ASCORBIC ACID CONTENT OF A NUMBER OF CITRUS FRUITS[1]

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INTRODUCTION

Among a number of citrus hybrids that have been developed by the Bureau of Plant Industry, United States Department of Agriculture, are the tangelo, a grapefruit and tangerine cross, the tangor having an orange and tangerine parentage, the limequat and orangequat, crosses of the lime and tangerine, respectively, with the kumquat, and the Perrine lemon, a lemon-lime hybrid.

Because of the prominence many citrus fruits have gained by reason of their high ascorbic acid content, it was considered important to determine the ascorbic acid values of some of these new citrus hybrids for comparison with the values for the more common citrus fruits.

A description of most of the hybrid fruits that were tested has been given elsewhere by Swingle, Robinson, and Savage.[3] In addition to the information about the vitamin C content of commercial types, this work will indicate the capacity for inheritance of this vitamin. The work is being continued on a cooperative basis between the two Bureaus concerned.

References to ascorbic acid values for a limited number of varieties of oranges, grapefruit, tangerines, lemons, and limes, may be found among the vitamin data reviewed by Daniel and Munsell.[4]

MATERIALS AND METHODS

The fruits were selected and shipped to Washington from the United States Horticultural Field Laboratory, Orlando, Fla., by members of the Bureau of Plant Industry. Except for two samples of Perrine lemons, which were picked in different stages of ripeness (ripe yellow and light green) and kept in cold storage 2 months before shipping, all of the samples represent freshly picked fruit. Analyses for ascorbic acid were made as soon as possible after the arrival of the fruit in Washington.

The first shipments contained a number of different fruits, among which were oranges, grapefruit, tangerines, tangelos, lemons, limes, limequats, and orangequats. These were received between December 20 and 27, 1935, and the analyses were made within the following 2 weeks. The ascorbic acid content of one sample of each of these fruits

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[2] Appreciation is expressed to H. P. Traub, T. R. Robinson, and E. M. Savage, Division of Fruit and Vegetable Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, for their cooperation in selecting and sending representative samples of fruit.

[3] SWINGLE, W. T., ROBINSON, T. R., and SAVAGE, E. M. NEW CITRUS HYBRIDS. U. S. Dept. Agr. Circ. 181, 20 pp., illus. 1931.

[4] DANIEL, E. P., and MUNSELL, H. E. VITAMIN CONTENT OF FOODS. A SUMMARY OF THE CHEMISTRY OF VITAMINS, UNITS OF MEASUREMENT, QUANTITATIVE ASPECTS IN HUMAN NUTRITION, AND OCCURRENCE IN FOODS. U. S. Dept. Agr. Misc. Pub. 275, 176 pp. 1937.

was determined. Some of the most promising varieties, selected by members of the Bureau of Plant Industry on the basis of fruits showing the greatest commercial possibilities, were tested at weekly intervals over a period of 6 weeks. A group of five varieties of these selected fruits, including Bowen grapefruit, Dancy tangerine, Minneola and Thornton tangelos, and Pineapple orange, were tested between February 2 and March 13, 1936. Five other varieties, including Davis and Foster (pink) grapefruit, Seminole tangelo, Umatilla tangor, and Valencia oranges were analyzed between March 20 and April 24, 1936.

The ascorbic acid measurements were carried out essentially according to the titration method described by Bessey and King.[5] The sample was prepared by hand-reaming several fruits and lightly shaking the resultant juice and pulp through an 8-mesh wire sieve.[6] After thorough mixing, a 10-cc aliquot of this juice was pipetted into a centrifuge tube, 25 cc of hot 8-percent acetic acid added, and the whole centrifuged for 5 minutes. After decanting into a 100-cc volumetric flask, 10 cc more of the hot 8-percent acetic acid was added to the residue, the sides of the tube were washed down with approximately 25 cc of water distilled from glass, and the mixture centrifuged for 3 minutes. After decanting, 10 cc more of the hot acid was added and the above procedure again repeated, this time centrifuging for 2 minutes. The combined supernatant liquids were made up to 100 cc, thoroughly mixed, and three 10-cc aliquots, each equivalent to 1 cc of the original juice, were titrated with a standardized solution of 2, 6 dichlorophenolindophenol. Two separate determinations using threefold checks on the titration procedure were made on each sample of fruit. Blanks were carried through with the earlier experiments until it was found that they consistently showed no titration value, after which they were discontinued.

The 2, 6 dichlorophenolindophenol was made up in 0.02-percent solution, filtered and titrated against a commercial ascorbic acid, also made up in 0.02-percent solution. This commercial preparation of ascorbic acid was found to have the same titration value as the International Standard of ascorbic acid. The ascorbic acid solutions were titrated immediately after preparation. The 2, 6 dichlorophenolindophenol was prepared in this laboratory according to the directions given by Bessey and King.[7] Solutions of this dye were made up each day and standardized against freshly prepared ascorbic acid solutions containing a known weight of the acid. Freshly boiled water previously distilled from glass was used for all solutions. The titrations were made as rapidly as possible and the first faint pink color was taken as indication that the end point had been reached. All of the citrus fruits tested gave a sharp end point which was readily determined. The ascorbic acid content of the samples was calculated in terms of milligrams of ascorbic acid per cubic centimeter of expressed fruit juice.

RESULTS

The average ascorbic acid values for a large number of citrus fruits are brought together in table 1. Included in this list are: The isolated

[5] BESSEY, O. A., and KING, C. G. THE DISTRIBUTION OF VITAMIN C IN PLANT AND ANIMAL TISSUES, AND ITS DETERMINATION. Jour. Biol. Chem. 103: 687-698. 1933.

[6] Olive McElroy, of this laboratory, has shown that juice strained in this manner gives the same ascorbic acid titration as juice squeezed through muslin.

[7] BESSEY, O. A., and KING, C. G. See footnote 5.

single samples of several hybrids; a number of the more common citrus fruits, including hybrid-parent fruits; other fruits which were analyzed at weekly intervals, and are reported in detail in table 2; and also several varieties of oranges tested in the course of a previous experiment [8], the results being recorded here for purposes of comparison. These last are all designated in the table as "commercial shipments." All other samples were obtained through the United States Horticultural Field Laboratory, Orlando, Fla. The soil conditions in which the different fruits were grown have been indicated in all cases in which this was known.

The individual and the average ascorbic acid values for six samples each of several varieties of citrus fruits tested at weekly intervals are given in table 2.

TABLE 1.—*Ascorbic acid content of a number of miscellaneous samples of citrus fruits*

Fruit tested	Variety	Origin of fruit and description of soil or fruit	Samples tested (2 determinations per sample)	Fruits per sample	Average ascorbic acid per cubic centimeter of juice
			Number	*Number*	*Milligram*
Orange (*Citrus sinensis*).	Pineapple	Merritt's Island, Indian River section, Fla., hammock soil (sandy loam) underlaid with marl subsoil.	1	5	0.62
		Florida, commercial shipments from Orlando locality during 2½ month period, Jan. 9, 1936, to Mar. 20, 1936.	9	6	.51
		Eustis, Fla., high pine land, Norfolk sand, clay subsoil, typical of Lake County citrus district.	1	6	.51
			6	5	.49
	Valencia	Florida, commercial shipments from Orlando locality during 1½-month period, Mar. 13, 1936, to Apr. 24, 1936.	7	6	.45
		California, commerical shipment from various parts of State during 3½-month period, Aug. 29, 1935, to Dec. 6, 1935.	16	6	.40
		Eustis, Fla., high pine land, Norfolk sand, clay subsoil, typical of Lake County citrus district.	6	5	.32
	Washington Navel.	California, commercial shipments from various parts of State during 3½-month period, Dec. 27, 1935, to Apr. 10, 1936.	15	6	.58
	Sanford Mediterranean.	Eustis, Fla., high pine land, Norfolk sand, clay subsoil, typical of Lake County citrus district.	1	6	.51
	Hamlin		1	3	.48
	Majorca		1	6	.43
	Homosassa		1	6	.43
	Ruby (Blood)		1	6	.37
Grapefruit (*Citrus grandis*).	Tresca [1]	do	1	2	.64
	Davis		1	3	.38
	do		6	2	.34
	Bowen		6	2	.35
	Foster (pink)		6	2	.33
Tangerine (*Citrus nobilis deliciosa*).	Clementine [2]	do	1	6	.37
	Dancy		6	5–6	.24
	do	Orlando, Fla., sandy loam soil	1	6	.18

[1] Belongs to shaddock group.
[2] Believed to be a natural hybrid of tangerine and sour orange.

[8] DANIEL, E. P., KENNEDY, M. H., and MUNSELL, H. E. RELATIVE VITAMIN C CONTENT OF ORANGE AND TOMATO JUICES DETERMINED CHEMICALLY AND BIOLOGICALLY. Jour. Home Econ. 28: 470–474. 1936.

TABLE 1.— *Ascorbic acid content of a number of miscellaneous samples of citrus fruits*—Continued

Fruit tested	Variety	Origin of fruit and description of soil or fruit	Samples tested (2 determinations per sample)	Fruits per sample	Average ascorbic acid per cubic centimeter of juice
			Number	*Number*	*Milligram*
	Clement [3]	Eustis, Fla., high pine land, Norfolk sand, clay subsoil, typical of Lake County citrus district.	1	[4] 3	0.64
	Thornton	Merritt's Island, Indian River section, Fla., hammock soil (sandy loam) underlaid with marl subsoil.	1	2	.43
	Wekiwa	Eustis, Fla., high pine land, Norfolk sand, clay subsoil, typical of Lake County citrus district.	1	[5] 6	.43
	Orlando		1	5	.35
Tangelo (*Citrus nobilis deliciosa* × *C. grandis*).	Thornton		6	5–6	.33
	Sunshine	Vicinity of Vero Beach, Indian River section, Fla., New Hybrid No. 52018–K–12 (quite soft when tested).	1	1	.29
	Sampson	Merritt's Island, Indian River section, Fla., hammock soil (sandy loam) underlaid with marl subsoil.	1	2	.28
	Minneola		1	[4] 2	.27
	----do	Eustis, Fla., high pine land, Norfolk sand, clay subsoil, typical of Lake County citrus district.	6	4–5	.22
	----do		1	[6] 4	.22
	Seminole		6	4	.18
Tangor (*Citrus nobilis* × *C. sinensis*).	Umatilla	----do	6	3	.40
Lemon (*Citrus limonia*).	Sweet		1	7	.33
		Eustis, Fla., high pine land, Norfolk sand soil, clay subsoil, typical of Lake County citrus district:			
	Perrine	Fresh picked fruit	1	6	.40
Lemon-lime hybrid (*Citrus aurantifolia* × *C. limonia*).	----do	Picked in ripe-yellow stage and stored (cold storage) Oct. 23 to Dec. 19, 1935.	1	10	.24
	----do	Picked in light-green stage and stored (cold storage) Oct. 23 to Dec. 19, 1935.	1	8	.26
Lime (*Citrus aurantifolia*).	West Indian or Key.	Orlando, Fla., Orlando sandy loam soil.	1	14	.22
Limequat (*Citrus aurantifolia* × *Fortunella japonica*).	Lakeland	Lake Alfred, Fla., substation, Norfolk sand, orange-colored clay subsoil typical of main Ridge citrus district.	1	12	.17
Orangequat (*Citrus nobilis* × *Fortunella* spp.).	Nippon	Eustis, Fla., high pine land, Norfolk sand, clay subsoil, typical of Lake County citrus district.	1	8	.23

[3] Hybrid of clementine tangerine with grapefruit; other tangelos had Dancy tangerine as pollen parent.
[4] Large. [5] Small. [6] Medium-sized.

TABLE 2.—*Ascorbic acid content of certain varieties of grapefruit, tangerines, tangelos, and oranges*

[Milligrams per cubic centimeter of juice]

Sample no.[1]	Grapefruit			Tangerine	Tangelo			Tangor	Orange	
	Bowen, 2 fruits per sample	Davis, 2 fruits per sample	Foster (pink), 2 fruits per sample	Dancy, 5–6 fruits per sample	Minneola, 4–5 fruits per sample	Thornton, 5–6 fruits per sample	Seminole, 4 fruits per sample	Umatilla, 3 fruits per sample	Pineapple, 5 fruits per sample	Valencia, 5 fruits per sample
	Milligram	*Milligram*	*Milligram*	*Milligram*	*Milligram*	*Milligram*	*Milligram*	*Milligram*	*Milligram*	*Milligram*
1	0.38	0.33	0.31	0.20	0.19	0.31	0.20	0.37	0.42	0.33
2	.33	.34	.32	.27	.23	.29	.20	.37	.48	.33
3	.34	.34	.35	.24	.22	.35	.20	.43	.50	.33
4	.35	.34	.34	.24	.19	.30	.15	.36	.50	.32
5	.33	.34	.32	.25	.23	.34	.17	.35	.54	.30
6	.34	.33	.34	.22	.27	.37	.16	.53	.53	.32
Average	.35	.34	.33	.24	.22	.33	.18	.40	.49	.32

[1] Each sample represents a weekly shipment of the different varieties of fruits which were tested.

SUMMARY AND CONCLUSIONS

Ascorbic acid values were determined for the following freshly picked citrus fruits: Eight varieties of oranges, three varieties of grapefruit, two varieties of tangerines, eight varieties of tangelos (a grapefruit-tangerine hybrid), one variety each of tangor (a tangerine-orange hybrid), lemons, limes, limequats (a lime-kumquat hybrid), orangequats (a tangerine-kumquat hybrid), and the Perrine lemon (a lemon-lime hybrid).

It was found that the ascorbic acid values of the juices of the eight varieties of oranges varied within the limits of 0.32 and 0.62 mg per cubic centimeter of juice. All the varieties of grapefruit tested except for the one sample of Tresca variety had ascorbic acid values in the region of the lower values found for the oranges. The average ascorbic acid values of six samples of Umatilla tangor was 0.40 mg per cubic centimeter of juice, a value slightly higher than the average value for all varieties of grapefruit and somewhat lower than that for most of the varieties of oranges tested.

Only a few samples of tangerines, limes, limequats, and orangequats were tested, but all of these carried relatively small concentrations of ascorbic acid, on the order of half the concentration of that found in most of the varieties of oranges that were analyzed.

The ascorbic acid content of the juices of eight varieties of tangelos (a grapefruit-tangerine hybrid) ranged all the way from the highest value found for grapefruit to the lowest value for tangerines.

Preliminary tests on Perrine lemons picked both in the ripe-yellow and light-green stages, and kept for 2 months in cold storage, indicated that the ascorbic acid was approximately the same for both. This was about 60 percent of the amount originally found to be present in the ripe, freshly picked fruit.