased with dosage and was readily observed in fruit irradiated at 0.60 and 0.90 kGy; the fruit were often not acceptable, especially those treated at 0.90 kGy. The injury that occurred in grapefruit treated at 0.15 and 0.30 kGy was generally slight and such fruit were usually considered acceptable by inspectors of the Florida Department of Agriculture and Consumer Services. Little or no increases in injury developed during the holding period at 21°C. Decay, however, did increase during this holding period (Table 2). Decay was not a problem with early- and mid-season fruit, but became serious with late-season fruit, regardless of treatment. Except for late-season fruit, decay was minimal after the initial simulated transit period at 10 or 16°C (data not shown). Additional tests by Hatton et al. (1984) with early-season fruit picked in September and October of 1982 showed only small amounts of injury even when treated at 0.90 kGy and all lots were considered acceptable. Such differences in response to irradiation points up the importance of the source, condition and past exposure of the fruit to adverse field conditions, 16°C for 4 weeks to simulate a typical shipment from Florida to Japan and were then examined for injury and decay. The fruit were held for another 2 weeks at 21°C and reexamined for injury and decay. The results of these examinations, as reported by Hatton et al. (1992), showed that scald, which appeared as a superficial browning of the rind, was the predominant injury in early-season fruit picked in October and December (Table 1). Rind breakdown, which included both pitting (dark, sunken surface lesions generally around the equatorial plane of the fruit) and aging (brown scald, shrivel and collapse around the stem button — often very dark brown and oil glands collapsed) was the predominant injury in mid- and late-season fruit picked in February, April and May. Injury increased with dosage and was already observed in fruit irradiated at 0.05 and 0.20 kGy; the fruit were often not acceptable, especially those treated at 0.50 kGy. The injury that occurred in grapefruit treated at 0.15 and 0.30 kGy was generally slight and such fruit were usually considered acceptable by inspectors of the Florida Department of Agriculture and Consumer Services. Little or no increase in injury developed during the holding period at 21°C. Decay, however, did increase during this holding period (Table 1). Decay was not a problem with early- and mid-season fruit, but became serious with late-season fruit, regardless of treatment. Except for late-season fruit, decay was minimal after the initial simulated transit period at 10 or 16°C (data not shown). Additional tests by Hatton et al. (1994) with early-season fruit picked in September and October of 1987 showed only small amounts of injury even when irradiated at 0.50 kGy and all lots were considered acceptable. Such differences in response to irradiation points up the importance of the season, condition and past exposure of the fruit to adverse field conditions.

such as temperature extremes, which increase sensitivity to injury.

Insect mortality. Mortality of immature stages of the Caribbean fruit fly together with adult emergence at various radiation dosages from a cesium-137 source is shown in Table 3 (von Windeguth, 1982). Percentage mortality was calculated by comparing the mean yield of pupae per grapefruit with that of infested control fruit handled in the same way as irradiated fruit, except that they were not irradiated when passed through the irradiator. No pupae were recovered from infested grapefruit irradiated at 0.60 or 0.90 kGy. Of the 9,707 insects irradiated at the 0.30 kGy dosage, only 4 pupae were recovered for a weighted mean mortality of 99.87%. The single adult female which emerged died within a week without laying eggs. Of the 13,226 insects irradiated at the 0.15 kGy dosage, 149 pupae were recovered for a weighted mean mortality of of 98.22% for the three replicates. The single male which emerged from the pupae died within a day of emergence. These data are in general agreement with those obtained in earlier tests (Burditt et al., 1981) in which a 94% reduction in pupae yield was found from fruit irradiated at 0.15 kGy and 100% at 0.30 kGy. The fact that no pupae were recovered from fruit treated at 0.30 kGy in these earlier tests is probably due to the small population (183 insects) treated.

Tests by von Windeguth (unpublished data, 1983) indicate that the earlier stages of the Caribbean fruit fly are more sensitive to gamma radiation than later stages. A dosage of 0.10 kGy did not prevent pupation of 20,000 7-day-old laboratory-reared larvae in semisolid agar medium, but did prevent

adult emergence since only dead pupae were found when large numbers were dissected 7 days into their 13-day development period. Earlier research with pupae and adults showed that irradiation at 0.08 kGy sterilized both male and female flies when irradiated as 10- and 12-day-old pupae or 1-day-old adults (Burditt et al., 1974). Such results strongly suggest that a dosage of less than 0.15 kGy is all that is needed to assure that only sterile adults could develop from the immature stages in irradiated fruit.

Quality and flavor. Moshonas and Shaw (unpublished data, 1983) evaluated irradiated Florida grapefruit for flavor and quality factors (vitamin C, soluble solids and total titratable acidity) together with essential peel oil and the composition of volatile constituents after storage for 4 weeks at 10 or 16°C followed by 2 weeks at 21°C. Fruit samples from all seven tests conducted during the 1981-82 and early 1982-83 harvesting seasons were included. Vitamin C, soluble solids and acidity of grapefruit irradiated at 0.90 kGy did not differ significantly from that of nonirradiated control fruit that had been similarly handled throughout the tests. Moshonas and Shaw (1982) had earlier found vitamin C levels to be significantly lower in juice from most irradiated fruit. In present tests, few adverse flavor effects on products from irradiated grapefruit were detected by the trained taste panel, with the exception of the first test run on early season fruit. Generally, no adverse flavors were detected in products made from fruit irradiated at 0.15 or 0.30 kGy. Undesirable flavors were reported more often in fresh juice than in fruit sections, but in the last test run in October, 1982, no significant flavor changes were found in either juice or sections prepared from grapefruit

irradiated at dosages up to 0.60 kGy. No adverse flavors were detected in pasteurized juice samples in contrast to the report in the earlier study by Moshonas and Shaw (1982) of flavor differences in all pasteurized juices from grapefruit irradiated at from 0.50 to 0.60 kGy.

Dosimetry. The question arose as to whether it would be more convenient and efficient commercially to irradiate grapefruit in individual or palletized cartons. Pallet loads are in common use in industry because of the ease and rapidity of handling in loading and unloading operations. Ismail et al. (unpublished data, 1983) determined the dose distribution using Fricke dosimeters for single and palletized cartons of packed grapefruit irradiated with cobalt-60 sources at commercial irradiation facilities. The maximum/minimum (max/min) ratio of fruit in individual cartons was 1.3 at a dosage of 0.30 kGy. The max/min ratio in a tight stack of 42 cartons with 7 cartons per layer was 1.7 in the bottom compartment of the carrier and 1.4 in the top compartment. The max/min ratio for a chimney stack loading pattern was 1.6 in both the bottom and top compartments. These results suggest the possibility of treating either single cartons or pallet loads of grapefruit. However, if 0.30 kGy, for example, is needed to obtain the presently required 99.9968% insect kill for quarantine security, and assuming a max/min ratio of 1.7, we would need to deliver 0.51 kGy to the external surfaces of a pallet load. Under such conditions, some injury could occur in fruit in the outer cartons. Less chance of injury would be present if the quarantine regulation was based on sterility or adult emergence rather than pupal mortality of fruit flies. A minimum target dosage of less than 0.15 kGy would only be needed for

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sterility and the maximum dosage would be only 0.26 kGy and the condition of the fruit for marketing should remain acceptable. Additional evaluation of irradiation under commercial conditions is recommended.

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Table 1. Irradiation injury to rind of early-, mid-, and late-season Florida grapefruit (1981-82) held for 4 weeks at 10 or 16°C followed by 2 weeks at 21°C.[z]

Treatment (kGy)	Percent injury				
	October	December	February	April	May
		Scald[y]			
0.00	0	2	0	0	0
0.15	—	8	0	0	1
0.30	29	7	0	0	2
0.60	44	23	0	0	1
0.90	61	31	0	0	1
		Rind breakdown[x]			
0.00	0	0	0	3	3
0.15	—	3	0	7	4
0.30	0	8	7	16	6
0.60	0	15	33	21	13
0.90	0	17	45	27	17

[z] Adapted from Hatton et al., 1982.

[y] Superficial brown discoloration of rind.

[x] Aging (stem end) or pitting of rind.

Table 2. Decay of early-, mid-, and late-season Florida grapefruit (1981-82) held for 4 weeks at 10 or 16°C followed by 2 weeks at 21°C.[z]

Treatment	Percent decay				
(kGy)	October	December	February	April	May
0.00	2	3	4	28	35
0.15	—	3	9	20	43
0.30	7	5	7	32	42
0.60	4	5	3	46	42
0.90	6	5	5	41	46

[z] Adapted from Hatton et al., 1982.

Table 3. Mortality of immature stages of the Caribbean fruit fly in Florida grapefruit irradiated in March, April and May, 1982.[z]

Treatment (kGy)	Fruit irradiated (no.)	Pupae recovered: Per fruit (no.)	Pupae recovered: Reduction (%)	Adults emerged (no.)
March				
0.00	241	20.51	—	--
0.15	449	0.06	99.71	0
0.30	236	0.004	99.98	1
0.60	239	0	100	--
0.90	248	0	100	--
April				
0.00	180	3.90	--	--
0.15	192	0.07	98.21	0
0.30	142	0.014	99.64	0
0.60	159	0	100	--
0.90	140	0	100	--
May				
0.00	224	19.05	--	--
0.15	176	0.62	96.75	1
0.30	227	0.004	99.98	0
0.60	192	0	100	--
0.90	132	0	100	--

[z] Adapted from von Windeguth, 1982.

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