

Effect of Large-Scale Methods of Preparation on the Vitamin Content of Food: II. Carrots¹

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CARROTS are the most important source of carotene in the Army garrison ration and in the quantity consumed they are the third most important vegetable. Furthermore, the carrot is also one of the major sources of carotene in the hospital menu as well as in the patient's customary dietary intake.

At the present time data available on the vitamin retention in carrots are scant. It was the purpose of this study to determine vitamin content in carrots prepared by several large-scale methods and to record the correlation of carotene content to the depth of coloring.

REVIEW OF THE LITERATURE

Carotene. A review of the literature shows the carotene content of carrots to vary from 25.6 mg. (1) to 2.3 mg. per 100 gm. (2). A representative value of 12,000 I. U. vitamin A (7.2 mg. beta-carotene) per 100 gm. has been given for the edible portion of fresh carrots (3).

¹ Received for publication November 22, 1945.

The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the Pentagon Post Restaurant Council. Acknowledgment is made to Lt. Col. Harvey K. Allen and to Dr. Robert S. Harris, Consultant in Nutrition to the Secretary of War, for their interest and initiative in organizing this study and for their counsel and guidance so generously given in planning and carrying out this project. Appreciation is also expressed to members of the Working Committee, Dr. Robert S. Harris; Col. John B. Youmans and Maj. Wm. F. Ashe, Office of the Surgeon General; Col. Paul P. Logan and Jane C. Ebbs, Office of the Quartermaster General; and Dr. Paul L. Pavcek, Secretary of Food and Nutrition Board, National Research Council, for their valuable assistance in selecting the foods to be studied and the methods of preparation and of assay to be used. Grateful acknowledgment is made of the advice and suggestions of: Dr. Esther L. Batchelder; Gertrude M. Cox; Dr. Floyd S. Daft; Dr. Conrad A. Elvehjem; Dr. Faith Fenton; Commander Clive McCay; Dr. E. M. Nelson; Lura Mae Odland; Sybil L. Smith; and Dr. C. D. Tolle.

Values for carotene presented in the literature are given variously in terms of "carotene", "crude carotene", and "beta-carotene." Recent work has shown that "crude carotene" consists of several carotenoid pigments of varying biological activity. Of these carotenoid pigments, only alpha-carotene and beta-carotene are present in carrots in important quantities (4). Alpha-carotene has been reported as having half the biological potency of beta-carotene (5). Harper and Zscheile (6) reported that the carotene of a number of garden varieties of carrots contained on an average 46 per cent alpha-carotene. Kemmerer, *et al.* (4) found that the carotene of a number of samples of raw carrots contained 20 to 36 per cent alpha-carotene and boiled carrots, 23 to 41 per cent.

Harper and Zscheile (6) observed that frequently the depth of external coloring of a carrot is a rough index of the carotene concentration. In each variety of carrots studied except the *Belgium White* they found the carotene content of the phloem or bast tissue was greater than that of the xylem or woody tissue per unit length of root.

Peterson (7, 8) reported losses of carotene in the large-scale preparation of boiled carrots to be 6 to 23 per cent, buttered carrots 12 to 13 per cent, and creamed carrots 9 per cent. Oser, *et al.* (9) prepared carrots in household quantities by waterless cooking and by boiling and found carotene losses of 4 and 6 per cent respectively. Pyke, *et al.* (10) obtained data which suggested no loss of carotene when carrots were steamed.

In a study of dehydrated carrots reported by Fenton and coworkers (11) losses of carotene were as follows: 19 per cent in bringing to a boil (45 min.) and simmering 20 min.; 5 per cent in pressure steaming 15 min. and 1 per cent in boiling 25 min. There was no carotene loss in simmering for 30 min. Dehydrated carrot bricks lost 11 per cent carotene when they were brought to a boil (45 min.) and simmered 20 min.

Ascorbic Acid. The ascorbic acid content of the carrot varies markedly. Two extreme values are 31 mg. (12) and 0.8 mg. per 100 gm. (13). A representative value of 6 mg. per 100 gm. is given for the edible portion of fresh carrots (3). The ascorbic acid concentration also varies between different parts of the carrot. Rudra (12) in his work on the Indian carrot found the skin to contain 75 mg. per 100 gm. and the flesh 31 mg. per 100 gm.

Reported losses of ascorbic acid in boiling of carrots average 61 per cent (1, 7, 8, 14-19), and range from 43 per cent to 77 per cent (14), (15). Most of these data were obtained in large-scale cookery. Data reported for ascorbic acid losses after steaming of carrots by institutional methods vary from 47 to 52 per cent (10, 14, 20). Similar results were obtained by Brinkman, *et al.* (16) who cooked carrots in a pressure saucepan and in a waterless cooker and found losses of ascorbic acid of 55 and 50 per cent respectively; and by Peterson (7, 8) who reported losses of 49 and 51 per cent in the preparation of buttered and creamed carrots. On the other hand Daum *et al.* (21), found a 25 per cent loss in carrots prepared by an unspecified institutional method.

Many investigators have reported losses of ascorbic acid in cooked carrots held on a steam table for various lengths of time (10, 14, 17, 18, 20, 21). A typical example was reported by Higgins (14) who found that carrots which lost 52 per cent of their ascorbic acid during steaming, lost an additional 21 per cent when held on the steam table 1 hr. Capps and Flanagan (22) found that destruction of ascorbic acid increased as the cooking period was lengthened. Carrots boiled 15 min. lost 47 per cent ascorbic acid but those boiled 60 min. lost 60 per cent.

Niacin. The niacin content of raw carrots as reported in the literature varies from .22 mg. (23) to .71 mg. per 100 gm. (1). A representative value of .5 mg. per 100 gm. has been given (3).

Oser, *et al.* (9) prepared carrots in small quantities by a waterless method and by boiling and found losses of niacin of 1 and 29 per cent respectively. Heller, *et al.* (15) found a loss of 45 per cent in carrots boiled in large quantities. Data on niacin content of raw and cooked carrots reported by Pyke *et al.* (10) would indicate a loss of 14 per cent when calculated on the dry weight basis.

Fenton and coworkers (11) in an investigation of dehydrated carrots found niacin losses of 52 per cent in simmering 30 min.; 43 per cent in bringing to a boil (45 min.) and simmering 20 min.; 58 per cent in pressure steaming; and 42 per cent in boiling. In cooking dehydrated carrot bricks 42 per cent of the niacin was lost in bringing them to a boil (45 min.) and simmering 20 min.

As this vitamin is quite heat stable, the "lost" portion can usually be found in the cooking water;

for instance, Russell, *et al.* (24) found 72 to 85 per cent of the original niacin content in the cooked carrots, and 5 to 12 per cent in the cooking water.

Thiamin. The thiamin content of raw carrots as reported in the literature varies from .025 mg. (23) to .100 mg. per 100 gm. (25). A representative value of .07 mg. per 100 gm. has been given (3).

Heller, *et al.* (15) in their study of large-scale cooking reported that 52 per cent of the thiamin was lost in boiling. Nagel and Harris (20) studied the effect of an institutional method of steaming and reported a 25 per cent loss. Fenton and coworkers (11) found thiamin losses in preparation of dehydrated carrots of 43 per cent in simmering 30 min.; 25 per cent in bringing to a boil (45 min.) and simmering 20 min.; 48 per cent in pressure steaming; and 48 per cent in boiling 25 min. In cooking dehydrated carrot bricks 43 per cent of the thiamin was lost in bringing them to a boil (45 min.) and simmering 20 min. Hinman, *et al.* (17) found an average thiamin loss of 4 per cent in family size portions of canned carrots prepared by concentrating the liquid, adding the solid portion and heating. When the same investigators boiled canned carrots by a typical Army method (18) they found that the boiled carrots contained only 64 and 68 per cent of the original thiamin content and the boiling water 30 and 27 per cent. The actual thermal destruction of thiamin amounted to 5 and 6 per cent.

Riboflavin. The riboflavin content of raw carrots as reported in the literature varies from .040 to .10 mg. per 100 gm. (23). A representative value of .06 mg. per 100 gm. has been given (3).

Heller, *et al.* (15) in their study of large-scale cooking found a loss of 61 per cent riboflavin when carrots were boiled. Pyke *et al.* (10) found a loss of 7 per cent (calculated on the dry weight basis) in carrots boiled in an Army Student Training Program mess. Fenton and coworkers (11) prepared dehydrated carrots in a number of ways and found riboflavin losses of 26 per cent in simmering 30 min.; 11 per cent in bringing to a boil (45 min.) and simmering 20 min.; 35 per cent in pressure steaming; and 39 per cent in boiling. In cooking dehydrated carrot bricks 45 per cent of the riboflavin was lost in bringing them to a boil (45 min.) and simmering 20 min. Hinman, *et al.* (17) found slight gains of riboflavin when canned carrots were heated in the concentrated canning liquor.

Pantothenic Acid. The literature available on the pantothenic acid content of carrots is at present scant. Values reported range from .12 mg. (23) to 3.2 mg. (1) per 100 gm. Pyke *et al.* (10) reported data on raw and cooked carrots which would indicate a loss of 17 per cent of pantothenic acid in cooking when calculated on a dry weight basis.

Biotin. Cheldelin and Williams (26) reported that 4 samples of carrots contained an average of .0025 mg. biotin per 100 gm.

EXPERIMENTAL PROCEDURE

Methods of Preparation

The general plan for this investigation was similar to that followed in a previous study on potatoes (27) except that boiling and steaming were the only methods of preparation studied. The methods of preparation were those used in the Army mess and other installations where large numbers are fed. In some installations carrots are prepared for cooking by peeling in a mechanical abrasive peeler, and in others they are cleaned with water and a stiff brush. Boiling is a common mess practice and steaming is typical in large restaurants and consolidated messes.

The plan of determining the batch weights at successive stages in the preparation was used as previously described (27). It was of particular value in the case of carrots since the leaching of solid matter was even more marked than in the case of potatoes. Determinations were made on a sufficient number of replicate samples, usually 10, to furnish data suitable for statistical analysis.

Study I

The carrots for this study were obtained from the general supply for the Pentagon Post Restaurants. The batches varied in size, depth of color, degree of maturity, freshness, and variety.

Samples were prepared of: unpeeled carrots, raw; and of peeled carrots, raw; boiled; boiled, held 1 hr.; steamed; steamed, held 1 hr. Water from the boiled carrots also was analyzed.

Raw carrots for one day's analysis were sorted by setting aside every 10th carrot for the raw unpeeled sample. These unpeeled carrots were washed by hand, trimmed of tops and roots, and sliced into disks in a mechanical vegetable slicer with blades set at $\frac{3}{8}$ in. This sample was thoroughly mixed and used immediately for preparation of subsamples. This mixing and immediate subsampling was the general practice for all raw samples. The remaining carrots, approximately 45 lb., were peeled in a mechanical abrasive peeler for 2 min. and then drained. The machine did not peel unsound carrots; therefore these could be detected and discarded. Green and purple epidermis and woody stalk parts were removed. The peeled carrots were then sliced by the machine into one large container and slices from every part of the container were used for the raw peeled samples and for the various cooking procedures.

For boiling, about 25 lb. of peeled carrot slices were placed in a 20-gal. tinned iron pot (small areas of iron were usually exposed), and covered with boiling water. The water was then brought back to a vigorous boil, 100 gm. of sugar and 100 gm. of salt were added, and the boiling continued until the carrots were tender, usually 45 min.

For steaming, approximately 6 lb. of the peeled

carrot slices were placed in 1-gal. stainless steel pans and cooked in a free-venting vegetable steamer until tender, usually 25 min.

For holding, quantities of the boiled or steamed slices were placed in 1-gal. stainless steel pans and kept on the steam table for 1 hr.

Study II

To eliminate some of the variables obtained in the first study, a second study was made with carrots of a single purchase-lot, and of a single variety. Twelve crates of the *Chantenay Coreless* variety were obtained from a producer in the Imperial Valley, California. The carrots were received in prime condition. After storage for one week, it was necessary to remove the tops from all the remaining carrots to reduce wilting and deterioration from fungus diseases. Sixty lb. of carrots were used for each analysis, approximately 5 lb. being taken from each of the 12 crates.

The carrots were cleaned in water with a stiff brush, and after removal of any green epidermis and, without previous peeling, were sliced in the mechanical slicer. The method of distribution of slices and the subsequent cooking procedures were the same as in Study I except that no sugar or salt was added. Samples were prepared as in Study I except that there was no sample for raw, unpeeled.

Study III

The remaining *Chantenay Coreless* carrots (266 lb.) were used for a special study on the relationship of carotene content to the physical characteristics of raw carrots. These carrots were separated into 3 groups according to weight, and a sample from each group prepared for carotene analysis.

In addition, 50 medium sized carrots were arranged according to the depth of external coloring. The two darkest, the two lightest, and the two of middle coloring were assayed individually for carotene content.

Analytical Procedures

Carotene was determined by the method of Bendor, *et al.* (28). Carotene as determined by this method is approximately equivalent to "pure" carotens as determined by the A.O.A.C. method.

Biotin and *pantothenic acid* determinations were made at the Department of Biochemistry, University of Wisconsin, on composites prepared from the replicate B-complex samples. Biotin was assayed according to the procedure of Shull, *et al.* (29) using the modified basal medium of Shull and Peterson (30). The samples were hydrolyzed for assay by autoclaving with 4N H₂SO₄ for 2 hr. at 15 lb. pressure. Extracts for pantothenic acid assay were prepared and assayed according to the procedure of Neal and Strong (31) with the modifications introduced by Ives, *et al.* (32).

Other analyses included determinations of dry solids, hydrogen ion concentration, total and dehy-

droascorbic acid, niacin, thiamin, and riboflavin. The methods used were similar to those previously described (27) with the following exceptions: (a) the incubation period for niacin and riboflavin cultures was uniformly 72 hr., and (b) the riboflavin extracts were prepared by autoclaving the subsamples in the presence of 1 N H₂SO₄ at 15 lb. for 30 min.

Subsamples for Analysis

All subsamples for vitamin assay except those from the boiling water samples were prepared for analysis by slurring with a stabilizing solution in a Waring Blendor, and were stored in brown glass bottles in a refrigerator room maintained at 40°F.

There are considerable variations in vitamin con-

tent between the inner and the outer parts and among top, middle and bottom portions of the carrot. This fact and variations among individual carrots, made it essential that subsamples represent as many slices as possible. For the subsamples of the raw carrots, large numbers of slices were selected at random from the entire sample. The slices were halved crosswise to give comparable subsamples for the assay of total and dehydroascorbic acid. In the case of the cooked carrots, ascorbic acid subsamples were prepared as for the raw. The remainder of the cooked sample was chopped thoroughly with a knife and mixed before aliquots were taken for the other subsamples.

Subsampling for ascorbic acid assays was completed within 15 min. of the time the samples were

TABLE 1

Vitamin content of raw carrots, those cooked by large-scale methods, and percentage retentions of vitamins in the cooked carrots

DESCRIPTION OF SAMPLES	BATCH WEIGHT	DRY SOLIDS	pH	VITAMIN CONTENT*						PERCENTAGE VITAMIN RETENTION**					
				Carotene content	Ascorbic acid		Niacin	Thiamin	Riboflavin	Carotene retention	Ascorbic acid		Niacin	Thiamin	Riboflavin
					Total	Reduced					Total	Reduced			
	units	%			mg./100 gm.					%	%	%	%	%	
<i>Carrots, miscellaneous varieties (Study I)</i>															
Raw, unpeeled...	120.0	13.0	6.2	11.0	5.8	5.1	.95	.069	.052	127	127	130	149	140	140
		12.3-14.1	5.7-6.6	9.9-12.5	5.1-6.8	4.1-6.3	.69-1.46	.057-.083	.041-.070						
Raw, peeled.....	100.0	12.3	6.3	10.5	5.5	4.8	.71	.060	.046	100	100	100	100	100	100
Boiled.....	93.7	9.4	5.9	10.6	1.7	1.2	.45	.032	.033	96	27	21	53	50	66
Boiled, held 1 hr.	99.9	9.0	5.9	10.2	1.4	.7	.44	.031	.031	97	25	14	54	52	68
Boiling water....	113.6	4.8	5.8	.1 ^a	.8	—	.37	.023	.023	1	16	—	51	42	56
Steamed.....	89.4 ^b	12.3 ^b	5.9 ^b	—	3.6 ^b	2.9 ^b	.62 ^b	.050 ^b	.045 ^b	—	62	56	84	82	92
Steamed, held 1 hr.....	90.4 ^b	12.9 ^b	5.8 ^b	—	3.4 ^b	2.0 ^b	.62 ^b	.047 ^b	.043 ^b	—	60	40	88	78	89
<i>Carrots, Chantenay coreless (Study II)</i>															
Raw, unpeeled...	100.0	12.5	6.1	8.4	6.3 ^c	5.7 ^c	.64	.066	.062	100	100	100	100	100	100
		12.0-13.0	6.0-6.3	7.4-9.6	5.8-6.6	5.1-6.1	.57-.70	.063-.069	.054-.068						
Boiled.....	91.9	9.5	6.0	8.7	2.8 ^c	2.2 ^c	.40	.044	.047	95	42	35	57	56	70
Boiled, held 1 hr..	95.4	9.3	6.0	8.4	2.4 ^c	1.2 ^c	.38	.040	.045	95	36	21	57	58	70
Boiling water....	81.7	5.0 ^c	5.8 ^c	0.1 ^d	1.8 ^c	—	.33 ^c	.030 ^c	.031	1	27	—	44	38	42
Steamed.....	90.7	12.6	6.1	8.7 ^d	4.4 ^c	3.8 ^c	.62	.061	.062	93	63	62	88	84	92
Steamed, held 1 hr.....	91.0	12.6	6.0	8.7 ^d	3.8 ^c	2.4 ^c	.60	.062	.063	93	55	38	86	85	92

* Values are averages of results from a number of replicate batches—usually 10-14. Averages based on less than 10 replicates are indicated as follows: a, 6 replicates; b, 4 replicates; c, 9 replicates; d, single samples composited of aliquots from the subsamples of various runs; e, 8 replicates.

** Per cent retention in the stored carrots (Study I) was calculated on the basis of the raw peeled as 100; in the case of the fresh carrots (Study II), the raw unpeeled was used as 100. The percentage retention values presented are averages of percentage retentions calculated individually from results for each batch.

received in the laboratory. Subsamples of carrots for the determination of *total ascorbic acid* were made by slurring 60 gm. of carrot and 180 ml. of 5 per cent metaphosphoric acid. For the subsample of boiling water, 150 ml. of the water and 50 ml. of 20 per cent metaphosphoric acid were used. Sixty gm. of carrot and 180 ml. of 5 per cent metaphosphoric acid containing 1 per cent thiourea were used in preparation of the *dehydroascorbic acid* subsamples. Ascorbic acid assays were made within 24 hr. after preparation.

Subsamples for the determination of *niacin*, *thiamin*, and *riboflavin* were made by slurring 150 gm. carrot with 300 ml. 0.1 N H₂SO₄. For the subsamples of boiling water, 270 ml. of the water and 30 ml. of 1 N H₂SO₄ were used. A small amount of chloroform was added to the vitamin B complex subsamples. Composite subsamples for the determination of *pantothenic acid* and *biotin* were prepared for each stage of preparation by pooling 30 gm. of slurry from each of the 10 replicate vitamin B complex subsamples for that stage.

Subsamples of raw and cooked carrots for *carotene* analysis contained 100 gm. of carrot slurried with 400 ml. of 3 per cent KOH in 32 per cent ethanol. These preparations were of such a consistency that representative aliquots for assay could be taken with a calibrated inverted pipette. Subsamples of boiling water contained 150 ml. of the water and 150 ml. of 3 per cent KOH in 32 per cent ethanol.

Subsamples for the determination of percentage *dry solids* were made by slurring 75 gm. carrot with 150 ml. distilled water. The boiling water was not diluted. *Hydrogen ion concentration* was determined on portions of the dry solids subsamples.

RESULTS

Data on vitamin content, dry solids and hydrogen ion concentration of carrots at all stages of preparation in each of the first two studies are summarized in Tables 1 and 2. For the raw, unpeeled carrots a range as well as the average is given. Percentages of vitamin retention in the carrots at the different stages of preparation also are presented in Tables 1 and 2. These percentages are the averages of the percentage retentions calculated for individual batches, (27). Since in Study I carrots were peeled before cooking, the retention percentage in that study was calculated on the basis of the raw peeled carrots as 100. In Study II the carrots were cooked without peeling, and raw, unpeeled was used as 100.

Differences between percentage values for the stages and methods of preparation were calculated (Table 3) to determine the relative effects of peeling, boiling, steaming and holding. The significance of each difference was assessed by comparison with the least significant difference (95 per cent) calculated according to Student's *t* method (27).

The *mechanical peeling* of carrots brought about significant decreases in concentration of carotene, total and dehydroascorbic acid, niacin, thiamin, and riboflavin. On the basis of 100 per cent for the unpeeled, the percentage concentration in the peeled was: for carotene, 95.5 per cent; total ascorbic acid, 94.8 per cent; reduced ascorbic, 94.1 per cent; niacin, 74.7 per cent; thiamin, 86.9 per cent; and riboflavin, 88.5 per cent. Niacin, thiamin and riboflavin are apparently more highly concentrated in the portion removed by peeling. Decrease in weight from peeling the stored carrots (Study I) was 16.7 lb. per 100 lb.

Boiling resulted in highly significant losses of ascorbic acid, niacin, thiamin and riboflavin. For the two studies the losses were as follows: total ascorbic

TABLE 2

The biotin and pantothenic acid content and percentage retention of Chantenay coreless carrots, raw and cooked by large-scale methods

DESCRIPTION OF SAMPLES	VITAMIN CONTENT*		VITAMIN RETENTION	
	Panto- thenic Acid	Biotin	Panto- thenic Acid	Biotin
	mg./100 gm.	mg./100 gm.	%	%
Raw, unpeeled.....	.22	.0018	100	100
Boiled.....	.13	.0016	54	82
Boiled, held 1 hr.....	.15	.0016	65	85
Boiling water.....	.11	.00065	41	29
Steamed.....	.26	.0019	107	96
Steamed, held 1 hr.....	.20	.0020	83	101

* Results are for samples composited of aliquots from the single subsamples in successive sets of samples.

acid, 73 and 58 per cent; reduced ascorbic acid, 79 and 65 per cent; niacin, 47 and 43 per cent; thiamin, 50 and 44 per cent; and riboflavin, 34 and 30 per cent. Loss² of pantothenic acid was 46 per cent and of biotin 18 per cent (Study II). Carotene losses were small in both studies and only one loss was significant, that of 5 per cent in Study II.

For the first two studies, the water in which the carrots were boiled contained respectively: 16 and 27 per cent of the total ascorbic acid, 51 and 44 per cent of the niacin, 42 and 38 per cent of the thiamin, and 56 and 42 per cent of the riboflavin present in the raw carrots. The boiling water also contained 41 per cent of the pantothenic acid and 29 per cent of the biotin present in the raw carrots. It is apparent, therefore, that vitamin losses in the boiling of carrots are due largely to extraction by the cooking water.

Steaming also resulted in highly significant losses of total and reduced ascorbic acid. For the first two studies the losses were 38 and 37 per cent for total ascorbic acid and 44 and 38 per cent for reduced ascorbic acid. Losses of niacin and thiamin were significant in both studies but not as great as those of

ascorbic acid. The losses were 16 and 12 per cent for niacin and 18 and 16 per cent for thiamin. Losses of riboflavin were small and significant only in Study II—8 per cent. Pantothenic acid showed a gain of 7 per cent; biotin a loss of 4 per cent and carotene a loss of 7 per cent.²

A comparison of the percentage retentions for boiled carrots with those for steamed carrots shows that the steamed carrots retained a much higher percentage of all vitamins studied than did the boiled carrots. In the two studies the steamed carrots retained 35 and 21 per cent more total ascorbic acid, 35 and 27 per cent more reduced ascorbic acid, 31 and 31 per cent more niacin, 32 and 28 per cent more thiamin, and 26 and 22 per cent more riboflavin. Retention of pantothenic acid was 53 per cent greater, and of biotin 14 per cent greater in the steamed than in the boiled carrots.³ Retention of

² Significance of these losses could not be determined since the assays for each stage were made on single samples composited of aliquots from the replicate samples.

³ Significance of these losses could not be determined since the assays for each stage were made on single samples composited of aliquots from the replicate samples.

carotene was practically the same for steaming and boiling—93 and 95 per cent.

Holding cooked carrots on the steam table for 1 hr. resulted in significant decreases in ascorbic acid content only. Boiled and steamed carrots lost respectively, 6 and 8 per cent of total ascorbic acid (Study II); losses of reduced ascorbic acid were 7 and 16 per cent in Study I and 14 and 24 per cent in Study II.

In carrots cooked or cooked and held, dehydroascorbic acid comprises a greater proportion of the total ascorbic acid present than in raw carrots; the percentage losses of reduced ascorbic acid from cooking and holding were always greater therefore than those of total ascorbic acid. In the case of *Chantenay Coreless* carrots cooked and held 1 hr. the actual content of dehydroascorbic acid was greater than in the original raw carrots.

Since the various carotene fractions have different biological values as sources of vitamin A., the carotene from one set of samples of raw and cooked carrots was fractionated into alpha and beta-carotene. The carotene of raw carrots was 22 per cent alpha and 78 per cent beta-carotene. The carotene

TABLE 3

Differences* in per cent vitamin retentions between stages in the large-scale boiling and steaming of carrots, with a test of their significance

DESCRIPTION OF SAMPLES	BATCH WEIGHT DIFF.	CAROTENE		ASCORBIC ACID				NIACIN		THIAMIN		RIBOFLAVIN	
		Diff.	l.s.d.†	Total		Reduced		Diff.	l.s.d.†	Diff.	l.s.d.†	Diff.	l.s.d.†
				Diff.**	l.s.d.†	Diff.	l.s.d.†						
<i>Carrots, miscellaneous varieties (Study I)</i>													
Raw, unpeeled—raw peeled.....	-20.0	-27	12	-27	9	-30	13	-49	10	-40	12	-40	9
Raw, peeled—boiled.....	-6.3	-4	10	-73	5	-79	7	-47	4	-50	5	-34	5
Raw, peeled—boiled plus boiling water.....		-3	—	-57	6	—	—	-4	8	-8	5	22	3
Boiled—boiled, held.....	6.2	1	—	-2	5	-7	6	1	—	2	6	2	—
Raw, peeled—steamed.....	-10.6	—	—	-38	11	-44	13	-16	15	-18	6	-8	16
Steamed—steamed, held.....	1.0	—	—	-2	—	-16	13	4	—	-4	9	-3	—
Steamed—boiled.....	—	—	—	-35	9	-35	13	-31	7	-32	8	-26	11
Steamed, held—Boiled, held.....	—	—	—	-35	10	-26	13	-34	7	-26	9	-21	9
<i>Carrots, Chantenay coreless (Study II)</i>													
Raw—boiled.....	-8.1	-5	4	-58	5	-65	6	-43	2	-44	3	-36	6
Raw—boiled plus boiling water.....	—	-4	—	-31	7	—	—	1	3	-6	3	12	5
Boiled—boiled, held.....	3.5	0	—	-6	4	-14	3	0	2	2	3	0	3
Raw—steamed.....	-9.3	-7	—	-37	7	-38	10	-12	3	-16	2	-8	3
Steamed—steamed, held.....	.3	0	—	-8	5	-24	7	-2	5	1	2	0	3
Steamed—boiled.....	—	—	—	-21	4	-27	6	-31	4	-28	3	-22	4
Steamed, held—boiled, held.....	—	—	—	-19	4	-17	5	-21	4	-27	3	-22	4

* Differences were derived from percentage vitamin retention values given in Table 1.

** Differences as great as or greater than the value calculated as the least significant difference are considered as significant. These are *italic*. A negative sign is used when the vitamin content of the first stage is greater than that of the second stage; no sign is used when the reverse is true.

† See text for method by which the least significant difference (95 per cent) is calculated.

of the cooked carrots gave values of 19 to 22 per cent alpha and 81 to 78 per cent beta-carotene, indicating no significant difference in the proportion of these two components in the raw and cooked carrots.

The carotene content of the carrots of the same variety grouped as small, medium and large, did not vary greatly being 7.0, 7.8, 8.3 mg. per 100 gm.

On the other hand, the depth of external coloring was a good index of the carotene content of individual carrots. The two "dark orange" carrots analyzed contained 12.6, and 13.4 mg. of carotene per 100 gm. The two samples of medium color contained 8.0, and 11.0 mg. of carotene per 100 gm., and the pale orange samples 6.8 and 8.0 mg. per 100 gm.

DISCUSSION

The data presented show that carrots cooked by boiling or steaming retain practically all of their original carotene and are thus to be considered at least as valuable as raw carrots as a potential source of vitamin A.

Steaming of carrots results in a markedly greater retention of ascorbic acid, niacin, thiamin and riboflavin than does boiling; the loss of solids is also much less in steamed than in boiled carrots. In addition, steamed carrots have better flavor, brighter color and a more pleasing texture.

Vitamin retentions in the peeled and cooked carrots representing *stored* carrots of several varieties (Study I) and in the unpeeled and cooked *fresh Chantenay Coreless carrots* (Study II) showed close agreement. Significant differences between corresponding values from the studies existed only in the case of thiamin retentions for carrots boiled and held and of riboflavin retentions for the boiled carrots plus the boiling water. From these results it is apparent that vitamin losses due to cooking *peeled stored carrots* are similar to those due to cooking of *unpeeled fresh carrots*.

SUMMARY

A study was carried out for the purpose of determining vitamin content and percentage retention of vitamins in raw carrots and those cooked by large-scale methods. The effect of holding the cooked carrots on a steam table for 1 hr. was studied. Calculations of percentage retention were made on the "batch weight" basis. Differences in retention between the several stages and between the two methods of cooking were statistically examined for significance.

Vitamin content of the raw unpeeled carrots varied moderately in the several miscellaneous varieties but only slightly in the ten batches of the *Chantenay Coreless* variety. Averages of the individual values from the two studies and the range in mg. per 100 gm. were respectively as follows: carotene, 9.7 and 7.4 to 12.5; total ascorbic acid, 6.0 and 5.1 to

6.8; reduced ascorbic acid, 5.3 and 4.1 to 6.3; niacin, .82 and .57 to 1.46; thiamin, .068 and .057 to .083; riboflavin, .056 and .041 to .070; pantothenic acid, .22 (no range); and biotin, .0018 (no range). The concentration of niacin, thiamin, and riboflavin was markedly greater in the portion removed by peeling.

Destruction of ascorbic acid was marked whether carrots were boiled or steamed. The retention of ascorbic acid in steamed carrots was more than double that in boiled carrots. There was additional destruction of ascorbic acid on holding the cooked carrots on the steam table 1 hr. The proportion of dehydroascorbic acid increased during cooking and holding.

Retentions of the B complex vitamins studied (niacin, thiamin, riboflavin, pantothenic acid, and biotin) were correlated with their solubilities in water. Steamed carrots retained 82 per cent or more of these vitamins; boiled carrots, 50 to 80 per cent. Most of the vitamins "lost" in boiling were found to be in the cooking water.

Holding of the cooked carrots on the steam table 1 hr. resulted in little or no loss of the B vitamins or carotene. Retention of carotene in cooked carrots was almost complete—93 to 96 per cent. Unpeeled fresh carrots and peeled stored carrots on cooking showed similar retention of vitamins. The depth of external coloring was a good index of carotene content.

From the standpoint of flavor, aroma, consistency, and appearance as well as retention of the water soluble vitamins and solids, steaming is recommended as superior to boiling for the preparation of carrots. It is also recommended that, when possible, raw carrots be prepared for cooking without peeling.

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