Redblush Grapefruit Quality as Affected by Controlled Artificial Climates[1]

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Abstract. 'Redblush' grapefruit borne on young fruiting trees and grafted on sour orange seedlings were exposed to natural and artificial climates. Fruit exposed to artificially controlled and naturally occurring minimum night temperatures above 70°F, combined with high day temperatures, had high Brix contents, low acid, and thin but green peels. Fruit exposed to minimum night temperatures below 60°, combined with moderate to cool day temperatures had both high Brix and acid and thicker but better colored peels. Cool temperatures in the late fall after hot summer and early fall conditions aided in thickening and coloring of peels of fruit which had already attained high Brix and early maturity.

Introduction

Seasonal changes in citrus fruit quality characteristics have been studied (1, 2, 5, 11), and changes in these characteristics have been correlated with differences in air temperature and humidity (2). Cooper et al. (2) reported that 'Valencia' oranges grown in the moist climates of Florida and South Texas had thinner rinds, lower juice acid and developed earlier high Brix content than in the drier climates of California and Arizona. Higher spring and summer night temperatures were influencing factors on fruit quality of fruit grown in the moist climates of Texas and Florida. Reduced light was shown to induce lower juice Brix and poorer colored peels of 'Valencia' oranges (12) but did not have any influence on juice acid (13).

More precision in measuring the effects of temperature on 'Valencia' oranges was reported by Erickson (4) and Young and Erickson (15). Fruit grafted on young seedlings and exposed to artificially controlled high temperatures were more mature due to lower acid content. Low temperatures favored acid accumulation and the development of orange colored peels.

'Redblush' grapefruit grown in the Rio Grande Valley of Texas reach a high Brix content by early fall, but the acid content does not decline to an acceptable level until late September and October (1, 6). Consequently, legal maturity is not reached until then. Rind thickness usually reaches a minimum in the fall and may thicken slightly during the winter months (1).

Since year-to-year variations in fruit quality factors often affect the date at which legal maturity is reached, studies characterizing temperature effects on fruit quality were initiated.

Materials and Methods

Plant materials. Two-year-old nucellar 'Redblush' grapefruit trees, *C. paradisi* Macf., budded on sour orange rootstock, *C. aurantium* Linn., and 'Redblush' grapefruit fruit grafted near the base of 9-to-12-month-old sour orange seedlings were used as test material. The fruiting trees were grown in 5-gal crocks, and the grafted seedlings were grown in 6-quart cans. Fruit were grafted between May 15 and June 15, with the technique described by Erickson (3) and Olson (8).

Sampling and analysis. Sampling procedures and sizes and numbers of replications were those described by Purcell, et al. (9). Analyses for degree Brix and per cent acid were conducted by standard techniques on preparations made for pigment analyses and described in a previous report (9). Peel color was determined visually with color standards reported by Harding and Fisher (5) with letter ratings converted to numerical ratings for convenience, so that A = 1, B = 2, etc.; therefore, a 1 rating was dark green and a 9 rating was golden-yellow. Peel thickness was measured in millimeters with a micrometer. Fruit were harvested every 2 or 3 weeks during each test for analysis but only the results at the end of each test are reported. Differences between individual treatments represent trends which developed during the test periods.

Chamber operation. Day temperatures were controlled from 8 AM to 4 PM and night temperatures from 4 PM to 8 AM. Light in the chambers was provided by banks of G.E. Powergroove fluorescent tubes and 100-watt incandescent bulbs. Illumination was 800 to 1000 ft-c at plant level and lights were on from 6 AM to 6 PM. Light measured with a pyrheliometer ranged from 0.1 to 0.2 g cal/cm²/min at peak intensity in the chambers to 1.1 to 1.2 g cal/cm²/min at peak intensity under natural conditions with full sunlight. Shaded fruit under natural conditions were exposed to 0.1 to 0.2 g cal/cm²/min at peak intensity. Humidity in the chambers was controlled between 50 and 60%.

Experimental trials. All trials were initiated in late July. In 1963, fruiting trees were exposed to day/night temperatures of 95°/85°F and 60°/40° for 5 weeks. Grafted fruit were exposed to the following: 1965—natural conditions, 95°/85°, 70°/60°, and 60°/40° for 18 weeks; 1966—natural conditions, 95°/85°, and 70°/60° for 7 weeks; 1967—natural conditions (shaded and unshaded), 95°/85°, and 60°/40° for 19 weeks; 1968—natural conditions (shaded and unshaded), 105°/98°, and 60°/40° for 5 weeks. A second set of grafted fruit in 1968 was exposed to natural conditions for 13 weeks, 90°/70° for 8 weeks, 80°/60° for 5 weeks, and 70°/50° and 60°/40° for 2 weeks each, successively. The average monthly maximum and minimum temperatures for natural conditions were as follows: August maximum 94° and minimum 74°; September, 92° and 71°; October, 84° and 63°; and November, 80° and 62°. Temperature variations in the controlled temperature chambers were ± 3° from mean temperature. Temperature variations in natural

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Table 1. 'Redblush' grapefruit juice Brix, acid, and Brix/acid ratio following exposure to different temperature conditions.

Fruit source and temperature scheme	1963 (5)[a]			1965 (18)			1966 (7)			1967 (19)			1968 (5)		
	Brix (°)	Acid (%)	Brix/ acid	Brix (°)	Acid (%)	Brix/ acid	Brix (°)	Acid (%)	Brix/ acid	Brix (°)	Acid (%)	Brix/ acid	Brix (°)	Acid (%)	Brix/ acid
Fruiting trees:															
95°/85°	9.6	0.98	9.8	—	—	—	—	—	—	—	—	—	—	—	—
60°/40°	12.2	1.30	9.4	—	—	—	—	—	—	—	—	—	—	—	—
Grafted fruit:															
natural—unshaded	—	—	—	12.7	1.39	9.1	14.1	1.80	7.8	11.8	1.24	8.5	13.9	1.92	7.2
natural—shaded	—	—	—	—	—	—	—	—	—	11.1	1.59	7.3	13.2	2.19	7.2
105°/98°	—	—	—	—	—	—	—	—	—	—	—	—	14.7	0.91	16.2
95°/85°	—	—	—	12.0	1.43	8.4	12.4	1.97	6.3	10.7	1.47	7.3	—	—	—
70°/60°	—	—	—	11.9	1.49	8.0	12.9	1.99	6.5	—	—	—	—	—	—
60°/40°	—	—	—	12.4	1.59	7.8	—	—	—	10.9	1.53	6.8	14.5	1.97	7.4
L.S.D. .05	2.1	0.15	N.S.	N.S.	0.13	N.S.	N.S.	0.19	N.S.	N.S.	0.22	1.0	N.S.	0.22	1.5

[a]All treatments started between July 14 and 21. Number indicates weeks of treatment.

conditions were greatest in September, October, and November when occasional Arctic cold fronts passed through the area. In August, 95% of the daily maximum and minimum temperatures were within ± 5° of the 4-year monthly means. In September, October and November the percentage occurrence of daily maximum and minimum temperatures within ± 9° of the 4-year monthly means were 97, 86 and 92%.

Statistical analysis. Results obtained each year were analyzed by analysis of variance. In all grafted fruit trials, treatment means were compared individually with that of fruit exposed to natural conditions.

Results and Discussion

Fruit Brix content was not significantly affected by exposure to day temperatures between 60° and 105° with 10° to 20° cooler nights, although fruit on young trees had higher Brix content following exposure to cool days and nights (Table 1). Brix values ranged from 9.6 to 14.7 with the largest differences occurring between test years. Shading did not reduce the Brix significantly in any one test year, although shaded fruit tended to have a slightly lower Brix both years. High Brix contents were obtained in the juice of fruit grown in both natural and artificially controlled climates in early September (1963, 1966, and 1968 tests) which corresponded to reports on field-grown 'Redblush' grapefruit (1, 6).

Acid content of the juice was lower following exposure to warm days and nights (Table 1). The lowest acid content was in fruit following exposure to 105°/98°, and was similar to the acid contents of fruit harvested in March (1). In the short term tests of 1966 and 1968, acid contents ranged from 1.80 to 2.19%. These values are similar to those of field-grown 'Redblush' grapefruit harvested in early September (1, 6, 7). Fruit on young trees harvested in September (1963 test) had lower acid contents than grafted fruit since the trees were grown the entire year, prior to differential treatment, in a warm glasshouse. Shaded fruit in natural conditions had higher acid contents than unshaded fruit. This may have been due to lower temperatures in the shade since acid content was not influenced by light intensity (13).

Lower acid contents in fruit exposed to warm temperatures resulted in a trend towards slightly higher Brix acid ratios although the differences in any one year were not significant (Table 1). These results are in general agreement with reports on quality of citrus fruit grown in various climatic areas (10, 14). Fruit harvested in September (1966 and 1968) were less mature than those harvested in the late fall, although the fruit on young trees were fully mature in September due to previous glasshouse exposure. The highest Brix/acid ratio was in fruit exposed to 105°/98°. Although these fruits may have been legally mature by Texas standards they would not be acceptable since the juice was still quite bitter due to a high naringen content. This was generally true of all fruit harvested in September.

Fruit exposed to cooler temperatures developed more yellow peel color and thicker peels (Table 2). Yellow coloring of peel was apparent after 2 weeks' exposure to 60°/40° and intensified with time. Fruit exposed to natural conditions eventually developed a yellow color late in the fall because of cooler temperatures (1965 and 1967 tests), but in short term tests (1966, and 1968) remained green. Thus, the effect of artificially controlled cooler temperatures was, in some cases, more pronounced after 5 to 7 weeks' treatment. Fruit exposed to continuous warm temperatures had not colored even in the late fall. Fruit peels were slightly thicker after exposure to cooler

Table 2. Redblush grapefruit peel color and thickness (mm) following exposure to different temperature conditions.

Fruit source and temperature scheme	1963 (5)[a]		1965 (18)		1966 (7)		1967 (19)		1968 (5)	
	color[b]	thickness	color	thickness	color	thickness	color	thickness	color	thickness
Fruiting trees:										
95°/85°	3.2	3.7	—	—	—	—	—	—	—	—
60°/40°	7.0	4.8	—	—	—	—	—	—	—	—
Grafted fruit:										
natural—unshaded	—	—	6.6	4.7	3.3	4.7	—	—	2.1	4.5
natural—shaded	—	—	—	—	—	—	—	—	1.7	5.4
105°/98°	—	—	—	—	—	—	—	—	2.1	4.6
95°/85°	—	—	4.8	2.7	2.0	4.5	—	—	—	—
70°/60°	—	—	7.8	5.3	2.0	5.3	—	—	—	—
60°/40°	—	—	8.8	5.3	—	—	—	—	7.0	6.2
L.S.D. .05	1.5	1.1	0.8	0.4	N.S.	0.8	—	—	0.7	0.6

[a]See Table 1.
[b]Harding-Fisher (5) color standards converted to numerical system so that A = 1, B = 2, etc. A 1 rating is dark green and a 9 rating is golden yellow.

temperatures which is in agreement with another report (1).

The effects of various controlled artificial temperatures in sequence on fruit quality were evaluated in 1968. Fruit were exposed, in mid-September, to 8 weeks at 90°/70° followed by 5 weeks at 80°/60° and 2 weeks each at 70°/50° and 60°/40° (Table 3). Fruit at the beginning of 90°/70°, had high Brix and acid and green, thick peels. Exposure to 90°/70° caused a large decrease in acid and a decrease of peel thickness. Exposure to 80°/60°, 70°/50°, and 60°/40° did not change the Brix or acid content, but yellow peel color increased considerably in 70°/50° and peel thickness also increased with cooler temperatures. The thickening of fruit peels exposed to cool temperatures following warm summer-like temperatures is similar to that reported for 'Redblush' grapefruit grown in the Rio Grande Valley of Texas (1).

Table 3. Changes in Redblush grapefruit quality following exposure to several controlled temperature schemes.[a] 1968.

Temperature scheme	Weeks (no.)	Juice			Peel	
		Brix (°)	Acid (%)	Brix/acid ratio	color	thickness (mm)
Natural	13	13.9	1.92	7.2	1.7	5.3
90°/70°	8	13.1	1.64	8.0	3.7	3.7
80°/60°	5	12.1	1.63	7.4	4.9	3.9
70°/50/	2	13.6	1.66	8.2	7.8	4.8
60°/40°	2	13.9	1.63	8.5	9.0	4.5
L.S.D. .05		N.S.	0.14	N.S.	0.4	0.5

[a]Fruit were exposed to each temperature scheme in sequence.

Thus, fruit exposed to artificially controlled and naturally occurring minimum night temperatures above 70° in combination with high day temperatures developed early high Brix content, and with continued treatment developed low acid and thin but green peels. Fruit exposed to minimum night temperatures below 60° in combination with moderate to cool day temperatures developed both high Brix and acid and thicker but yellow peels. Cool temperatures in the late fall after hot summer and early fall conditions aided in the thickening and coloring of peels of fruit which had already attained high Brix.

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