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FREEZE EFFECTS ON JUICE YIELD AND OTHER CHARACTERISTICS OF 'VALENCIA' ORANGE AND 'MARSH' GRAPEFRUIT

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Abstract. **'Valencia' oranges and 'Marsh' grapefruit were randomly harvested from adjacent tracts several times during 21 weeks following the December 1983 freeze. Fruit were analyzed for juice yield, composition and physiological characteristics. In 'Valencia' oranges severe drying and significant yield losses were found through the eighth week when some increase in yield began. In 'Marsh' grapefruit little drying and some early juice yield losses were noted, but the juice yield losses were almost offset by yield increases in 16 weeks.**

Freezing weather has caused significant economic losses to the Florida citrus industry. This is due not only to foliage and tree losses but also to juice loss by drying of the fruit on the tree. Since over 80% of the citrus crop is processed for juice (3), on tree drying can represent large losses. A mathematical model predicting juice losses following freezes would be useful in determining the best picking times for optimum returns.

The purpose of this paper is to report on analyses of juice quality and juice yield of oranges and grapefruit harvested at intervals following the December 1983 freeze and to compare this data with data from a similar experiment after another freeze (1).

Materials and Methods

Temperatures. No recordings were made in the experimental tracts during the freezing weather. However, careful estimates were made by averaging actual readings in an adjacent commercial grove and from the nearest National Weather Service thermographs.

Oranges. A limited harvest (40 lb.) of 'Valencia' oranges was made December 29, 1983 and after that larger harvests of approximately ten 90-lb. boxes (2.23 bu.) of 'Valencia' oranges were made from the same 40 trees on each harvest date during the 21-week experiment between January 17 and May 23, 1984. The mature trees were located in 3 north-south rows in Tract 4 of the Citrus Research and Education Center Davenport grove located at the intersection of I-4 and U. S. Highway 27.

Fruit were harvested by hand with special instructions to insure a representative sampling of all trees each harvest. Eight fruit were harvested from each quadrant of each tree each harvest, 4 fruit from the top of each quadrant including 1 inside fruit and 4 fruit from the bottom of each tree quadrant including 1 inside fruit. A total of 32 fruit were removed from each tree for each harvest and transported to the Citrus Research and Education Center, Lake Alfred (CREC-LA) packinghouse in 900 lb. pallet boxes where the fruit were washed and sized so that samples included fruit from 2 1/4 to 3 1/8 inches in diameter and a size distribution was determined.

At each harvest, three 100-fruit randomized samples, weighing approximately 40 lb., were extracted and analyzed using Toledo auto state test equipment (2, 7). Also at each harvest, one size-randomized sample weighing approximately 700 lb. was extracted using an FMC 291 extractor and FMC model 35 finisher with 0.020 inch screen modified for pneumatic pressure control and settings listed in Table 1. Preliminary extraction-finishing tests were made on each harvest to produce a desired finisher discharge pulp quick fiber value of 160 on each experiment extraction (4). Weights of the various components of the fruit were re-

Table 1. Extractor and finisher settings for 'Valencia' orange and 'Marsh' grapefruit.

	Orange		Grapefruit	
	State test FMC 091B extractor No finisher	FMC 291 extractor FMC 35 finisher	FMC 391 extractor	FMC 591 extractor
			FMC 35 finisher	
Cup size (inches)	3	3	4	5
Upper cutter type	Long	Long	Long	Long
Strainer tube holes, diam. (inches)	0.025	0.040	0.040	0.040
Orifice tube, diam. (inches)	0.850	0.438	0.625	0.625
Ring, type	Split	Split	Split	Split
Orifice type restricter (inches)	None	7/16 long	1/2 short	1/2 short
Beam set (inches)	1/8 down	3/4 down	3/4 down	3/4 down
Finisher screen opening (inches)	None	0.020	0.020	0.020
Finisher psi air range	None	46-62	47-54	
Quick fiber range	None	128-186	156-174	
Quick fiber mean		155	165	

corded as: juice, finisher pulp and peel plus core. Unit volumes of randomized fruit from each harvest were weighed. The weight of the components were expressed in terms of 2.23 bu. or the volume of the traditional "90 lb." field box, jumble filled (7). Average individual fruit weights and volumes (by displacement) were determined on a 100-fruit randomized sample for each harvest.

On each harvest throughout the experiment random samples of fruit were cross-sectioned serially beginning with a 1/2-inch cut at the stem end. As dryness progressed during the experiment, cross-sectioning proceeded to a center cut and a 1/2 inch below center cut (6). The cross sectioned fruit were observed for drying and related characteristics and photographed. Average peel thickness values were obtained from measurements made at one point in each fruit quadrant by means of a scale photographed in the same plane as the fruit cross sections.

Grapefruit. A limited harvest (40 lb.) of 'Marsh' grapefruit was made December 29, 1983 and after that larger harvests of approximately ten 85-lb. boxes (2.23 bu.) were made from the same 30 trees on each harvest between January 17 and April 16, 1984. These mature trees were in a test plot similar and adjacent to the 'Valencia' test plot described earlier. As in the 'Valencia' harvests described earlier, careful picking methods were used to insure samples, each harvest, representative of all trees. Six fruit per tree quadrant including one inside top and one inside bottom fruit for a total of 24 fruit were harvested from each tree, each harvest. An 850-lb. pallet box of fruit for each harvest was washed at the CREC-LA packinghouse, sized to retain fruit between 3 and 4 1/4 inches in diameter and a size-distribution was determined. Three 50-fruit (approximately 40 lb.) randomized samples were extracted using the Toledo auto state test equipment (2, 7). One size randomized sample was constructed of approximately 700 lb. each harvest which was weighed and extracted for a medium yield using FMC equipment. Models 391 and 591 extractors were used and a model 35 finisher (0.020 inch screen) modified for pneumatic pressure control with extraction parameters listed in Table 1. As with 'Valencia' oranges, equipment was primed with experimental fruit from a desired quick-fiber value of 160. Weights of the various components of fruit were recorded as: juice, finisher pulp and peel plus core. The weights of these components were expressed in terms of 2.23 bu. or the volume of the traditional 85-lb. field box, jumble filled. Average individual fruit weights and volumes (by water displacement) were determined on a 50-fruit randomized sample for each harvest.

On each harvest random samples of fruit were cross sectioned with a 1/2-inch cut at the stem end (6). Average peel thickness measurements were determined as described for 'Valencia' oranges.

Results and Discussion

Temperatures and durations. Estimated temperature data for our experimental tracts during the 2 freeze nights of December 24 and 25, 1983, indicated the fruit was exposed at 24 and 25°F or lower for 5 hr with 21 or 22°F minimums each night.

During another experiment in another comparable grove during the March 1980 freeze Valencia oranges were exposed for 5 hr at or below 25° with a 23°F minimum. In general, the temperatures and durations of each of these 3 freeze nights of the 2 freeze years were comparable. Of course the 1983 fruit experienced 2 nights of freezing. Some comparisons of the effects of these different freezes will be made later.

Oranges. Between December 29 and May 23 °Brix of 'Valencia' oranges increased from 9.4 to 11.3 and the °Brix: acid ratio increased from 7.5 to 15.1 (Table 2). The unfactored state test yield decreased from 50.38% to a minimum of 35.22% on April 16, then increased slightly to 38.48 by May 23. Commercial extraction yields paralleled state test values. These yields also dropped to a minimum on April 16 and then rose slightly. The same minima pattern is also found for fruit specific gravity, fruit weight and lb. solids per 2.23 bu box, but fruit volume remained fairly constant through the test period (Table 2).

The plot of the state test yield data at each harvest was curvilinear, with a regression coefficient (R^2) of 0.77 (Fig. 1). Juice content decreased linearly from December 29 to February 20 and then increased by the final harvest date (May 23). This curve was different from a curve shown at the top of Fig. 1 and was based on a similar study of 'Valencia' oranges following another freeze (1), where the juice volume decreased linearly during the 12 weeks after the freeze in March 1980.

The difference between the two curves may be due to the 3-month difference in the stages of maturities of the fruit in the 2 studies. The fruit in the 1980 study were completing maturity at the time of the freeze whereas the fruit in the 1983-84 study were relatively immature and may have continued to grow accounting for no juice loss and an increase in lb. solids per box after February 20.

As drying of fruit on the tree increased during the experimental period, photographs of fruit cross sections

Table 2. Fruit quality of 'Valencia' oranges at various times after a freeze.

	1983	1984						
Harvest Date	Dec. 29[z]	Jan. 17	Jan. 30	Feb. 20	Mar. 8	Apr. 16	May 8	May 23
°Brix	9.4	10.1	10.2	10.8	10.7	11.4	10.9	11.3
Acid (% by wt.)	1.26	1.11	0.93	0.87	0.89	0.87	0.74	0.75
Ratio (°Brix/acid)	7.5	9.1	11.0	12.4	12.0	13.1	14.7	15.1
State test juice unfactored (% by wt.)	50.38	44.47	40.83	36.11	37.18	35.22	35.81	38.48
Standard 2.23 bu box (lb.)	—	88.27	82.04	72.79	75.44	72.39	72.26	81.55
Peel (+ core) (lb.)	—	44.53	44.12	42.52	43.97	43.20	41.93	46.30
Finisher pulp (lb.)	—	3.07	1.94	2.42	2.89	2.77	2.90	3.18
Juice (lb.)	—	40.67	35.98	27.85	28.58	26.42	27.43	32.07
Commercial extraction (% juice by wt.)	—	46.07	43.86	38.26	37.88	36.50	37.96	39.33
Specific gravity, fruit	—	0.84	0.77	0.70	0.70	0.68	0.75	0.73
Avg. wt. per fruit (lb.)	—	0.42	0.40	0.37	0.37	0.35	0.36	0.38
Avg. vol. per fruit (oz.)	—	7.6	7.9	8.1	8.1	8.0	7.5	7.9
Solids per 2.23 bu box (lb.)	—	4.10	3.67	3.01	3.06	3.01	2.99	3.62

[z]Limited harvest.

Table 3. Effects of freezing on 'Marsh' grapefruit.

Harvest Date	1983 Dec. 29[z]	1984 Jan. 17	Jan. 30	Feb. 20	Mar. 8	Apr. 16
°Brix	9.4	9.6	9.2	9.2	9.1	8.5
Acid (% by wt.)	1.22	1.27	1.21	1.19	1.16	1.05
Ratio (°Brix/acid)	7.7	7.6	7.6	7.9	7.9	8.1
State test juice unfactored (% by wt.)	50.99	43.26	45.73	46.35	47.20	49.64
Standard 2.23 bu box (lb.)	—	66.70	70.60	74.57	77.42	82.85
Peel (+ core) (lb.)	—	37.32	40.38	42.80	41.12	44.73
Finished pulp (lb.)	—	0.87	0.85	1.19	1.32	1.49
Juice (lb.)	—	28.01	29.36	30.57	31.97	36.62
Commercial extraction (% juice by wt.)	—	41.99	41.59	41.00	41.29	44.20
Sepecific gravity, fruit	—	0.66	0.69	0.74	0.73	0.73
Avg. wt. per fruit (lb.)	—	1.00	1.01	1.03	1.03	1.04
Avg. vol. per fruit (oz.)	—	23.4	22.4	21.5	21.8	21.7
Solids per 2.23 bu box (lb.)	—	2.69	2.70	2.81	2.91	3.11

[z]Limited harvest.

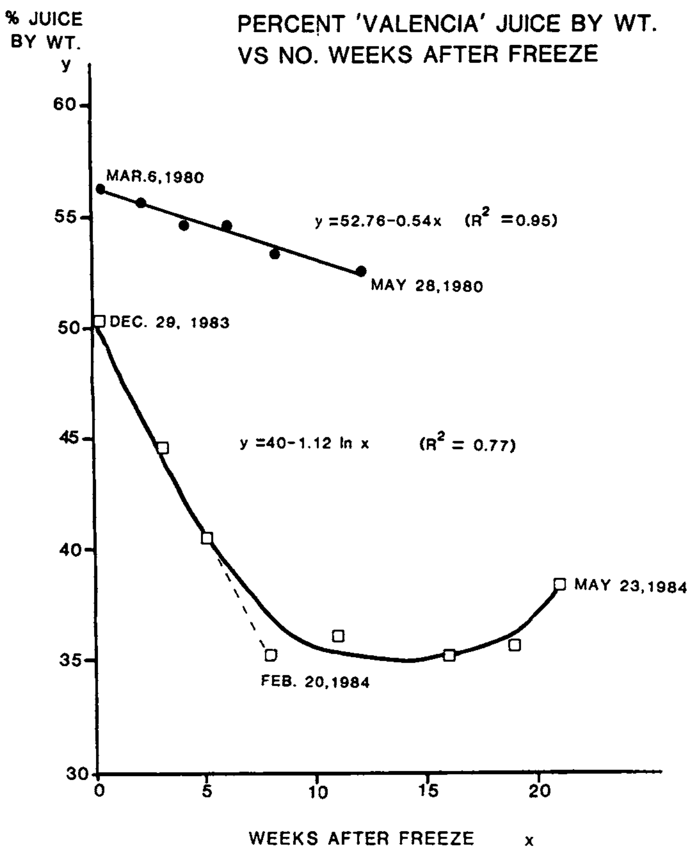

Fig. 1. Effect of the time after the freeze on the percent juice in 'Valencia' oranges.

indicated that peel thickness was greater adjacent to segment areas with dry vesicles than adjacent to areas with normal juice filled vesicles. This has been discussed in another report (5). As juice content per 2.23 bu of fruit decreased through the experiment, extractor tests showed peel and core weight actually decreased from the January 17 harvest through the May 8 harvest (Table 2). However, on May 23, the last harvest, this trend was reversed and the 46.30 lb. peel and core per 2.23 bu of fruit on this date was 4% more than the 44.53 lb. measured on January 17. This indicated a possible accumulation of liquid material by the parenchymatous sponge like cells of the albedo, but only during the last part of the experimental period. Average peel thickness was 20% greater on May 22 than on December 29.

Grapefruit. Results from 'Marsh' grapefruit are summarized in Table 3. The unfactored state test yield values showed an initial loss probably due to minimal freeze damage and drying. In spite of this, the yield did not decrease between January 17 and April 16 as it did in the orange experiment. In fact, the grapefruit unfactored state test yield values increased from 43.26 to 49.64% juice by weight during this period, a 5% increase. This might indicate minimal or no freeze damage or resultant drying, a fact confirmed by examination of cross section cuts of representative fruit of each harvest. °Brix decreased about 1 degree and the °Brix:acid ratio increased about 1/2 point during the 16 week experimental period. Fruit weight increased only slightly and fruit volume decreased slightly. The weight of the 2.23 bu. volume of fruit showed a definite increase during the experimental period.

The peel of the experimental grapefruit increased in thickness 22% (0.429 to 0.542 inch) from December 29 to April 16.

Average peel thickness of grapefruit on December 29, 1983 was 0.43 inch or 81% greater than the 0.24 inch thickness of the experimental oranges at the same time. This differential in peel thickness may explain the lack of freeze damage to the grapefruit at or below 25°F for 5 hr when the adjacent experimental oranges were severely damaged at the same time.

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