VITAMIN C CONTENT AND JUICE QUALITY OF EXPOSED AND SHADED CITRUS FRUITS[1]

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INTRODUCTION

That the vitamin C (ascorbic acid) con tent of a fruit is dependent upon the intensity of incident light was suggested by findings of Zilva and his associates (10) reported in 1935. These investigators found that the red peel of Bramley's Seedling apples contained twice as much vitamin C as the green peel. Although they did not mention light as a factor in the production of this difference in vitamin content, it is well known that the red side of an apple is normally the one that has been exposed on the tree to direct sunlight.

A review of the literature in 1936 failed to show that a comparison as to vitamin C content had been made between citrus fruits from shaded and exposed parts of the tree. It had long been common knowledge, of course, that shaded fruit degreens later than exposed fruit and sometimes never completely degreens and that its juice quality as judged by the taste test is not generally so high.

In 1936 an investigation was begun primarily to determine whether insolation influences the vitamin C content of Florida-grown citrus fruits; total soluble solids and total acid also were measured. The results of this study, terminated in 1943, are reported herein.

In 1939 and 1940 Harding, Winston, and Fisher (4) (5) reported analyses indicating that Valencia and Lue Gim Gong oranges exposed to direct sunlight on the tree contained significantly more vitamin C than those not so exposed. In 1942 Harding and Thomas (6) reported that grapefruit obtained from the outside branches of the tree contained a little more vitamin C than that obtained from the inside branches.

MATERIALS AND METHODS

In December, 1936, initial tests were made to determine the vitamin C content, total acid, and total soluble solids of Dancy tangerines (*Citrus reticulata* Blanco). Later, Temple oranges (supposedly *C. reticulata* x *C. sinensis*) and early, midseason, and late varieties of round oranges (*C. sinensis* (*L.*) *Osbeck*) were included in the study. Between 1936 and 1943 juice of 44 lots of round oranges from widely separated groves of the varieties Parson Brown, Hamlin, Pineapple, Indian River, Seedling, and Valencia, and of 7 lots of Temple oranges, and of 11 lots of Dancy tangerines from groves in central Florida were analyzed. The Temple oranges were grafted on rough lemon (*C. Limon* (L.) Burm. f.) or sour orange (*C. aurantium* L.)

Like numbers of exposed fruits and of shaded fruits were taken from the same trees. Each test sample consisted of the composited juice of 25 to 52 representative fruits of average size from 10 to 15 trees. The methods used for determining total soluble solids, total acid, and vitamin C were identical with those described by Harding, Winston, and Fisher (5) except that a Brix spindle was used to measure the total soluble solids.

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Results

Round Oranges

The exposed fruits of each of the 6 varieties of round oranges contained on an average larger percentages of total soluble solids than did comparable shaded ones (table 1). For the 44 lots tested, regardless of variety, the average difference was 1.65 in percentage points, or 18.1 percent, which is mathematically highly significant.

Statistical analysis of the data on total acid revealed no significant difference between exposed and shaded fruit.

Exposed oranges were consistently higher in vitamin C than shaded fruit. The tests on 44 lots showed that on an average the ouside fruit contained 0.09 mg. per milliliter more vitamin C than the shaded fruit, a difference of 20.9 percent. The results were highly significant statistically.

Temple Oranges

For the seven lots of Temple oranges analyzed, total solids were not significantly greater in the exposed than the shaded fruit. The difference amounted to 1.02 in percentage points, or 9.0 percent (table 2).

For four of the seven lots of Temple oranges, total acid was significantly higher in exposed fruit than in shaded fruit. On an average the acid content of the exposed fruit was greater by 0.049 percentage point.

The vitamin C content of Temple oranges averaged 0.08 mg. per milliliter, or 16.7 percent higher for the ouside than for the inside samples. This difference was found to be statistically highly significant. As the samples were not collected to determine whether kind of rootstock had any effect, it is possible that they differed in other respects besides rootstock; but since Harding and Thomas (6) reported that grapefruit had a higher ascorbic acid content "but the difference was not significant" when the trees were grafted on rough lemon rootstock than when on sour orange, the reverse relation noted in this study is interesting.

Tangerines

In 11 lots of Dancy tangerines picked at various times during the 1936-37 harvest season and from several different groves, the outside (exposed) fruit consistently had more total soluble solids and more vitamin C than did the inside fruit, which was highly significant (table 2). There was less total acid in the outside fruit, and this difference was highly significant, though less marked than the differences in other constituents. On an average, the exposed fruit was 23 percent higher in soluble solids, 27 percent higher in vitamin C, and 16 percent lower in total acid.

Discussion

As oranges mature, normally there is an increase in total soluble solids and a decrease in acid. It seems logical to assume that oranges on the outside branches of the tree mature more rapidly than those on inside branches, since in the former the solids were found to be higher than in the latter. However, even after both types of fruit have attained full maturity, there is a vast difference in quality between the two. It seems likely that, just as most of the higher plants require direct sunlight for best growth and development, exposed branches produce better oranges than shaded ones.

The higher vitamin C content of the exposed oranges is no doubt a definite result of the incidence of sunlight. Other investigators (2) (3) (8) (9) (1) have reported instances in which it was evident that direct sunlight increased the vitamin C content of plants. Mention has already been made of the report of Zilva and his associates (10) that the red peel of apples contained more ascorbic acid than did the green peel. Ezell and his associates (1) have shown that strawberries grown in the shade contained significantly less ascorbic acid than did those exposed to normal sunlight. Kohman and Porter (7) found that tomato plants set out in flats lost vita-

min C from stems and leaves when held in a laboratory in subdued light, but showed an increase in this vitamin when the flats were removed to the roof of the building.

In the past citrus growers have been warned against planting orange trees too close to each other, attention being directed to the fact that shaded fruit does not attain maximum color even when mature. This observation is most strikingly true of tangerines and of Temple oranges early in the season, but is not so marked when the fruit attains full maturity. The results of the present investigation indicate an additional reason for comparatively wide spacing of citrus trees, that is, to prevent unnecessary shading of fruit with consequent inferiority in general juice quality and in vitamin C content. This holds for round oranges, tangerines, and Temple oranges. During recent years there has been a rapid increase in the amount of citrus fruit canned, both as hearts and as juice. Juice quality rather than rind appearance determines the market value of citrus offerings to canneries. It is becoming more and more economically important to produce fruit of high nutritive quality as well as of attractive external appearance.

SUMMARY

In these investigations vitamin C content was found to be significantly higher in fruit from outside branches than in those from inside branches of the same tree. This was true for all varieties of round oranges studied, which included Parson Brown, Hamlin, Pineapple, Indian River, Seedling, and Valencia, as well as for Temple oranges, and for Dancy tangerines. Percentage of total soluble solids was significantly higher in the exposed fruit of all varieties tested. Total acid averaged somewhat higher in the outside Temple fruit than in that from the inside branches, while Dancy tangerines showed the reverse difference. Round oranges, including early, midseason, and late varieties, showed no significant difference in total acidity between fruit collected from inside and outside branches.

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TABLE 1—INFLUENCE OF INSOLATION ON TOTAL SOLUBLE SOLIDS, TOTAL ACID AND VITAMIN C (ASCORBIC ACID) CONTENT OF THE JUICE OF FLORIDA-GROWN ROUND ORANGES.

Variety and date of test	Fruits tested		Total soluble solids		Total Acid		Vitamin C content	
	Exposed fruits	Shaded fruits	Exposed fruits	Shaded fruits	Exposed fruits	Shaded fruits	Exposed fruits	Shaded fruits
	Number	Number	Percent	Percent	Percent	Percent	Mg./ml.	Mg./ml.
Parson Brown:								
Nov. 10, 1938	50	52	11.33	9.53	1.284	1.190	0.62	0.50
Nov. 4, 1940	50	50	10.15	9.25	1.042	1.340	.62	.48
Nov. 15, 1940	50	50	10.60	9.33	.944	1.126	.53	.40
do	50	50	11.13	10.43	1.346	1.230	.61	.49
Average	50	50.5	10.80	9.64	1.154	1.222	.60	.47
Hamlin:								
Nov. 4, 1940	50	50	9.84	8.98	.940	.990	.57	.49
Nov. 15, 1940	50	50	8.93	8.43	.904	.948	.54	.45
Average	50	50	9.39	8.71	.922	.969	.56	.47
Pineapple:								
Dec. 17, 1937	55	51	11.33	9.53	1.284	1.190	.62	.50
do	45	44	9.98	8.73	1.190	1.280	.53	.45
Dec. 21, 1937	46	48	9.71	7.97	1.002	.990	.49	.41
do	51	50	9.46	8.91	1.158	1.054	.58	.50
do	59	51	10.66	9.23	1.434	1.422	.63	.55
do	52	51	10.66	9.20	1.430	1.422	.64	.55
Jan. 20, 1938	55	50	9.89	8.90	1.018	.984	.43	.34
do	52	53	9.50	8.10	.604	.535	.34	.28
do	50	50	11.79	9.84	1.130	.984	.48	.38
do	50	50	10.59	9.70	.981	1.022	.47	.39
Feb. 2, 1938	50	50	11.66	11.26	1.062	1.062	.59	.57
do	50	50	11.71	11.06	.928	.944	.57	.51
do	50	50	12.31	11.91	.978	.972	.56	.51
do	50	50	11.73	11.13	.872	.888	.56	.48
do	50	50	12.98	12.38	1.010	1.002	.63	.56
do	50	50	12.83	12.38	.900	.892	.53	.48
Nov. 20, 1940	50	50	11.62	10.62	1.266	1.324	.69	.52
Average	50.9	49.9	11.08	10.05	1.073	1.057	.55	.47
Indian River:								
Dec. 21, 1937	49	50	10.03	9.53	1.613	1.414	.51	.42
do	56	50	10.58	9.23	1.142	1.268	.39	.35
do	51	55	11.43	9.73	1.716	1.750	.52	.38
Average	52	51.7	10.68	9.50	1.490	1.477	.47	.38
Seedling:								
Jan. 9, 1937	25	25	12.84	11.86	1.466	1.570	.62	.52
do	50	25	11.71	10.64	1.199	1.316	.62	.50
Jan. 23, 1937	25	25	12.53	11.43	1.138	1.272	.59	.50
Feb. 2, 1937	25	25	12.64	12.53	1.162	1.193	.59	.49
Average	31.3	25	12.43	11.62	1.241	1.338	.61	.50

Valencia:								
Jan. 9, 1937	25	25	10.64	10.11	1.870	1.864	.60	.50
Jan. 16, 1937	25	25	10.21	8.11	1.217	1.126	.53	.36
Jan. 23, 1937	25	25	10.03	8.83	1.074	1.220	.50	.43
Feb. 13, 1937	25	25	10.50	9.70	1.094	1.142	.39	.32
do	25	25	9.90	8.50	1.122	1.074	.45	.34
Feb. 20, 1937	26	26	10.34	9.24	1.054	1.086	.49	.37
Mar. 13, 1937	26	27	10.67	10.00	1.094	1.070	.42	.34
do	31	26	10.90	8.67	1.022	1.002	.47	.36
Apr. 16, 1937	25	25	11.15	9.65	.960	.934	.38	.30
do	27	28	11.50	8.75	.908	.824	.47	.34
May 12, 1937	28	31	11.80	9.73	.904	.764	.39	.28
do	36	34	11.73	8.09	.774	.649	.43	.30
May 22, 1937	12	12	12.26	9.71	.690	.607	.43	.37
June 4, 1937	24	24	9.16	8.65	.592	.582	.39	.37
Average	25.7	25.6	10.77	9.12	1.027	.996	.45	.36
Average for all varieties	41	40.1	10.98	9.76	1.103	1.103	.52	.43

TABLE 2.—INFLUENCE OF INSOLATION ON TOTAL SOLUBLE SOLIDS, TOTAL ACID AND VITAMIN C (ASCORBIC ACID) CONTENT OF THE JUICE OF FLORIDA-GROWN TEMPLE ORANGES AND DANCY TANGERINES.

TEMPLE ORANGES

Date of Test	Fruits tested		Total soluble solids		Total acid		Vitamin C content	
	Exposed Fruits	Shaded Fruits	Exposed Fruits	Shaded Fruits	Exposed Fruits	Shaded Fruits	Exposed Fruits	Shaded Fruits
	Number	Number	Percent	Percent	Percent	Percent	Mg./ml.	Mg./ml.
Dec. 21, 1937	52	50	10.53	9.22	1.450	1.482	0.50	0.44
Jan. 20, 1938	53	55	11.89	11.09	1.205	1.070	.53	.45
Feb. 11, 1943	50	50	13.29	11.99	1.458	1.340	.68	.58
do	50	50	13.49	12.99	1.644	1.744	.58	.51
Average	51.3	51.3	12.30	11.32	1.439	1.409	.57	.50
Jan. 20, 1938	50	50	10.84	9.79	1.082	.928	.47	.38
Feb. 11, 1943	50	50	14.18	12.79	1.616	1.623	.59	.49
do	50	50	12.19	11.39	1.344	1.268	.58	.51
Average	50	50	12.40	11.32	1.347	1.273	.55	.46

DANCY TANGERINES

Dec. 12, 1936	27	27	9.63	7.80	0.912	1.086	.024	0.16
do	25	25	9.32	7.20	0.751	0.872	.26	.22
do	25	25	9.40	6.12	.666	.662	.31	.20
Dec. 22, 1936	25	25	10.30	8.10	.974	1.228	.37	.33
do	25	25	10.95	9.10	1.264	1.399	.44	.33
do	25	25	10.60	8.90	1.395	1.432	.29	.24
do	25	25	10.90	8.60	1.392	2.011	.35	.24
Jan. 9, 1937	25	25	10.61	8.21	.649	.908	.20	.18
Jan. 23, 1937	25	25	10.83	9.33	.710	.760	.20	.17
Feb. 6, 1937	25	25	11.29	9.75	.660	.714	.21	.16
Feb. 20, 1937	31	30	11.00	10.38	.662	.784	.20	.16
Average	25.7	25.6	10.44	8.50	.908	1.078	.28	.22