HILGARDIA

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CONTENTS

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EFFECT OF STORAGE ON LEACHING OF MINERALS AND NITROGEN FROM ASPARAGUS AND PEAS DURING COOKING[1]

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INTRODUCTION

FRESH GREEN ASPARAGUS and peas are recognized as highly nutritious vegetables and, when properly cooked, good sources of minerals. California produces more than half of all the asparagus in this country for both canning and marketing, and a large proportion of peas for marketing fresh, for canning, and for quick freezing. Asparagus and peas produced here are stored for various periods before reaching the consumer. Several days usually elapse between the harvest of the vegetables and their consumption. As has been known for some time, asparagus and peas undergo significant changes during storage. Bisson, Jones, and Robbins (*1*)[5] report changes in crude fiber, sugar, dry matter, and weight of asparagus stored at various temperatures for various periods.

Bisson, Jones, and Allinger (*2*) report changes in peas stored at 25° C. When the fruit was stored unshelled, there was a rapid translocation of material from pods to peas, as indicated by the increasing weight of the

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[5] Italic numbers in parentheses refer to "Literature Cited," at the end of this paper.

dry material. These authors report also that the elements nitrogen, carbon, phosphorus, and magnesium were translocated in determinable amounts to the peas.

The experiments here reported were begun primarily to determine the influence of different storage periods upon the amounts of minerals and nitrogen leached from asparagus and peas during cooking and the changes, if any, in crude-fiber content. The minerals studied were magnesium, calcium, phosphorus, copper, and iron. In addition, total nitrogen and crude fiber were determined.

Considerable work has been done on the mineral losses sustained when vegetables are cooked (*3, 4, 5, 6*). But hitherto, most of the work reported on vegetable cookery has been done on typical market vegetables of uncertain variety and source. As investigators have shown (*7, 8, 9, 10, 11, 12, 13, 14, 15*), the quality of asparagus and peas is influenced by cultural practices, fertilizer treatment, the nature of the soil, seasonal conditions, the stage of development at harvesting, and the methods of handling and storage employed thereafter. In the experiments herein reported, not only the variety but also the cultural practices were controlled, together with the maturity and freshness of the vegetables.

As far as we are aware, no work has been done on storage as affecting the amounts of mineral constituents and nitrogen leached from asparagus and peas of a known variety and source during cooking. Since these vegetables are always eaten cooked, it is important, from the standpoint of human nutrition, to determine the exact mineral losses, if any, during the cooking processes. It is important also from a consumer standpoint to determine the effect of storage on mineral losses sustained in cooking because of the delay that usually occurs between harvest of market vegetables and their consumption.

MATERIAL AND METHODS

Preparation of Asparagus Samples.—The asparagus used in these experiments was Palmetto. All the asparagus was uniformly collected before 6:45 A.M. on April 14, 1936. The work of preparing the samples for storage was carried out in the cold-storage room in order to keep the asparagus as fresh as possible. It took approximately 4 hours.

Samples were composed of 40 spears selected in the field as representative for uniformity of size, height, and cleanliness. Two size grades were used: 3/8 to 1/2 inch and 1/2 to 5/8 inch. (The diameter was measured 3 inches from the tip.) After grading, the spears were bunched and trimmed to a length of 5 1/2 inches. Each bunch was weighed immediately to a tenth of a gram; the weight of each was approximately 400 grams.

After the sample had been weighed, the spears were washed in distilled water to remove sand adhering to their surfaces. The amount of sand thus washed out was saved to determine the amount of correction to be applied to the weight of the fresh asparagus. As the average weight of the sand was less than 0.10 gram, it was considered negligible, and no correction was applied to the original weight. After having been washed, the samples were placed in 1-liter beakers with the butt ends resting in about ⅓ inch of distilled water. This corresponds more or less with commercial practice, for asparagus is packed with the butts resting on moist moss or some other absorbent.

All samples were then taken to an unventilated storage room where the temperature over the 10-day storage period averaged 35 ± 2° F. The storage periods were for 0, 24, 48, 96, 168, and 240 hours. These intervals correspond to time required to transport asparagus to different sections of the country. Six samples chosen at random the first day of the experiment comprised the master sample, which was not cooked. Twelve samples were removed from the storage room at the end of each period. Four of these were not cooked, and eight were cooked.

Preparation of Pea Samples.—Marketable peas, Giant Stride variety, mechanically shelled from Fancy and U. S. No. 1 grades, were used in this experiment. The peas were picked, shelled, and weighed on the same day, May 18, 1936. The shelling and the preparation of samples for storage were carried out in the cold-storage room in order to keep the peas as fresh as possible. After shelling, the peas retained by screens 5, 6, and 7 (from about 22/64 to 28/64 inches in diameter) were thoroughly mixed so as to yield uniform samples. Each sample was weighed to a tenth of a gram; the weight of each was approximately 400 grams. Each was then put in a liter beaker. Fifty-eight samples were used in analyses. All samples were stored uncovered in a storage room for the required time. Moist moss was kept on the floor of the storage room. The average temperature of the storage room was 34 ± 2° F, and the storage periods were the same as for asparagus. Four unstored, uncooked samples comprised the master sample.

The 58 samples were divided among the storage periods and methods of treatment as follows:

Storage period	Number uncooked	Number boiled	Number steamed
0	4	4	4
24	3	3	4
48	3	4	3
96	3	3	3
168	3	3	3
240	2	3	3

Originally it was planned to have as many samples as in the asparagus work, but unfortunately there were only enough peas to make 58 samples of 400 grams and 6 samples of 50 peas each.

The 6 samples of 50 peas each were taken at random, and puncture tests were performed on them to determine changes in toughness of the pericarp, probably associated with changes in the crude fiber. The puncture tests were made on 50 seeds the day the peas were picked and at each storage period thereafter by means of a standard apparatus loaned by the United States Department of Agriculture Bureau of Plant Industry. A reading of one unit on the puncture-test scale corresponds to a spring depression of 10 grams. The needle used was blunt, with a diameter of 0.02 cm and an area of 0.0003 sq. cm.

Methods of Cooking.—The procedure was standardized in an endeavor to reduce experimental errors to a minimum. Two different methods of cookery were used throughout the experiments: steaming and boiling. In cooking, the aim was to make the vegetable look attractive and taste good. Aluminum vessels were selected for boiling and steaming. Distilled water was used: 250 cc for steaming and 2,500 cc for boiling. All cooking was done on 1,000-watt electric hot plates. In every case, the water was first brought to a boil before the vegetable was added.

The samples of asparagus to be cooked were gently washed in distilled water to remove adhering sand, care being taken not to break off the scalelike leaves and spear heads.

In the boiling method the asparagus spears were dropped into the rapidly bubbling water, and the time for the cooking, counted from the instant the water came back to the boiling stage, was 20 minutes.

In the steaming method the asparagus spears were laid in layers across a perforated aluminum disk, and the time was counted as soon as the last spear had been placed. Quadruplicate samples of asparagus of each storage period were cooked by each method.

The samples of peas were emptied directly into the cooking vessel from the liter beaker in which they were stored.

Drying of Samples and Evaporation of Extract.—At the close of the cooking period, the samples of asparagus were carefully lifted from the cooking water and from the aluminum disk, drained for 1 minute, and placed on trays. The water was then filtered to remove the small particles of asparagus broken off from the spears during cooking and the sand that had lodged underneath the scalelike leaves and in the spear heads. The cooking water from each sample was evaporated, and the residue partially dried over a water bath. The partially dried residues were then transferred to an electric oven and dried for approximately 3 days at

149° F, or until the variation of two consecutive weighings was not greater than 0.05 gram. They were then stored for later analysis.

The cooked and uncooked samples of asparagus were placed crosswise on wire trays especially made for this experiment and were dried in a homemade drier for 2 days at about 149° F. A vacuum motor, circulating the hot air through the drier, enabled the samples to dry as uniformly as possible. The partially dried samples were then transferred to an electric oven, and the drying was continued at the same temperature until two consecutive weighings agreed within 0.20 gram. The dried samples were then broken up by hand and were ground in an iron mill so that they would pass through a 40-mesh screen, except the master samples, which were ground by hand in a porcelain mortar. The ground samples were redried at 167° F to constant weight, after which they were placed in bottles, sealed airtight with paraffin, and stored for later analysis.

The drying of the pea samples, the evaporation of extracts, and the grinding of the dried material were the same as that described for the asparagus samples, except for slight differences in handling because of the difference in type of vegetable.

Analytical Methods.—The ground samples were ashed and made into solution with dilute nitric acid.

The dried cooking-water residue of each cooked sample was dissolved by adding 5 cc of sodium citrate (1 cc equivalent to 5 mg of sodium) and enough hot water to make a uniform solution. This solution was then evaporated to dryness over a steam bath in the electric muffle. Next, the ash was dissolved in dilute nitric acid, evaporated to dryness, and baked in an electric oven for 2 hours at 230° F to render the silica insoluble. The dried residue was dissolved with 10 cc of 6*N* nitric acid and 20 cc of water. The solution was filtered into a 100-cc volumetric flask, and volume made to mark. A 10-cc aliquot was removed for the phosphorus determination. The remainder was used for determining calcium, magnesium, copper, and iron.

The procedure outlined in the official methods of analysis (*16*) was used in determining calcium and magnesium.

Phosphorus was determined essentially according to the official methods (*16*), with this modification: The phosphorus was precipitated as ammonium phosphomolybdate and digested for 30 minutes at a temperature of 113° to 122° F. The precipitate was then filtered on an asbestos mat, washed with boiled water, dissolved in excess standard sodium hydroxide, and boiled for 30 minutes. After cooling, the excess alkali was titrated with standard hydrochloric acid, phenolphthalein indicator being used. This modification gives a sharper end point in the final titration.

Copper and iron were determined from the filtrate after calcium and magnesium had been removed. The citrates and oxalates, which interfere with the determination of iron, were decomposed before the iron and copper determinations were made. Iron was determined colorimetrically by the potassium thiocyanate method (*16*). Elvehjem and Lindlow's (*17*) method was used in determining copper.

Total nitrogen was determined according to the Kjeldahl, Gunning, Arnold method (*16*), except that selenium was used to hasten the digestion process.

The method used for determining crude fiber was that given in the official method of analysis (*16*).

RESULTS WITH ASPARAGUS

Edible Quality of Steamed and Boiled Asparagus.—One of the most important aims in cooking a vegetable is to prepare an appetizing product of highest edible quality. Provided the harvesting is done at the proper time and the product stored at a suitable temperature, the most important factor influencing edible quality is the method of cooking. Color, flavor, and palatability influence edible quality. Unless a vegetable looks appetizing and tastes good, it is not readily eaten. In the preliminary tests, eight persons carefully compared steamed and boiled asparagus with respect to color, flavor, and palatability.

The color was altered during both processes of cooking. The bright green of the fresh material was changed to a darker green. When the cooked products were allowed to stand in air, the tips became much darker, probably because tannins and related substances were oxidized. No color differences could be distinguished between the steamed and the boiled product.

A pronounced characteristic asparagus flavor was common to both lots. The tips were mild with nutlike or meatlike flavor. There were no differences in sweetness. When cooked too long, asparagus develops an astringency or bitterness; but no such flavor could be detected in either the boiled or the steamed product. The spears in both lots were tender and made an agreeable food throughout their entire length. Although no differences in color, flavor, and palatability were noted between steamed and boiled asparagus, differences in mineral content were found when the respective products were analyzed.

Composition of Asparagus Used in This Study and Uniformity of Samples.—The partial composition of the master sample for the constituents studied in this experiment was as follows:

Constituent	Milligrams in 400 grams of fresh asparagus
Copper	0.76
Iron	3.60
Calcium	61.00
Magnesium	84.55
Phosphorus	326
Nitrogen	2,050
Crude fiber	2,810

In order to collate results, it was important to know whether or not the samples were uniform. Even though they had been selected carefully as to size, length, and color of spear, their uniformity could be established only by chemical analyses. Phosphorus was selected as the reference element. If the samples were uniform, then the amount of phosphorus leached during cooking plus the amount remaining in the residue should

TABLE 1

Uniformity of Asparagus Samples, Expressed as Total Phosphorus
(Storage temperature 35° F)

Storage period	Total phosphorus					
	Master sample		Boiled asparagus (residue+extract*)		Steamed asparagus (residue+extract*)	
	Mean†	s‡	Mean†	s‡	Mean†	s‡
hours	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
0	326	4	329	12	349	13
24	....	..	328	6	320	12
48	....	..	330	9	320	10
96	....	..	337	5	332	8
168	....	..	324	7	325	8
240	....	..	326	7	322	7

* Cooking waters from boiling and steaming.
† The master sample consisted of six bunches of forty spears each; four such bunches were used for each cooking method at each storage interval.
‡ s=Estimated standard deviation $=\sqrt{\frac{\Sigma d^2}{n-1}}$.

equal the amount of phosphorus in the master sample. All samples of the steamed and boiled asparagus and their respective extracts (the cooking waters from steaming and boiling) were analyzed for phosphorus. The results are given in table 1. At each storage period, the total weight of phosphorus of both boiled and steamed asparagus was within about 2 per cent of that found in the master sample. Such consistent results show that the samples were uniform. The total nitrogen and crude-fiber analyses (discussed later in the paper) of the uncooked samples at the various storage periods further substantiate this uniformity.

Effect of Storage on Minerals Leached from Asparagus during Cooking.—The amounts of total solids in the asparagus extracts are represented graphically in figure 1. The extracts from the boiled asparagus contained approximately four times as much solid material as the extracts from the steamed. With both methods of cooking, the total solids

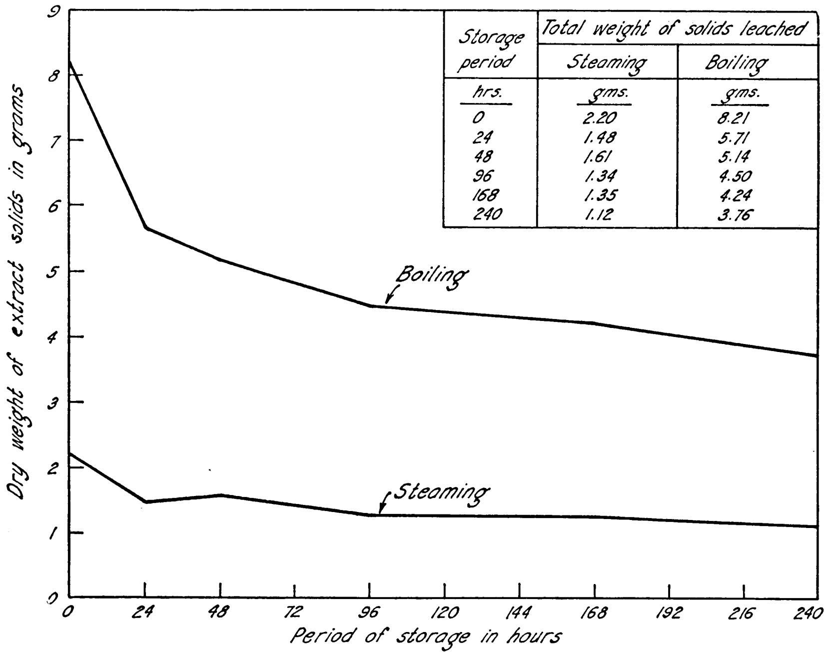

Fig. 1.—Total solids leached from asparagus spears during cooking (on 400-gram fresh basis).

in the extracts were greater when cooked immediately after trimming than when cooked after storage. The leaching of total solids decreased rapidly during the first 48 hours. After that time, the decrease was gradual.

Total solids of each extract for each storage period were analyzed for magnesium, calcium, phosphorus, iron, and copper. The results of the analyses for the first three of these elements appear in table 2. At each storage period, more magnesium, more calcium, and more phosphorus were leached out during boiling than during steaming. Steamed asparagus, therefore, contains more of these minerals than boiled asparagus. Judging from the wide difference in the amount of each mineral leached during boiling and steaming, the rate of leaching is dependent not only on the particular element but also on the amount of water coming in contact with and passing through the vegetable.

TABLE 2

MINERALS LEACHED FROM ASPARAGUS DURING TWO DIFFERENT METHODS OF COOKING, ON 400-GRAM FRESH-WEIGHT BASIS
(Storage temperature 35° F)

Storage period	Magnesium*				Calcium†				Phosphorus‡			
	Boiling		Steaming		Boiling		Steaming		Boiling		Steaming	
	Mean	s¶	Mean	s	Mean	s	Mean	s	Mean	s	Mean	s
hours	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
0	32.84	1.72	10.06	2.32	17.20	1.70	4.76	0.89	67.59	2.84	18.43	3.40
24	26.71	2.31	7.04	0.91	13.45	1.25	3.91	0.53	50.20	3.21	13.23	1.51
48	23.38	0.92	6.75	0.94	12.00	0.76	3.99	0.38	43.44	1.27	14.10	1.48
96	21.46	2.34	6.79	0.91	11.05	0.31	3.78	0.20	41.01	2.80	13.15	0.86
168	20.41	0.02	7.63	0.69	10.30	0.75	3.50	0.65	39.27	2.00	13.58	1.09
240	19.22	0.42	6.18	0.58	7.94	1.40	3.26	0.24	40.16	0.47	12.25	1.37

* Master sample, $M=84.55$, $s=3.27$.
† Master sample, $M=61.00$, $s=7.02$.
‡ Master sample, $M=326.10$, $s=4.18$.
¶ s=Estimated standard deviation.

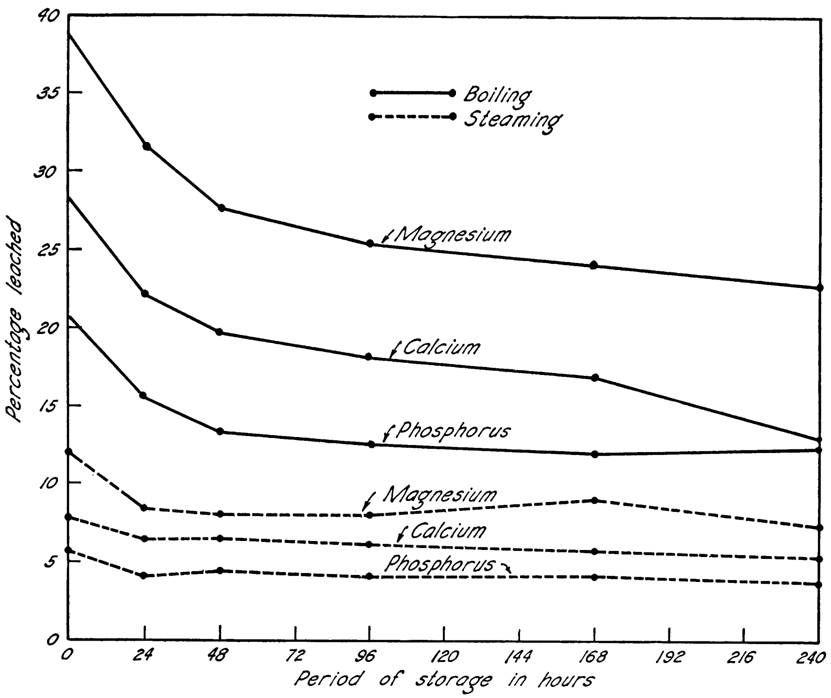

Fig. 2.—Percentage of minerals leached from asparagus during two different methods of cooking.

The percentages of magnesium, calcium, and phosphorus leached from boiled and from steamed asparagus are plotted in figure 2. With the boiled asparagus, the amount of each mineral leached decreased rapidly during the first 48 hours of storage. After that time, the rate of decrease in leaching was gradual. With the steamed asparagus, the rate of decrease in leaching was most rapid during the first 24 hours and then practically constant. This high initial decrease probably results from a rapid transference of the elements into less-soluble organic forms. Bisson

TABLE 3

TOTAL NITROGEN IN UNCOOKED AND COOKED ASPARAGUS AT DIFFERENT STORAGE PERIODS, ON 400-GRAM FRESH-WEIGHT BASIS

(Storage temperature 35° F)

Storage period	Uncooked samples		Cooked samples			
			Boiled		Steamed	
	Mean	s*	Mean	s*	Mean	s*
hours	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*
0	2.05	0.03	1.76	0.05	2.08	0.05
24	2.01	0.02	1.84	0.02	1.95	0.05
48	2.05	0.10	1.89	0.06	2.05	0.01
96	2.10	0.09	1.98	0.06	2.08	0.03
168	2.10	0.06	1.96	0.05	2.10	0.06
240	2.04	0.03	1.90	0.07	2.04	0.06

* *s*=Estimated standard deviation.

and his co-workers (*1*) report that the length of asparagus spears increases rapidly during the first 48 hours of storage even at a temperature of 33° F, but that its subsequent increase is slight.

During both methods of cooking, a greater percentage of magnesium is leached than of either calcium or phosphorus. Magnesium compounds are generally more soluble than calcium compounds. Phosphorus was pobably held by the protein, which is readily coagulated by heat, and its leaching thus inhibited.

Copper and iron were found in the extracts in such small amounts that the results were not sufficiently reliable to include. These analyses do show, however, that the amounts of copper and iron leached were practically the same—0.10 mg to 0.20 mg—for both boiled and steamed asparagus.

Effect of Storage on the Nitrogen and Crude-Fiber Content of Asparagus.—Although the master sample was tested for nitrates, none were detected. The observation of Culpepper and Moon (*18*) that nitrates are absent in all young shoots and are present only in small amounts in shoots

72 inches long, explains this finding; all the asparagus shoots used in this study had been cut to a length of 5½ inches.

The results of the analyses for total nitrogen in the uncooked and cooked asparagus at different storage periods are presented in table 3. The total nitrogen of the uncooked samples at the various storage periods did not vary appreciably. Less nitrogen was found in the boiled asparagus than in the steamed. Obviously, some nitrogen was leached out. Amino nitrogen, which, according to Culpepper and Moon (*18*), is fairly equally distributed throughout the length of the spear, is soluble and

TABLE 4

CRUDE-FIBER CONTENT OF UNCOOKED ASPARAGUS, ON 400-GRAM FRESH-WEIGHT BASIS

Storage period	Crude-fiber content		Storage period	Crude-fiber content	
	Mean	s*		Mean	s*
hours	*grams*	*grams*	*hours*	*grams*	*grams*
0	2.81	0.07	96	2.86	0.06
24	2.78	0.02	168	2.83	0.07
48	2.80	0.09	240	2.80	0.08

* *s*=Estimated standard deviation.

was evidently leached out during the boiling. Little if any amino nitrogen was leached out from the steamed asparagus; the total nitrogen content was practically identical with that of the uncooked product.

The crude-fiber determinations are presented in table 4. The crude-fiber content of the uncooked asparagus at various storage periods did not vary significantly. The master sample was found to contain only 0.70 per cent crude fiber—a figure much lower than that reported by Bisson and his co-workers (*1*) for the same variety (Palmetto) grown under similar conditions. Their samples, however, were composed of shoots 8½ inches in length, whereas those used in this experiment were only 5½ inches. The spears used in this study, furthermore, were green from the tip to the basal segment; and in the preliminary cookery tests, shoots 5½ inches long made an agreeable food product throughout their entire length. Culpepper and Moon (*18*) report that in stalks 8 inches long, 1 to 2 inches of the basal segment is distinctly too tough and fibrous to be highly palatable and that an additional 1 or 2 inches contains fiber in noticeable amounts but not in sufficient abundance to make the material unsuitable for eating.

RESULTS WITH PEAS

Composition of Peas Used in This Study and Uniformity of Samples.—The partial composition of the master sample for constituents studied in this experiment was as follows:

Constituent	Milligrams in 400 grams of fresh peas
Magnesium	118.20
Calcium	35.45
Phosphorus	517.40
Iron	6.71
Copper	3.53
Nitrogen	4,380.00
Crude fiber	6,280.00

To show the effect of storage on the leaching of minerals, each sample cooked must contain as much of a given constituent as any other sample; otherwise, the picture will be distorted. Even though sampling is done carefully to insure uniformity, a chemical analysis is necessary to establish this point. As with asparagus, phosphorus was chosen as the reference element. If the samples are uniform, then the phosphorus leached out during cooking plus the amount remaining in the peas should be constant or equal to the amount found in the master sample. The phosphorus found in the extracts (cooking water) has been added to the amount remaining in the cooked peas (residues), with the results shown in table 5.

TABLE 5

UNIFORMITY OF PEA SAMPLES, EXPRESSED AS TOTAL PHOSPHORUS
(Storage temperature 34° F)

Storage period	Total phosphorus					
	Master sample		Boiled peas (residue+extract*)		Steamed peas (residue+extract)	
	Mean	s†	Mean	s	Mean	s
hours	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
0	517	12	494	6	513	10
24	....	..	507	10	516	15
48	....	..	494	10	512	9
96	....	..	493	18	525	14
168	....	..	494	15	501	8
240	....	..	493	13	505	2

* Cooking waters from boiling and steaming.
† s=Estimated standard deviation.

The results indicate that we were successful in obtaining uniform samples: the total phosphorus was within an average of 3 per cent of the total phosphorus found in the master sample. Further evidence indicating the uniformity of samples is that of the total nitrogen found in the uncooked samples. A glance at table 7 (p. 309) will prove this point, even though the value of the total nitrogen for the initial storage period is a little higher than the others.

Effect of Storage on Minerals Leached from Peas during Cooking.—The average weights of total solids leached at each storage period during both methods of cooking are graphically shown in figure 3. Approxi-

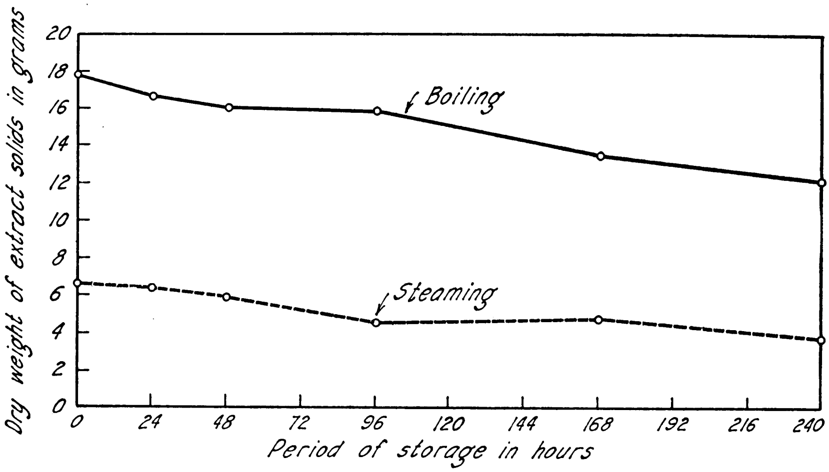

Fig. 3.—Total solids leached from peas during cooking (on 400-gram fresh basis).

mately three times as much solid material was leached from boiled peas as from steamed—a somewhat smaller difference than in asparagus. The amount of total solids leached by either method of cooking was between two and three times as much for peas as for asparagus.

In contrast with asparagus, in which the amount of leaching decreased rapidly during the first 48 hours of storage, the amount of solids leached from peas decreased gradually at each successive storage period. The rate of decrease of solids is practically the same for both methods of cooking; evidently storage affects the solids to the same degree for both.

The calcium, magnesium, and phosphorus leached by both cooking methods are recorded in milligrams per sample in table 6 and shown by percentage leached in figure 4. In every case, except for calcium at the 24-hour and the 48-hour storage period, a higher percentage of the mineral constituents was leached by boiling than by steaming.

A higher percentage of magnesium was leached out than of phosphorus or calcium, both by boiling and by steaming. In contrast with asparagus, where the order of decreasing percentage leached with both

TABLE 6

MINERALS LEACHED FROM PEAS DURING TWO DIFFERENT METHODS OF COOKING, ON 400-GRAM FRESH-WEIGHT BASIS

(Storage temperature 34° F)

Storage period	Magnesium*				Calcium†				Phosphorus‡			
	Boiling		Steaming		Boiling		Steaming		Boiling		Steaming	
	Mean	s¶	Mean	s	Mean	s	Mean	s	Mean	s	Mean	s
hours	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
0	39.21	1.91	18.23	0.48	4.97	0.51	4.32	0.25	112.60	7.54	47.90	0.90
24	37.95	2.90	20.07	1.37	4.12	0.45	4.17	0.28	111.50	9.12	48.51	3.73
48	36.88	1.24	19.04	1.52	3.87	0.31	4.10	0.12	109.90	8.41	46.25	3.28
96	38.52	2.89	15.93	0.93	4.64	0.51	4.35	0.41	111.60	7.50	38.64	1.64
168	36.07	1.78	16.87	0.38	4.74	0.64	3.81	0.44	102.60	6.32	41.20	2.33
240	35.33	2.14	14.18	0.50	4.18	0.38	3.50	0.61	98.50	5.72	34.19	2.02

* Master sample, M=118.2 mg, s=5.69 mg.
† Master sample, M=35.45 mg, s=1.21 mg.
‡ Master sample, M=517.4 mg, s=12.30 mg.
¶ s=Estimated standard deviation.

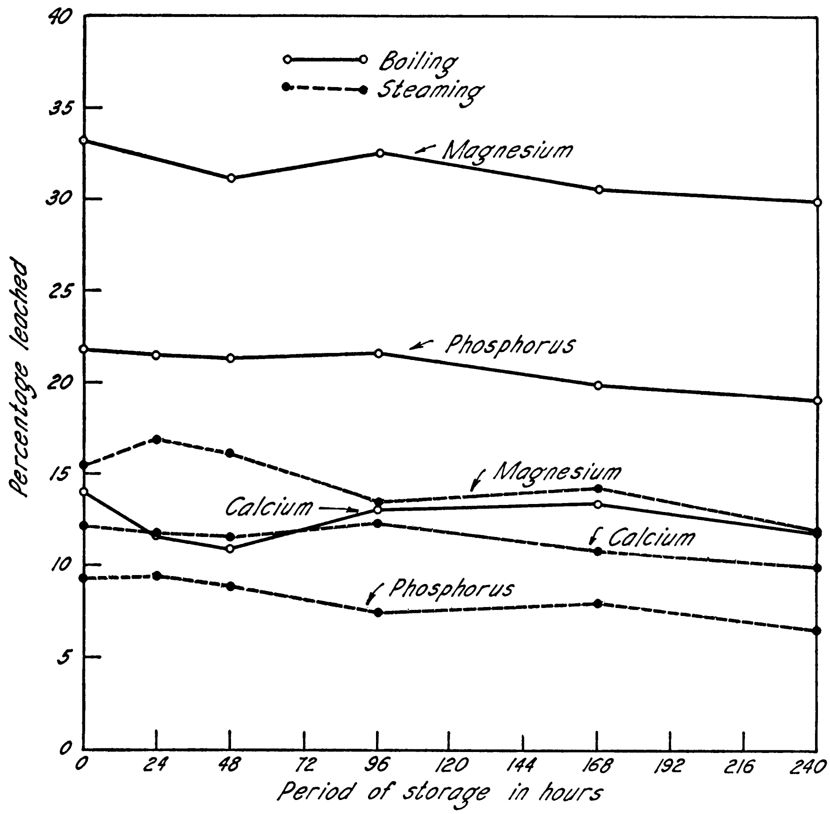

Fig. 4.—Percentage of minerals leached from peas during two different methods of cooking.

methods of cooking was magnesium, calcium, and phosphorus, that with peas was magnesium, phosphorus, and calcium.

Storage slightly decreased the percentages of magnesium, phosphorus, and calcium leached, but the differences with calcium are not significant.

Approximately twice as much magnesium and phosphorus were leached out by boiling as by steaming. Calcium, however, was leached only slightly more by the boiling. At the 24-hour and 48-hour periods, in fact, the percentages of calcium leached was greater for the steam-cooked

TABLE 7

TOTAL NITROGEN IN UNCOOKED AND COOKED PEAS AT DIFFERENT PERIODS, ON 400-GRAM FRESH-WEIGHT BASIS

(Storage temperature 34° F)

Storage period	Uncooked samples		Cooked samples			
			Boiled		Steamed	
	Mean	s*	Mean	s*	Mean	s*
hours	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*
0	4 38	0.09	3.45	0.16	3.84	0.09
24	4.12	0.23	3.52	0.27	3.94	0.19
48	4.08	0.05	3.49	0.16	3.93	0.14
96	4.18	0.08	3.47	0.23	4.11	0.11
168	4.24	0.10	3.56	0.23	3.85	0.09
240	4.10	0.06	3.56	0.21	3.95	0.07

* s = Estimated standard deviation.

peas. The greater irregularity of the calcium curve for boiled peas is no doubt due to the combined effect of slight nonuniformity of samples and the greater error involved in determining calcium, since only between 4 and 5 mg of this element is present in the extract.

As for iron and copper in the extracts, the amounts found were so small that the results were not sufficiently reliable to include in detail. There was a difference, however, in the amounts of these constituents leached by the two cooking methods. The amount of iron leached during boiling varied from 0.8 to 1.7 mg, whereas, that leached during steaming varied between 0.16 and 0.50 mg. The amount of copper leached during boiling was from 0.4 to 0.7 mg; that leached during steaming varied between 0.07 and 0.20 mg. Leaching of these elements was higher early in the storage period.

Effect of Storage on the Nitrogen Content of Peas.—The dried, cooked, and uncooked peas were analyzed for total nitrogen, with results shown in table 7. The nitrogen content of the uncooked peas did not vary appreciably throughout the storage period. Except for the master sample, which constitutes the initial point, the curve for the uncooked peas would form practically a straight line. More nitrogen was found in the uncooked peas than in the cooked, and more in the steamed peas than in the boiled. Obviously, more nitrogenous material was leached out during the boiling than during the steaming; and more with either method of cooking than with asparagus.

Tests were made for nitrate in the master sample, but none was found.

A test was also made to determine whether or not nitrogen is lost during the drying of peas. Some peas were bought from the market and

TABLE 8

CRUDE-FIBER CONTENT AND PUNCTURE TEST ON UNCOOKED PEAS

(Storage temperature 34° F)

Storage period	Crude-fiber content per 400 grams of peas		Puncture tests,* mean	Storage period	Crude-fiber content per 400 grams of peas		Puncture tests,* mean
	Mean	s†			Mean	s†	
hours	*grams*	*grams*	*units*‡	*hours*	*grams*	*grams*	*units*‡
0	6.28	0.50	4.94	96	7.29	0.12	11.08
24	7.18	0.23	7.08	168	7.63	0.29	12.10
48	7.29	0.26	7.62	240	7.40	0.06	13.94

* F=25.53. One per cent point 3.08. Minimum significant difference 1.94 puncture units.
† s=Estimated standard deviation.
‡ See page 310 of text.

cooked. The cooked peas were placed in a large flask and heated over a steam bath. At the same time, air, which had previously been bubbled through concentrated sulfuric acid, was passed through the flask and bubbled again through concentrated sulfuric acid. When the peas had dried for 2 days, this acid solution was then analyzed for ammoniacal nitrogen, and less than 1 mg was found. Since this is nearly within the limit of accuracy of detecting nitrogen, one may safely conclude that little or no nitrogen is lost during drying—especially if the peas are dried at a low temperature, so that no scorching takes place.

With peas more nitrogenous material was leached during either method of cooking than with asparagus.

Effect of Storage on Crude-Fiber Content of Peas.—The crude-fiber content per 400 grams of peas and the mean puncture units for uncooked peas at each storage period are shown in table 8. The crude-fiber content increased with storage, the most rapid increase occurring during the first 24 hours of storage. The difference in mean puncture units between peas fresh from the field (0 hours, 4.94 units) and those stored 24 hours (7.08 units) is 2.14; and between 0 hours and 240 hours, the difference is 9.00 units; both of these differences are statistically significant. Between 96 and 168 hours, on the other hand, the difference is only 1.02 units and is not considered statistically significant. The calculated differences show that peas grow measurably firmer with age and that differences in twelve out of fifteen cases (that is, all the possible combinations that can be made between the six means given in table 8) are statistically significant.

SUMMARY AND CONCLUSIONS

Data presented show the effect of storage at 35° F for various periods of time on the leaching of magnesium, calcium, phosphorus, and nitrogen from asparagus (Palmetto variety) and peas (Giant Stride variety) when boiled and steamed, and on the crude-fiber content.

At each storage period greater amounts of total solids were leached from asparagus and peas during boiling than during steaming. Approximately four times as much solid material—which of course includes sugars, starches, proteinaceous material, as well as salts—was leached from boiled asparagus as from steamed, and approximately three times as much from boiled peas as from steamed. These results are in accord with those of Peterson and Hoppert (*3*), who found that the mineral losses increased when vegetables were boiled; and with those of Talenti and Ragno (*5*), who concluded that steaming is superior to boiling in water because it extracts one-half less organic matter and two-thirds less mineral matter.

With asparagus, approximately four times as much magnesium, calcium, and phosphorus were leached by boiling as by steaming. With peas, approximately twice as much magnesium and phosphorus were leached during boiling as during steaming, but only slightly more calcium.

With asparagus, the order of decreasing percentage leached, both for boiling and for steaming, was magnesium, calcium, and phosphorus; with peas, however, the order was magnesium, phosphorus, and calcium.

The rate of leaching from asparagus during both processes of cooking decreased rapidly during the first 48 hours and then gradually decreased with increase of storage period. With the peas, the rate of leaching gradually decreased throughout the storage period; there was no marked initial decrease. The initial decrease in the case of the asparagus probably results from a rapid transference of the elements into less-soluble organic forms.

More nitrogen was leached from boiled peas and asparagus than from steamed. More nitrogenous material was leached from peas during either method of cooking than from asparagus.

The crude-fiber content of uncooked asparagus at the various storage periods did not vary significantly. Peas, however, grow measurably firmer with storage. The most rapid increase in crude-fiber content occurred during the first 24 hours.

Peas and asparagus harvested and stored under suitable temperature and humidity conditions for more than 48 hours, retain more of their mineral constituents when cooked either by boiling or steaming than when cooked immediately after harvesting. This is an extremely important point; for peas and asparagus, whether marketed fresh, canned, or quick-frozen, are usually held over several hours or even a few days before being processed.

The rate of leaching is dependent not only on the particular element but also on the amount of water coming in contact with and passing through the vegetable. For this reason, steamed peas and asparagus retain more of their constituent elements than boiled.

LITERATURE CITED

[1] BISSON, C. S., H. A. JONES, and W. W. ROBBINS.
1926. Factors influencing the quality of fresh asparagus after it is harvested. California Agr. Exp. Sta. Bul. **410**:1–28. (Out of print.)

[2] BISSON, C. S., H. A. JONES, and H. W. ALLINGER.
1936. Determining changes in stored peas by use of a reference element. Hilgardia **10**(6):143–65.

[3] PETERSON, W. H., and C. A. HOPPERT.
1925. The loss of mineral and other constituents from vegetables by various methods of cooking. Jour. Home Econ. **17**:265.

[4] FLANLEY, M. G., and E. M. JOHNSON.
1932. Iron loss in cooking broccoli. Jour. Home Econ. **24**:821.

[5] TALENTI, M., and A. RAGNO.
1936. [Studies on vegetables, no. 1.] Ann. Chim. Applicata **26**:115–25.

[6] FISHER, G.
1934. Changes in the content and proportions of mineral substances in vegetables with special reference to iodine. Biedermann's Zentbl. A, **4**:484.

[7] JONES, H. A., and W. W. ROBBINS.
1928. The asparagus industry in California. California Agr. Exp. Sta. Bul. **446**: 1–105. (Out of print.)

[8] MORSE, F. W.
1913. Some effects of fertilizers on the growth and composition of asparagus roots. Massachusetts Agr. Exp. Sta. Ann. Rept. **25**:154–67.

[9] TIEDJENS, V. A.
1925. Some physiological aspects of *Asparagus officinalis*. Amer. Soc. Hort. Sci. Proc. **21**:129–40.

[10] WHITE, T. H., and V. R. BOSWELL.
1929. Field and sand culture experiments on fertilizing asparagus. Maryland Agr. Exp. Sta. Bul. **314**:147–61.

[11] WORKING, E. B.
1924. Physical and chemical factors in the growth of asparagus. Arizona Agr. Exp. Sta. Tech. Bul. **5**:87–124.

[12] JODIDI, SAMUEL L., and VICTOR R. BOSWELL.
1934. Chemical composition and yield of the Alaska pea as influenced by certain fertilizers and by the stage of development. Jour. Agr. Research **48**:703–36.

[13] COLEMAN, J. M., and R. W. RUPRECHT.
1935. Effect of fertilizers and soil types on the mineral composition of vegetables. Jour. Nutrition **9**:51–62.

[14] PARKER, M. M., J. B. HESTER, and R. L. CAROLUS.
1933. The effect of soil conditions on the growth and composition of certain vegetable crop plants as influenced by soil reaction. Amer. Soc. Hort. Sci. Proc. **30**:452–57.

[15] JONES, H. A., and C. S. BISSON.
1932. Changes in the composition of the garden pea after harvest. Plant Physiol. **7**:273–83.

[16] Association of Official Agricultural Chemists.
1931. Official and tentative methods of analysis. 3d ed. 593 p. Assoc. Off. Agr. Chem., Washington, D. C.

[17] Elvehjem, C. A., and C. W. Lindlow.
1929. The determination of copper in biological materials. Jour. Biol. Chem. **81**: 435–43.

[18] Culpepper, C. W., and H. H. Moon.
1935. Composition of the developing asparagus shoot in relation to its use as a food product and as material for canning. U. S. Dept. Agr. Tech. Bul. **462**:1–23.