initial MA dropped below 1% in less than 24 hours, whereas the CO_2 content rose to ca. 20%. The O_2 content in the sealed jar with an initial atmosphere of normal air dropped to less than 1% in 5 days, whereas CO_2 increased to over 20% in 3 days. Avocados are relatively tolerant of high CO_2 concentrations; for example, Brooks *et al.* (3) reported that atmospheres averaging up to 50% CO_2 at 40-50°F (4.4-10.0°C) for 2 days caused no injury and improved the flavor. All the 'Simmonds' avocados were hard on removal from the sealed jars and had developed brown irregular areas of rind injury. Similar results and injury (data not shown) were obtained with 'Nadir' avocados stored in air, but in the simulated MA with an initial 6% O_2 and 13% CO_2, no injury developed since the leakage into the container apparently was sufficient to keep the O_2 content from dropping below 1% and the CO_2 content from rising above 29%. Maintenance of avocado quality would be best if the MA could be stabilized in the range of 1-2% O_2 and 7-10% CO_2 (5, 7).

Injury in Laboratory CA Tests. In tests with 'Lula' avocados, symptoms of rind injury appeared first in fruit held only 3 days in 0.5% O_2 + 25% CO_2, and was but trace to slight in 0.5% O_2 + 0% CO_2, and absent in 21% O_2 + 25% CO_2 and in the air control. Fruit from all atmospheres were hard after 2 weeks at 45°F (7.2°C). Rind injury was most severe in 'Lula' avocados held in 0.5% O_2 + 25% CO_2 and appeared as brown or gray areas over the entire fruit surface (Table 2). Injury to 'Lula' avocados was slight in 0.5% O_2 + 0% CO_2, trace in 21% O_2 + 25% CO_2, and absent in air. Results with 'Nadir' and 'Simmonds' avocados confirmed that of the atmospheres tested the combination of 0.5% O_2 with 25% CO_2 caused the most injury, 0.5% O_2 without CO_2 generally caused less injury than with CO_2, and 21% O_2 with 25% CO_2 and air caused no injury. Internal condition of avocados was checked by cutting all fruit after holding them for 1 week at 70°F (21°C) after removal from the CA chambers. Avocados held in 0.5% O_2 with or without 25% CO_2 developed moderate to severe internal injury and were not edible. Avocados held in 21% O_2 with 25% CO_2 or in air did not develop internal injury and were edible.

Table 2. Comparative phytotoxicity of four controlled atmospheres to fruit of three avocado cultivars during simulated transit.[z]

Atmosphere		Index of Injury[y]		
O_2 (%)	CO_2 (%)	'Lula'	'Nadir'	'Simmonds'
21.0	0.0	0.0	0.0	0.0
0.5	0.0	1.8	1.2	0.1
0.5	25.0	4.0	0.9	1.4
21.0	25.0	0.2	0.0	0.0

[z]'Lula' avocados were stored at 45°F (7.2°C) for 14 days and 'Nadir' and 'Simmonds' avocados at 55°F (12.8°C) for 10 days.
[y]Injury was rated as 0 (none), 1 (trace), 2 (slight), 3 (moderate), and 4 (severe).

The laboratory results indicate that symptoms similar to those encountered in MA shipments to Europe can be produced by exposure of avocados to low-O_2 (less than 1%) or a combination of low-O_2 and high-CO_2 (25% or higher). However, no atmosphere analyses were made of the commercial containers in which injured avocados were found by receivers in Europe. Once the container is opened and the damage found, it is too late to obtain an atmosphere sample. Greater care is needed to ensure proper precooling to keep respiration low during transit and, if a MA is used, more care must be taken to assure that ventilation is sufficient to avoid the state of insufficient O_2 and excessive CO_2 that can injure the avocados.

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TOLERANCE OF FLORIDA 'MARSH' GRAPEFRUIT TO METHYL BROMIDE FUMIGATION AND COLD STORAGE COMBINATION TREATMENTS EFFECTIVE AGAINST THE CARIBBEAN FRUIT FLY

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Abstract. **Early season grapefruit harvested in October was injured by fumigation with methyl bromide (MB) for 2 hr at 24 or 32 g/m³, followed by storage for 3 weeks at 45°F (7.2°C) or 50°F (10°C) respectively. Midseason (Jan) and late fruit (Apr) suffered no injury. Decay from all treatments was negligible in early fruit but increased as the season progressed. The peel injury to early fruit and increased decay in mid- and late-season fruit make these treatments questionable for Florida grapefruit. When fruit was fumigated with 32 or 40 g/m MB and then stored at 60°F (15.6°C) for 3-4 weeks, early fruit sustained no peel injury and had only a 0.4-3.2% increase in decay over non-treated lots. The corresponding values for mid- and late season fruit were: 0-12.0% peel injury, 0% decay, and 0% peel injury, 0% decay, respectively. Two hard freezes ca. 2 weeks prior**

[1]The author is indebted to the Florida Dept. of Citrus for the grapefruit used in this study.

to harvest may have contributed to the unusual amount of peel injury observed in some of the mid-season fruit.

Florida citrus destined for Japan and other citrus producing areas of the world must be treated in some manner to eliminate the risk of introducing the Caribbean fruit fly, *Anastrepha suspensa* (Loew) into new ecological niches where it could propagate. Methyl bromide (MB) has been investigated extensively as a possible fumigant to destroy fly infestations in grapefruit. Benschoter (1) developed the baseline information on the amount of MB required to kill the insect in grapefruit. Subsequent studies (3) examined treatments that utilized MB fumigation and cold storage. Infested fruit was fumigated at ambient temperature with various dosages of MB, when placed in cold storage at temperatures recommended for transport and handling of grapefruit. The result was development of combination treatments that were logistically compatible with commercial handling procedures, and that would destroy the insect in grapefruit. Recent tolerance work (2, 4) using MB dosages reported in the original research (1) indicated that peel injury might be a problem with early (Oct) fruit, and decay a problem with midseason (Jan) and late (Apr) grapefruit. The purpose of this study was to determine if grapefruit, under different seasonal conditions, could tolerate combination treatments, that were effective against the Caribbean fruit fly.

Materials and Methods

These experiments represented a partial simulation of procedures used for export of citrus to Japan. The grapefruit were exposed to combination treatments in which the fruit was fumigated, aerated for a short time, and then placed in cold storage. Grapefruit used in these tests were obtained from packing houses in Fort Pierce and Vero Beach, Florida. The fruit was packed into 4/5 bushel (28.2 liters), export-grade, fiberboard cartons with diphenyl pads, transported by truck to the USDA-ARS Miami Station, and placed at 70°F (21°C) for 1-3 days before testing. In preparation for treatment, all cartons were examined and any decayed or blemished fruits were removed and replaced with sound fruit. Cartons were randomly assigned to treatments prior to testing. The basic combination treatments consisted of fumigating grapefruit with MB at a 3 carton load (20% of chamber capacity) in 28 ft^3 (0.8m^3) chambers for 2 hr. Air circulation was continuous and the temperature was maintained at 70-75°F (21-24°C). After fumigation the fruit was aerated for 4 hr then placed in cold storage at 45°, 50°, or 60°F (7.2°, 10°, or 15.6°C) for periods of 1-4 weeks. The basic treatments described in this paper had previously been shown to destroy eggs and larvae of the Caribbean fruit fly in grapefruit at a level adequate for guarantine use.

Experiment 1. The treatments were 32 g/m^3 MB followed by storage at 50°F for 3 weeks, and 24 g/m^3 MB and storage at 45°F for 3 weeks. In this study additional storage periods referred to as "conditioning units" were introduced into the basic treatment pattern. These units were 60°F for 1 week, and 50° for 1 wk. They were inserted between fumigation and the cold storage period with the hope that they would reduce any chilling injury caused by the cold storage period and possibly modify any adverse effects contributed by MB as well.

Experiment 2. The treatments were 40 g/m^3 MB followed by storage at 60°F for 3 weeks, and 32 g/m^3 MB and storage at 60°F for 4 weeks. In this study, aeration periods of 4 hr and 24 hr were introduced between fumigation and cold storage and compared for each treatment.

Fumigated and non-fumigated grapefruit stored at 75° served as controls for evaluation of treatment effects. Injury symptoms were classified as either decay or peel injury.

Results and Discussion

Experiment 1. We know that 50°F or lower storage temperatures produce peel injury in early season grapefruit. Our purpose was to determine if conditioning units inserted between fumigation and cold storage could eliminate or at least reduce this damage to an acceptable level. Fumigated and nonfumigated control fruit (stored at 75°F) showed no peel injury. Comparing the two tests with 32 g/m^3 MB, the conditioning unit of 60°F for 1 week inserted between fumigation and cold storage very significantly reduced peel injury (Table 1). With the combination of 24 g/m^3 MB and 45°F for 3 weeks, even higher injury resulted, suggesting that storage temperature was the principal cause. Overall injury was so high that these treatments were considered unacceptable for early fruit.

Table 1. Effect of combined methyl bromide fumigation and cold storage on peel injury of grapefruit.

Treatment			% Peel injury on indicated dates[z]		
MB (g/m^3)	Conditioning Unit (°F)	Cold storage (°F)	Oct '79	Jan '80	Apr '80
32	None	50°—3 wk	44.4	0	0
32	60°—1 wk	50°—3 wk	24.5	0	0
24	60°—1 wk	45°—3 wk	61.0	0	0
24	50°—1 wk	45°—3 wk	—	0	0

[z]Readings made over a period of 2 weeks after fruit was removed to ambient temperature (75°F). Each value is based on examination of 216 fruits (6 replicates).

Decay was negligible in early fruit, but increased as the season progressed (Table 2). This trend was evident in the control lot as well. Fruit that was fumigated with 32 g/m^3 MB then stored at ambient temperature of 75°F had no more decay than non-fumigated controls. This was demonstrated with late season (Apr) fruit which is the most susceptible to decay. Percentage decay appears to be a function of the amount of MB used, since 32 g/m^3 generally produced more decay than 24 g/m^3 even though the latter dosage was combined with a lower storage temperature. In the 24 g/m^3 treatments decay was consistently higher for fruit conditioned at 50°F than for fruit conditioned at 60°F. MB fumigation definitely increased the incidence of decay in grapefruit that was refrigerated at 50°F or 45°F after fumigation. Florida grapefruit shows considerable variation from year to year in its response to tests such as these even under carefully controlled laboratory experiments. There are many

Table 2. Effect of combined methyl bromide fumigation and cold storage on decay of grapefruit.

Treatment			% Decay on indicated dates[z]		
MB (g/m^3)	Conditioning unit (°F)	Cold storage (°F)	Oct '79	Jan '80	Apr '80
0	75°—4 wk	None	1.9	0.9	7.4
32	None	50°—3 wk	0.9	16.7	28.2
32	60°—1 wk	50°—3 wk	0.5	14.8	32.4
24	60°—1 wk	45°—3 wk	1.4	9.7	12.5
24	50°—1 wk	45°—3 wk	—	12.0	24.5

[z]Readings made over a period of 2 weeks after fruit was removed to ambient temperature (75°F). Each value is based on examination of 216 fruits (6 replicates).

contributing factors that cannot be controlled, such as, weather, pest and disease pressures, soil types, cultural practices, etc. The results of this experiment were disappointing. Although the MB dosages were 8 to 16 g/m³ less than those reported in earlier work (2), reduction in the amount of decay was not sufficient to eliminate it as a problem. It is questionable whether industry could tolerate so much loss in mid and late season grapefruit.

Experiment 2. Peel injury was observed in the January lot of fruit only (Table 3). We believe that 2 hard freezes which occurred ca. 2 weeks prior to harvest are the principal causes of this atypical injury. Aerating the fruit for 24 hr following fumigation significantly reduced peel injury as compared to 4 hr aeration.

Table 3. Effect of methyl bromide fumigation followed by 4 or 24 hr aeration, then storage at 60 F, on peel injury of grapefruit.

Treatment		Aeration after Fumigation (hr)	% Peel injury on indicated dates[z]		
MB (g/m³)	Cold storage °F		Oct '80	Jan '81	Apr '81
0	60°—4 wk (control)	—	0	0	0
40	75°—4 wk (control)	—	0	2.8	0
40	60°—3 wk	4	0	14.8	0
40	60°—3 wk	24	0	1.9	0
32	60°—4 wk	4	0	13.0	0
32	60°—4 wk	24	0	6.5	0

[z]Readings made over a period of 2 weeks after fruit was removed to ambient temperature (75°F). Each value is based on examination of 144 fruits (4 replicates) for Oct. and 108 fruits 3 (replicates) for Jan. and Apr.

It appears that overall decay was slightly higher in the January fruit as compared to the other lots, (Table 4), again, possibly due to the freezes that closely preceded harvest. None of the decay can be attributed to MB fumigation since the control (60°F for 4 weeks) had more decay than the fumigated lots. There were no consistent differences between the 4 hr and 24 hr aeration periods.

Table 4. Effect of methyl bromide fumigation followed by 4 or 24 hr aeration, then storage at 60°F, on decay of grapefruit.

Treatment		Aeration after Fumigation (hr)	% Decay on indicated dates[z]		
MB (g/m³)	Cold storage °F		Oct '80	Jan '81	Apr '81
0	60°—4 wk (control)	—	5.6	16.7	3.7
40	75°—4 wk (control)	—	6.5	5.6	2.8
40	60°—3 wk	4	6.9	13.9	3.7
40	60°—3 wk	24	6.3	10.2	0.9
32	60°—4 wk	4	7.6	6.5	1.9
32	60°—4 wk	24	9.7	10.2	2.8

[z]Readings made over a period of 2 weeks after fruit was removed to ambient temperature (75°F). Each value is based on examination of 144 fruits (4 replicates) for Oct. and 108 fruits (3 replicates) for Jan. and Apr.

Methyl bromide fumigation, when followed by storage temperatures of 50° or lower, produced peel injury in early grapefruit and increased decay in mid- and late-season fruit to levels that would not be commercially acceptable.

Combining MB fumigation with a storage temperature of 60°F would provide an alternative for minimizing peel injury and decay when treatments to destroy the Caribbean fruit fly are required.

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EFFECTS OF STORAGE TEMPERATURE ON MARKET QUALITY OF FREEZE-DAMAGED MURCOTTS

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Abstract. **Murcotts from a freeze-damaged grove, picked within a few days following the January 1981 freeze, were tested to detrmine best holding conditions and whether fruit could be salvaged for the fresh fruit market or processed products. External and internal quality (such as blemishes, softness, °Brix, acid, alcohol content and appearance), as well as juice processing characteristics (such as % culls, juice yield and pulp content) were determined prior to storage. The freeze-damaged Murcotts were not acceptable for the fresh fruit market under any conditions studied, because of excess softness, discoloration and formation of mold. Fruit held at 10°C or above was also unsuitable for canned juice. However, fruit before storage, and after 2 wks at 4°C or 4 wks at 1°C yielded acceptable canned juice for use in processed products. Thus, 1°C is the recommended temperature for holding freeze-damaged Murcotts for salvage.**

The January 1981 freeze produced problems for Florida Murcott growers. Murcotts (a mandarin hybrid) are usually sold to the fresh fruit packer, and packinghouse rejects (due to surface blemishes, color, etc.) or excess fruit are processed

[1]Southern Region, Agricultural Research Service, U. S. Department of Agriculture. Mention of a trademark or propirietary product is for identification only and does not recommend its approval over other products that may also be suitable by the U. S. Department of Agriculture.