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Quality of Citrus Fruit Following Cold Treatment as a Method of Disinfestation against the Caribbean Fruit Fly

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Abstract. **Fruit of 'Valencia' orange *(Citrus sinensis* Osbeck) and 'Murcott' tangerine *(Citrus reticulata* Blanco) were subjected to cold treatment at 1.1°C for 17 days as prescribed for the disinfestation of citrus of the Caribbean fruit fly *(Anastrepha suspensa* (Loew) in the plant protection and quarantine treatment manual. Fruit quality was evaluated during subsequent storage at 4.4°C for one week followed by 2 weeks at 21.1°. Fruit under cold treatment did not develop any physiological disorders. Fruit color and general appearance remained unaffected. Loss due to decay was 2.3% for 'Murcott' tangerine and 7.2% for 'Valencia' orange. Moisture loss for both varieties was about 5%. Fruit quality, including flavor, was found to be acceptable in 'Murcott' during subsequent storage. Yet the quality of 'Valencia' remained acceptable for one week only at 4.4°. Cartons used for packing fruit and stored at 1.1° absorbed more moisture when transferred to 21.1° than the cartons at 4.4° or 21.1° because of moisture condensation on fruit.**

Quarantine treatments for the disinfestation of fruit and vegetables from insect pests include chemical fumigation, cold treatment, and treatment with vapor heat (8). Citrus fruit shipped from Florida to other citrus producing states were fumigated with ethylene dibromide (EDB) to protect against the spread of Caribbean fruit fly [*Anastrepha suspensa* (Loew)] from infested to noninfested regions (6). The Environmental Protection Agency (EPA) had proposed to "phase-out" the use of EDB in postharvest quarantine fumigation of citrus and tropical fruits and vegetables in 1980, because it induced cancer in laboratory test animals (6). Its use as a postharvest fumigant was later abolished for domestically consumed fruit and vegetables (9). Subjecting fruit and vegetables to low temperatures for specified durations is a viable and approved quarantine treatment method against a

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Table 1. The percentage of decay in 'Murcott' tangerine and 'Valencia' orange fruit during storage at different temperatures.

Storage period (days)	Temperature (°C)			Temperature (°C)		
	21.1	4.4	1.1–4.4–21.1	21.1	4.4	1.1–4.4–21.1
	'Murcott' tangerine			*'Valencia' orange*		
7	1.4 a[z]	0.0 b		2.3 a	0.0 b	
14	2.5 a	0.0 b		7.5 a	0.0 b	
19		0.0	0.0	10.6 a	0.0 b	0.0 b
26	5.3 a	0.0 b	0.0 b	15.5 a	0.3 b	0.0 b
33	8.5 a	0.0 b	0.6 b	19.8 a	0.3 b	1.5 b
40	10.9 a	0.53 b	2.3 b	24.2 a	0.3 b	7.2 b

[z]Mean separation within each storage time and cultivar by Fisher's LSD test, $P = 0.05$.

Table 2. The percentage of weight loss during storage at different temperatures in 'Murcott' and 'Valencia' fruit.

Storage period (days)	Temperature (°C)			Temperature (°C)		
	21.1	4.4	1.1–4.4–21.1	21.1	4.4	1.1–4.4–21.1
	'Murcott' tangerine			*'Valencia' orange*		
7	1.83 a[z]	1.25 b		1.40 a	0.90 b	
14	2.52 a	1.86 b		2.13		7.47
19				3.26 a	2.36 a	2.37 a
26	3.90 a	2.87 b	2.87 b	3.81 a	2.70 b	2.82 b
33	4.53 a	3.54 b	3.40 b	4.53 a	3.28 b	
40	5.19 a	4.32 b	4.26 b	5.00 a	3.85 b	4.64 ac

[z]Mean separation within each storage time and cultivar by Fisher's LSD test, $P = 0.05$.

Table 3. Changes in peel color (a/b ratio) during storage at different temperature levels in 'Murcott' and 'Valencia' fruit.

Storage period (days)	Temperature (°C)			Temperature (°C)		
	21.1	4.4	1.1–4.4–21.1	21.1	4.4	1.1–4.4–21.1
	'Murcott' tangerine			*'Valencia' orange*		
0	1.065 a[z]	1.060 a	1.07 a	0.78 a	0.80 a	0.80 a
7	1.08 a	1.08 a		0.79 a	0.78 a	
14	1.08 a	1.06 a		0.79 a	0.76 a	
19				0.78 a	0.76 a	0.78 a
26	1.12 a	1.04	1.00 b	0.77 a	0.72 a	0.73 a
33	1.12 a	1.10 ab	1.08 b	0.80 a	0.79 a	0.80 a
40	1.13 a		1.09 a	0.82 a	0.80 a	0.81 a

[z]Mean separation within each storage time and cultivar by Fisher's LSD test, $P = 0.05$.

variety of fruit flies (8). In cold treatment against the Mediterranean fruit fly (*Ceratitis capitata* Wiedemann), fruit are held at 0° to 1.7°C for a period of 11 to 17 days once the pulp of fruit attains this temperature (8). Many tropical and subtropical fruit, including grapefruit and limes, develop physiological disorders when exposed to low temperatures (3, 5).

In this paper, the effect of cold treatment on 'Murcott' tangerine and 'Valencia' orange was studied in relation to their subsequent storage and flavor qualities at 4.4° for one week and 21.1° for 2 weeks.

Materials and Methods

'Murcott' tangerine and 'Valenica' orange fruit obtained from a commercial grove were washed and sprayed with 1000 ppm thiabendazole followed by waxing with petroleum-based wax and drying at 43°C. Fruit were graded and packed in cartons with 65 and 95 fruit/carton of 'Valencia' and 'Murcott', respectively. Cartons for each cultivar were randomized into 3 treatments each with 6 cartons. The treatments were as follows: 1) storage at 21.1°; 2) storage at 4.4°; and 3) storage at 1.1° for 17 days followed by storage for one week at 4.4° and for 2 weeks at 21.1°. The relative humidity within the storage room was 85% to 95%.

A PD 2064 Esterline Angus data logger was used in determining internal temperature of fruit (center of pulp). Thermocouple sensors were inserted through the equitorial plane of the fruit and sealed with waxed tape. Five sensors were used to monitor temperature change in fruit and one was used to monitor air temperature. The positions of the monitored fruit in the carton were as per the specifications in the manual on Plant Protection and Quarantine program (8). The temperature of the fruit was monitored until the fruit pulp attained the desirable temperature of 1.1°C needed for the purpose of disinfestation. The fruit was held at this temperature for 17 days.

Upon completion of the cold treatment, and during subsequent storage, fruit were examined for chilling injury, color, weight loss, decay, physiological breakdown, total soluble solids (TSS), percentage of acidity, ascorbic acid, and flavor.

Ten fruit from each replication were numbered and used for color and weight loss determinations. Color change was measured with a Hunterlab D25 color difference meter, and the a/b ratio values were reported. Percentage of weight loss was calculated. Decay caused by green mold, stem-end rot, sour rot, and anthracnose was evaluated at weekly intervals by counting the number of spoiled fruit/carton in each treatment and reporting cumulative data. Juice was extracted from 30 fruit (composite sample of 5 fruit from each replication) using a small laboratory hand-reamer and analyzed for the percentage of TSS, acidity, ascorbic acid, and flavor.

Ascorbic acid concentration was determined by the method suggested by the Association of Vitamin Chemists (1), TSS with an Abbe refractometer, acidity by titration with standard NaOH using phenolphthalein indicator and flavor by an experienced 13- to 15-member taste panel evaluating samples using a 9-point hedonic scale. Flavor data were subjected to analysis of variance. The moisture estimation was made on composite samples of cut pieces from the top, bottom, and sides of cartons under each treatment by drying the sample at 100°C for 48 hr.

Results

Cold treated fruit were examined for symptoms of chilling injury and physiological breakdown in the juice vesicles immediately after termination of treatment and also after storage for one week at 4.4°C and 2 weeks at 21.1°. Fruit of neither variety developed any kind of disorder.

Decay increased in both varieties during storage at 21.1°C (Table 1). There was more decay in 'Valencia' orange as compared to 'Murcott' tangerine. No decay was observed during storage at 4.4° irrespective of fruit type. There was no decay in cold-treated fruit when transferred to 4.4° but it became evident after they were stored at 21.1° for 2 weeks. 'Valencia' oranges showed more decay than did 'Murcott'.

Cumulative weight loss of fruit increased during storage irrespective of storage temperature and variety (Table 2). Weight loss was highest at 21.1°C followed by storage at 4.4° and cold

Table 4. Changes in chemical composition of juice during storage in 'Murcott' and 'Valencia' fruit.

Storage period (days)	Chemical constituents	Temperature (°C)			Temperature (°C)		
		21.1	4.4	1.1–4.4–21.1	21.1	4.4	1.1–4.4–21.1
		'Murcott' tangerine			*'Valencia' orange*		
26	TSS	13.13	13.24	13.24	12.18	11.91	11.91
	Acidity (%)	0.49	0.56	0.58	0.92	1.05	1.04
	ratio	26.79	23.64	22.82	13.24	11.34	11.45
	Ascorbic acid[z]	18.40	20.60	22.10	51.85	51.85	52.46
33	TSS	12.80	13.22	13.60	11.78	11.70	11.50
	Acidity (%)	0.53	0.59	0.50	0.90	1.00	1.00
	ratio	24.15	22.40	27.2	13.08	11.70	11.50
	Ascorbic acid[z]	17.90	21.50	21.50	52.40	53.61	53.01
40	TSS	13.00	12.92	13.40	11.48	11.70	11.40
	Acidity (%)	0.48	0.55	0.48	0.88	1.04	1.00
	ratio	27.08	23.49	29.91	13.04	11.25	11.40
	Ascorbic acid[z]	17.40	20.30	18.90	50.61	55.55	51.85
Initial	TSS	13.70			11.98		
	Acidity (%)	0.66			0.94		
	ratio	20.75			12.74		
	Ascorbic acid[z]	26.80			56.52		

[z]mg/100 ml.

Table 5. Mean hedonic flavor scores during storage at different temperatures.[z]

Storage period (days)	Temperature (°C)			Temperature (°C)		
	21.1	4.4	1.1–4.4–21.1	21.1	4.4	1.1–4.4–21.1
	'Murcott' tangerine			*'Valencia' orange*		
26	6.6	5.8	5.9	4.5	6.1[y]	6.5[y]
33	6.2	5.2	5.7	4.1	6.0[x]	5.1
40	6.2[w]	5.0	6.5[v]	5.4	6.9[u]	5.1

[z]Where 9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely, etc.
[y]Significant difference at 1% level from treatment at 21.1°C.
[x]Significant difference at 0.1% level from treatment at 21.1°C.
[w]Significant difference at 5% level from treatment at 4.4°C.
[v]Significant difference at 1% level from treatment at 4.4°C.
[u]Significant difference at 5% level from treatment at 21.1° and 1.1°C.

treatment at 1.1°. Fruit from cold treatment showed more loss in weight when they were transferred and stored at 21.1° for 2 weeks than in the initial treatment. There was no difference between loss in weight of 'Valencia' and 'Murcott' fruit.

External color was not affected substantially by storage duration or temperature in both the 'Valencia' orange and 'Murcott' tangerine fruit (Table 3). Cold treatment did not inhibit color development, and the a/b values measured were comparable in fruit stored at 4.4°C and 21.1°. No blemishes of any type were observed on the surface of fruit exposed to cold treatment.

TSS, percentage of acidity, and ascorbic acid decreased slightly in 'Murcott' juice during storage irrespective of treatment (Table 4). No difference was noticed in these constituents between fruit continuously stored at 21.1° and fruit that received cold treatment. In 'Valencia' orange, changes in TSS, percentage of acid, and ascorbic acid were negligible.

Flavor evaluation data for all samples is presented in Table 5. 'Murcott' tangerines remained acceptable throughout the storage period of 40 days at 21.1°C or under cold treatment temperature. Yet the flavor was acceptable only up to 26 days in fruit stored at 4.4°. In 'Valencia' oranges, flavor was acceptable throughout the storage period of 40 days in fruit held at 4.4°, but was acceptable only up to 26 days in fruit subjected to cold treatment.

During storage, cartons used for packing fruit subjected to cold treatment accumulated more moisture than did cartons stored at 4.4°C and 21.1° (Table 6). Irrespective of treatment, bottom and top portions of cartons absorbed more moisture as compared with the side portions.

Discussion

Chilling injury and other disorders in citrus fruit such as grapefruit, lime, and lemon as well as other tropical fruit have been reported (3, 5). In the present study no internal or external disorders were found, including chilling injury in the fruit exposed to cold-treatment. The cumulative percentage of decay in cold treated fruit increased only when fruit were transferred to 21.1°C for a period of 2 weeks. Nevertheless, decay was only 2.3% in 'Murcott' and 7.2% in 'Valencias'. The increased level of decay in 'Valencia' may have been due to the greater difference between its optimum cold storage temperature and the ambient storage temperature of 21.1°.

Cold-treated fruit did not differ in weight loss in comparison with fruit constantly stored at 4.4°C. As expected, loss in weight did not affect TSS, acidity, and ascorbic acid, as most of the water was lost from the peel rather than the pulp (2). Unlike deciduous fruit, citrus fruit does not undergo rapid chemical or physical changes after harvest. With the exception of lime and lemon (3), citrus fruit are nonclimacteric and therefore do not ripen or improve in quality after harvest.

Irrespective of treatment, the change in TSS, ascorbic acid, and acidity for both varieties were in agreement with results reported by Kefford and Chandler (7).

Table 6. Percent moisture absorption by the fiberboard carton during storage at various temperatures after 40 days.

Variety	Temperature (°C) 21.1			4.40			1.1–4.4–21.1		
	Top and bottom	Sides	Average	Top and bottom	Sides	Average	Top and bottom	Sides	Average
Murcott	21.06	6.74	13.90	10.08	9.53	9.81	16.33	13.24	14.79
Valencia	11.92	9.63	10.77	10.91	9.71	10.31	13.44	11.60	12.52

Retention of ascorbic acid often is used as an indication of all nutrient retention, and there is belief that other nutrients, being more stable than ascorbic acid, are less affected during storage (4). Flavor of 'Murcott' remained acceptable in fruit subjected to cold treatment during storage for 40 days. The loss of flavor or development of stale flavor in 'Murcott' after 26 days at 4.4°C is difficult to explain. On the contrary, in 'Valencia' the flavor was acceptable in cold treated fruit stored at 4.4°C and there was a negative change in flavor when they were moved to 21.1°. This indicated that post cold treatment warming of 'Valenica' is an important factor in its fruit quality.

Cartons used for packing fruit subjected to cold treatment may lose their strength because of moisture absorption when transferred to 21.1°C. The high moisture content of these cartons was caused by condensation of moisture on fruit when they were moved from 4.4° to 21.1°. When a 2-tier stacking system was used during storage, the top portion of the bottom tier of cartons and the bottom portion of the upper-tier became damp. This was due to the percolation of condensed water from the surface of fruit in boxes from upper layers. In order to avoid the weakening of boxes, fruit must be conditioned gradually to ambient temperature, or strong cartons must be employed for packing fruit. Condensation of moisture on the surface of fruit also is not desirable if fruit is to be fumigated with hydrogen cyanide as required in Japan for disinfestation of scale insects and mites, since the solubility of this gas in water may cause injury to the fruit peel.

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Development of Drought-stressed Poinsettias

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Abstract. **Single stem *Euphorbia pulcherrima* Willd. cv. Eckespoint C-1 Red were exposed to single or repeated episodes of drought stress to leaf water potentials of −1.0 or −1.3 MPa at different times during crop development. Decreased plant height and delayed flowering generally were caused by treatments including stress prior to time of initial bract coloration. Plant quality was reduced by those treatments that inhibited bract development and caused leaf abscission. Inflorescence diameter was reduced the most by stress after bract coloration. Bract dry weight was sensitive to stress and was reduced by stress between the time of initiating long nights and bract coloration. Leaf abscission resulted from a single exposure to −1.3 MPa after flower initiation. Stress prior to start of long nights had little effect on plant development.**

Drought stress of poinsettias was used as a means of height control in some commercial operations prior to the advent of growth retardants (11). A side effect of this practice was reduced inflorescence size and increased leaf abscission. Research with other crops has shown drought stress to cause reduced rates of growth, reduced organ size, and organ abscission (5, 8). The response to drought stress may vary with level of stress and stage of crop development (2, 7). Research on poinsettia water relations has found that growth retardants caused reduced transpiration rates (3) and total crop irrigation requirements (4), but that drought stress had less effect on development of growth-retardant-treated plants than it had on nontreated ones (4). This report describes the development of poinsettias exposed to 2 levels of drought stress at different stages of crop development.

Materials and Methods

Plant materials and general procedures. Rooted 'Eckespoint C-1 Red' poinsettia cuttings were obtained from a commercial propagator and planted 1 per 15-cm pot in Metro Mix 500 (W.R. Grace Co., Cambridge, Mass.). N, P, and K were applied weekly at 0.50, 0.23, and 0.46 g, respectively, per liter irrigation water. Spacing between plants provided 0.17 m^2 per plant. Chlormequat was applied 2 weeks after planting at 0.53 g per pot as a 180-ml soil drench. Developing laterals were removed to maintain single stem plants. Poinsettias were main-

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