THE EFFECT OF STORAGE AND PROCESSING ON THE ASCORBIC ACID CONTENT OF DIFFERENT VARIETIES OF CABBAGE PEAS AND POTATOES

By

MARGARET I. WARREN

A THESIS PRESENTED TO THE COMMITTEE ON POST-GRADUATE STUDIES OF THE UNIVERSITY OF MANITOBA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE 1946

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In Canada today there is considerable evidence of suboptimal nutrition as shown by dietary surveys carried out in a number of cities across the country. (83) In each study it was found that the ascorbic acid consumed by the family was below the standard requirement, and that it was one of the most extreme deficiencies in a large proportion of the people.

There are two distinctly separate dietary standards used in Canada today. To determine the requirement of a nutrient for an individual, a standard was drawn up by the National Research Council of the United States in 1941, (54) and tentatively accepted by the Canadian Council of Nutrition (58) in 1942. This standard allows a wide margin of safety for each nutrient to insure optimum nutrition for everyone. The daily adult allowances suggested are 75 mgm. for men and 70 mgm. for women. Allowances are given also for children of various ages. The second dietary standard was constructed by the Canadian Council of Nutrition (11) in 1945 for the purpose of planning food supplies for a population. The average requirement for a representative group of people was used to construct the standard, and the suggested daily allowances for ascorbic acid are 50 mgm. for adults and 30 mgm. for children.

Although the nutritional status of the people of Canada may be below the optimum level, extreme malnutrition is practically unknown. (57) In other parts of the world, however, particularly in Europe and India starvation is prevalent. The shortage of food supplies is extremely grave, and it is imperative that the losses in nutrient

value caused by such universal practises as transportation, storage and cooking should be determined and minimized as much as possible. It is also of extreme importance that the food which is produced is of the highest possible nutritional value.

Ascorbic acid, or vitamin C is one of the most unstable of the vitamins. It is water-soluble and destroyed by oxidation in the air, especially in an alkaline solution. The losses caused by storage, cooking and canning of fruits and vegetables may be so large as to impair the usefulness of these foods as sources of the vitamin in question.

Although there are many data on the ascorbic acid content of vegetables grown elsewhere, there is little known concerning the amount in Manitoba vegetables. Therefore it was considered worth while to study Manitoba vegetables along these lines. The three vegetables chosen for this study are cabbage, peas and potatoes, since they are all good sources of ascorbic acid and commonly grown in the province. The purpose of the work is threefold; firstly to determine the ascorbic acid content of several varieties of cabbage, peas and potatoes grown in Manitoba, and to compare these results with those of other workers; secondly, to compare the ascorbic acid content of these vegetables grown at the University of Manitoba with that of vegetables grown in other districts of the province; and thirdly, to determine the effect of maturation, short-term refrigerator storage, long-term root-house storage, cooking, canning and other household practises on the ascorbic acid content of the vegetables.

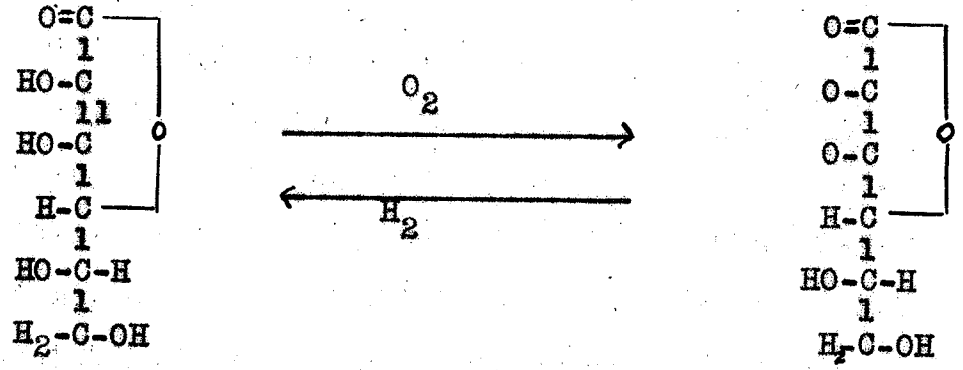
History

Scurvy was well-known in Europe before the introduction of the potato but after that time it was rarely seen on land. (8) It was, however, a familiar disease to sailors who were long away from shore. (66) In 1847 an interesting experiment was carried out by a British surgeon, Lind, (63) for the purpose of finding a cure for scurvy in sailors. Many suggested remedies were tested but only oranges and lemons were found to be effective. In the same year it was suggested by Budd (63) that scurvy was caused by the deficiency of some essential element, but it was not until 1907 that Holst and Frolich (25, 26) proved this prophecy to be true, and showed that scurvy was caused by the deficiency of a specific substance - later called vitamin C.

The constitution of vitamin C was established by the work of a number of investigators. Zilva, (84) in 1924, succeeded in concentrating the antiscorbutic substance to an almost pure state, and using the concentrate established the molecular formula $C_6H_8O_6$. He also noticed its resemblance to hexoses and its instability towards oxygen. In 1920 Drummond (21) suggested that the antiscorbutic substance be called vitamin C - fat-soluble A and water-soluble B having been named already.

While studying the oxidation - reduction system of the adrenal cortex, Szent-Györgyi (67) isolated a strongly reducing substance in lemon juice and cabbage, and also an enzyme which oxidizes hexuronic acid in the presence of oxygen into a reversible oxidation product. Waugh and King (79) identified hexuronic acid as vitamin C when they isolated the latter from lemon juice in 1932. In the next year the dehydro form of the vitamin was pro-

duced by oxidation and isolated by Karrer, Solomon and Schopp. (33) The structural formulae of the two forms were established by Haworth, (22) Hirst, (23) Karrer, Schöpp and Zehender, (34) Micheel and Kraft (44) and Von Euler and Klussmann (14)



(63)

It was suggested by Szent-Gyorgyi and Haworth (69) that the name hexuronic acid be changed to ascorbic acid, since the former is the name of a class of substances rather than an individual compound. The American Medical Association, however, preferred to call it cevitamic acid to prevent therapeutic suggestiveness, but later they accepted the name ascorbic acid because of its more common usage.

The first synthesis of ascorbic acid was accomplished in 1933 by Reichstein, Grussner and Oppenauer (60) using l-xylose as a base. The l-xylose was treated with phenylhydrazine and hydrolysed to l-xylosone. Hydrocyanic acid was then added and it was further hydrolysed to 3-Ketogulanic acid, and finally l-ascorbic acid. Three other synthetic processes have been dev loped, and one which has been used commercially was developed by Reichstein and Grussner using d-glucose as a base.

Methods

The first quantitative determination of vitamin C in food was

made by Holst and Frolich. (26) They found that guinea-pigs on a diet deficient in the vitamin developed a hemorrhagic disease which was similar to scurvy in humans. The amount of the food necessary to prevent scurvy in the animal was used as an index of the vitamin C concentration. The diet consisted of oats and water and therefore was deficient in other factors as well as vitamin C. Cohen and Mendel, (12) and Sherman, La Mer and Campbell (64) made improvements in the diet until it was free from vitamin C but contained all the other essential factors.

There are three general types of biological methods. Sherman, La Mer and Campbell (64) used the growth or preventive method to determine the minimum amount of vitamin C necessary to prevent scurvy. In 1932 a curative method was developed by Birch, Harris and Ray (7) which determines the amount of the vitamin necessary to cure scurvy, and the third method, developed by Hojer, (65) used the histological changes in the teeth of the guinea-pigs as an indication of vitamin C concentration. Biological methods are used today mainly as a check for chemical procedures.

The first color test for vitamin C was developed by Bezsanoff (65) using the Folin-Denis phenol reagent. The dye 2-6 dichlorophenolindophenol was first suggested by Tillmans and Hirsch (70) as being specific for Vitamin C, and in 1933 Bessey and King (6) used this dye in a quantitative test to determine vitamin C in plant and animal tissues. The samples were ground in a mortar and the vitamin extracted with three per cent metaphosphoric acid. It was then centrifuged and the determination carried out by direct titration. In 1938 Bessey (4) modified the dye titration method to use a photoelectric colorimeter. The machine automatically

corrects for extraneous matter, and the subjective reading of the end-point is eliminated.

In 1941 Morell (50) revised Bessey's method to determine ascorbic acid in plant materials. A Waring Blendor was used for extracting and grinding, and the solution was filtered through number twelve Whatman fluted filter paper. To simplify calculations a standard curve was prepared using solutions of pure ascorbic acid. The log of the galvanometer reading was plotted against the amount of ascorbic acid in the sample to form a straight line.

In 1942 Loeffler and Ponting (41) modified Morell's method to make it adaptable for the determination of many kinds of fruits and vegetables, fresh, frozen and dehydrated. A solution of one per cent metaphosphoric acid was used in place of the three per cent in order to eliminate the need for buffering. It was found that a one per cent solution, with a ratio of seven volumes of acid to one volume of plant material, yielded a PH low enough to prevent losses during blending and yet sufficiently high to prevent the fading of the dye.

Dichlorophenolindophenol determines reduced ascorbic acid only. When dehydroascorbic acid is present in materials it must be reduced to ascorbic acid before it can be determined by this dye. The most generally used reduction technique is that originated by Tillmans and Hirsch. (70) Hydrogen sulfide was used as the reducing agent and the excess driven off by carbon dioxide or nitrogen. The total ascorbic acid was then determined by 2-6 dichlorophenolindophenol titration. However it has been shown by King (35) that sulfhydryl salts produce a noticeable error,

and a technique has been developed by Roe and Oesterling (62) to determine ascorbic acid directly in plants by using the dye 2-4 dinitrophenylhydrazine. This is a modification of the method of Roe and Keuther (61) to determine total ascorbic acid in the blood. The extracting solution was five per cent metaphosphoric acid and one per cent thiourea. The latter stabilizes ascorbic acid and prevents its oxidation to the dehydro form in the presence of the dye.

Certain types of foods, such as green walnuts, (81) and dehydrated (44) and cooked (75) vegetables were found to contain other dye-reducing substances, which reacted as ascorbic acid when it was being determined. Wokes (75) suggested the name "apparent vitamin C" to include these substances which have no antiscorbutic activity. Two methods to determine "apparent vitamin C" have been suggested. Lugg (42) and Mapson (43, 44) both used fomaldehyde to separate ascorbic acid from reductones. The basis of the method is the fact that at a PH of 2.0 ascorbic acid is rapidly condensed by a solution of eight per cent formaldehyde, while reductones react more slowly. In 1943 Levy (40) found that a twenty per cent solution of hydrochloric acid, when added to a solution of ascorbic acid, completely inhibited the reversible oxidation process and only "apparent vitamin C" reacted with the dye. On dilution with water, ascorbic acid again was oxidized in the presence of the dye, and the difference in the two readings gave the ascorbic acid content of the solution.

Review of Literature

A very wide variation in the ascorbic acid content of cabbage,

peas and potatoes has been reported in literature. The variation is large not only between varieties, but also within varieties of the same vegetable. The range and mean ascorbic acid values of the raw vegetables, as reported in literature, are shown in Table 1. Winter cabbage was found by Gould and Tressler (19) to contain less ascorbic acid than summer cabbage, while Burell, Brown and Ebright (10) reported the opposite fact. The wide range of 48 to 181 mgm. per 100 gm. was reported by both Burell et al. (10) and Maynard and Beeson (46) for thirty and thirty-one strains and varieties respectively. The average ascorbic acid content of the Golden Acre variety was found to be 55 mgm. per 100 gm. by Gould and Tressler (19) and 82.5 mgm. by Burell et al. (10) The values reported for the Danish Ballhead variety by these workers were 30 and 127.0 mgm. respectively. Copenhagen Market and Pennsylvania State Ballhead values were reported by Burell, Brown and Ebright (10) as 71.9 and 106.7 mgm. per 100 gm. respectively. Hollyman, Brodie and Willard (24) found a range of 36 to 92 mgm. per 100 gm. for cabbage purchased on the Toronto retail market.

For eighteen varieties of peas, Mack, Tressler and King (43) reported a variation of 19 to 40 mgm. per 100 gm., and Van Duyne, Bruckhart, Chase and Simpson (76) found a comparative range of 22 to 40 mgm. per 100 gm. for nine varieties. The mean values for Laxton's Progress and Little Marvel varieties were reported by Van Duyne et al. (76) to be 27 and 25 mgm. per 100 gm. respectively. Both Mack et al. (43) and Bessey (4) found that the ascorbic acid content of peas decreased during maturation.

A smaller variation was reported by Esselen, Lyons and Fellers

TABLE I

Vegetable	Reference	Variety	Number of Varieties	Ascorbic Acid Range	Ascorbic Acid Mean
Cabbage	Burell Brown and Ebright (10)	Copenhagen Market	30	48.0-180.9	71.9
		Golden Acre			82.5
		Penn. State Ballhead			106.7
		Danish Ballhead			127.0
	Gould and Tressler (19)	Winter	3	26-30	
		Summer	3	55-56	
		Danish Ballhead			30
		Golden Acre			55
	Hollyman, Brodie and Willard (24)	Ballhead		36-92	58
	Maynard and Beeson (46)		31	48-181	
Peas, fresh	Fellers and Stepat (15)		5	21.7-43.4	
	Mack, Tressler and King (42)		18	19-40	
	Van Duyne, Bruckhart, Chase and Simpson (76)		9	22-40	
		Laxton's Progress			27
		Little Marvel			25
frozen	Fellers and Stepat (15)		5	9.3-15.6	13.1
	Fitzgerald and Fellers (18)		4 brands	15-22	
Potatoes	Esselen, Lyons and Fellers (13)		7	9.7-13.1	
		Irish Cobbler		7.2-20.0	
	Julen (30)		10	14.2-29.2	
	Karikka, Dudgeon and Hawk (32)	Irish Cobbler 1938		10.4	
		" " 1939		15.2	
		Warba 1938		9.8	
		" 1939		15.5	
	Lampitt, Baker and Parkinson (39)		15	20-41	
	Murphy (52)		6		17.3
	Murphy, Dove and Akeley (53)		22	22-38	
		Irish Cobbler		21-30	22
		Warba		27-30	29
		Irish Cobbler 1st Yr			12.3
		" " 2nd Yr			13.7
		" " 3rd Yr			25.2

(13) between seven varieties of potatoes grown in six states, than within the Irish Cobbler variety grown in seven states. A range of 22 to 38 mgm. per 100 gm. for twenty-two varieties was reported by Murphy et al., (52) while a similar variation of 20 to 41 mgm. per 100 gm. was reported by Lampitt, Baker and Parkinson (39) for fifteen varieties. For ten varieties, Julen (30) reported a range of 14.2 to 29.2 mgm. per 100 gm. A great difference within the Irish Cobbler and Warba varieties was reported by both Karikka, Dudgeon and Hauk (32) and Murphy, Dove and Akeley. (52)

It was reported by Burell, Brown and Ebright, (10) Murphy, Dove and Akeley (52) and Maynard and Beeson (46) that genetic influences overwhelm any variations due to climate, soil or fertilization. The absolute values for the ascorbic acid content of a variety was found to depend upon environmental factors, but the relative position of a variety within a range, grown under the same conditions, remained constant. Of the environmental factors, Maynard and Beeson (46) found that light was the most effective, while the effect of soil and fertilization was slight.

The original ascorbic acid content of a vegetable may change with storage. Bessey (5) reported a 26 per cent loss in the ascorbic acid content of cabbage when stored for one month at room temperature. The loss was 10 per cent for storage of the same length of time at 45° to 50° F. Van Duyne, Chase and Simpson (77) reported that in storage at 31° to 39° F. there was a slight rise in ascorbic acid in three days, a 10 per cent loss in twenty-nine days, and a 21 per cent loss in ninety-three days. A rise in the ascorbic acid value after storage for two days at 3° C. was also reported by Lampitt, Baker and Parkinson, (37)

and these workers suggest that the apparent increase in ascorbic acid is due to weight changes in the vegetable.

Peas kept at room temperature for one and three days were found by Tressler (73) to lose 15 and 30 per cent of their ascorbic acid content respectively. At 0° to 2° C there was no loss in one day, and a 1 per cent loss in three days.

It was reported by Esselen, Lyons and Fellers (13) and Julen (29) that storage tended to level differences between varieties of potatoes. Esselen et al. (13) found a loss of from 0 to 60 per cent for eight varieties during five month's storage, while Murphy (52) found the average loss for six varieties during seven month's storage was 71 per cent.

As might be expected cooking changes the ascorbic acid content of a vegetable. There has been a great variation in the method, the utensil, the time, and the ratio of water to vegetable used by different workers who have studied this problem. Table II shows the percentage of ascorbic acid retained in the cooked vegetable, dissolved in the cooking water and destroyed, as found in literature. The amount of ascorbic acid retained in the cooked cabbage varied from 22 to 58 per cent. The amount dissolved in the cooking water varied from 23 to 66 per cent, and the amount destroyed, from 12 to 35 per cent. The ascorbic acid retained in the cooked potato varied from 53 to 87 per cent, while the amount dissolved in the water was found by two workers to be 19 and 15 per cent, and the amount destroyed 28 and 7 per cent.

The retention of ascorbic acid in cooked fresh peas was reported by Bessey (5) and Fenton, Tressler and King (17) to be approximately 50 per cent. Fenton, et al. (17) reported that as

peas became overcooked, there was a continual rise in the ascorbic acid values for the water, while the values for the vegetable remained constant, or tended to increase slightly. These workers suggest that the apparent increase in the ascorbic acid content may be due to an increase in other dye-reducing substances. A similar rise was reported by Fenton and Tressler (16) when frozen peas were overcooked. Todhunter and Robbins (71) reported that cooked frozen peas contained 40 to 50 per cent of their original ascorbic acid content, and Fellers and Stepat (15) found that the loss in ascorbic acid due to freezing and cooking was 69.6 per cent. The commercial canning of peas was reported by Bessey (5) to cause a loss in ascorbic acid of 50 to 85 per cent, while Fellers and Stepat (15) found a loss of 83.9 per cent.

The effect of a very large volume of cooking water was reported by Olliver (56) to lower the retention of ascorbic acid in the cooked vegetable, and a very small volume of water was shown by Van Duyne, Chase and Simpson (77) to increase the retention. A wide variation within these extremes, however, had little effect. Olliver (56) reported that the length of the cooking time had little effect on the retention unless the vegetable was overcooked. No loss in ascorbic acid during the soaking of potatoes for three hours in tap water was reported by Olliver (56) and Allen and Mapson. (1)

There may be a further loss in ascorbic acid from the hot cooked food when left standing. The loss when cabbage was kept hot for one hour after cooking was found by Lampitt, Baker and Parkinson, (36) Allen and Mapson (1) and Olliver to be 60 per cent. Hollyman, Brodie and Willard (24) reported a loss of 62

TABLE II

Vegetable	Reference	Cooking Time	Ratio of Water to Vegetable	Ascorbic Acid		
				Retained	Dissolved	Destroyed
		Min.		%	%	%
Cabbage	Allen and Mapson (1)	-	2:1	44	44	12
	Hollyman, Brodie and	8	5:1	44	53	4
	Willard (24)	8	25:1	55	37	8
	Nobel and Waddell (55)	-	4:1	30-40	48-49	17-22
	Van Duyne, Chase	7	4:1	50	23	27
	and Simpson (77)	7	2:1	58	25	17
	Wellington and Tressler (81)	8	5:1	22	66	12
Peas, fresh	Bessey (5)	-	-	50	25	25
frozen	Fenton, and Tressler (16)	8	1:1	59	36	5
	McIntosh, Tressler and Fenton (48)	-	3:1	59-75	20-28	5-15
Potatoes	Kahn and Halliday (31)	208° F Int.Temp	2:1	66	-	-
	Lampitt, Baker and Parkinson (36)	-	-	79	15	7
	Olliver (56)	20	3:1	53	19	28
	Van Duyne, Chase and Simpson (78)	96° C Int.Temp	-	87	-	-

to 88 per cent in thirty minutes. It was found by Jenkins (27) that boiled potatoes, kept hot on a steam-table for sixty minutes, lost an additional 54 per cent of their ascorbic acid content.

The dehydroascorbic acid of cabbage and potatoes purchased on the retail market was found by Bacharach and Coates (3) to be 3 or 4 mgm. and 1 mgm. per 100 gm. respectively. Morgan, MacKinney and Cailleau (5) reported that no dehydro ascorbic acid was found in any vegetables, and Esselen, Lyons and Fellers (13) found no dehydroascorbic acid in the potato. However Tuba, Hunter and Steele (75) reported that two raw cabbage samples contained 13.6 mgm. and 9.1 mgm. per 100 gm. of dehydroascorbic acid, while the cooked vegetable contained 3.1 and 5.7 mgm. These workers reported that fresh peas contained 20.0 mgm. of dehydroascorbic acid while the cooked samples had a content of 3.1 and 2.7 mgm. per 100 gm.

Mapson (45) reported that no "apparent vitamin C" was found in either fresh fruits and vegetables or typically cooked and preserved foods. However Wokes, Organ and Jacoby (82) have found "apparent vitamin C" in a wide variety of foods, including those which have been stored under normal conditions. It was reported by Tuba, Hunter and Steele (75) that 20 and 36 per cent of the ascorbic acid values of two samples of cooked cabbage, and 14 and 15 per cent of the content of two samples of cooked peas was "apparent vitamin C", although no "apparent vitamin C" was found in the raw sample.

EXPERIMENTAL

Method

The analytical procedure used to determine the ascorbic acid content of the vegetables was that of Loeffler and Ponting, (41) and readings were taken in a Coleman Spectrophotometer using a 520 M.μ. filter. A series of colorimeter tubes were matched in the spectrophotometer and used throughout the experiments. A stock solution of 2-6 dichlorophenolindophenol dye was prepared containing 800 mgm. per l. of distilled water, from which a weaker solution of 16 mgm. per l. was prepared and standarized daily. It was found that the stock solution could be used for a month if stored in a refrigerator.

The method in detail was as follows: From 25 to 50gm. of plant material were ground in a Waring Blendor with 350 cc. of one per cent metaphosphoric acid for five minutes, and the extract filtered through number twelve Whatman fluted filter paper. The spectrophotometer was set at 100 with a tube containing 9 cc. of distilled water and 1 cc. of filtered extract. To two other tubes, 9 cc. of the previously standardized dye solution and 1 cc. of the filtered extract were added and well stirred. Readings were taken within fifteen seconds after adding the extract until two checked within 0.5 galvanometer units. The average of these two was used in calculations. Duplicate samples prepared from the same extract checked within one per cent.

To standardize the dye, the machine was set at 100 with a tube of distilled water. To two other tubes containing 9 cc. of

the dye, 1 cc. of the one per cent metaphosphoric acid was added, and readings taken within fifteen seconds after adding the acid until two checked within 0.5 galvanometer units. The average of the two values was used in calculations.

A standard curve as suggested by Morell (50) was prepared by using a series of known ascorbic acid solutions containing from 5 to 40 µgm. of ascorbic acid per cc. The standard solutions were prepared by dissolving 125 mgm. of ascorbic acid crystals in 250 cc. of one per cent metaphosphoric acid. From 1 to 8 cc. amounts of the solution were added to 100 cc. volumetric flasks, made up to the mark with one per cent metaphosphoric acid and tested by the procedure described above. The log of the galvanometer reading for the sample minus the log of the reading for the dye standardization was plotted against the ascorbic acid content in ugm. per cc. The line of best fit was calculated using the method of least squares, and the equation was $Y=0.0074X-0.0001$. The calibration data for the determination of the standard line are shown in Table III, and the graph of the line in Figure 1.

To calculate the amount of ascorbic acid per 100 gm. of plant material the following equation was used:

$$\frac{100(\text{µgm. ascorbic acid})}{1000\ (\text{weight of sample})} \quad \frac{(\text{moisture in sample})(\text{weight of sample})+350}{}$$

The moisture percentage was approximated from food tables, since it was found by Loeffler and Ponting (41) that a variation of seven per cent caused less than a one per cent difference in the ascorbic acid calculation. Moisture determinations were

TABLE III

CALIBRATION DATA FOR THE SPECTROPHOTOMETRIC DETERMINATION OF ASCORBIC ACID

µgm. per cc.	Galvanometer Reading (a) Gs	Log Gs	Observed Log Gs- (b) Log Gso	Calculated(c)
5	48.1	1.6821	0.0319	0.0360
10	52.8	1.7226	0.0723	0.0730
15	58.0	1.7634	0.1131	0.1100
20	63.5	1.8028	0.1525	0.1470
25	68.5	1.8357	0.1854	0.1840
30	74.6	1.8727	0.2224	0.2210
35	80.2	1.9042	0.2539	0.2580
40	87.7	1.9430	0.2927	0.2950

(a) Mean of two 15 second readings used.

(b) Galvanometer reading for the dye standardization = 44.7. Log Gso . = 1.6502

(c) Calculated from the line of best fit using the method of least squares

$$Y = 0.0074X - 0.0001$$

The Standard Error of Estimate in percent of the mean was 2.25 per cent.

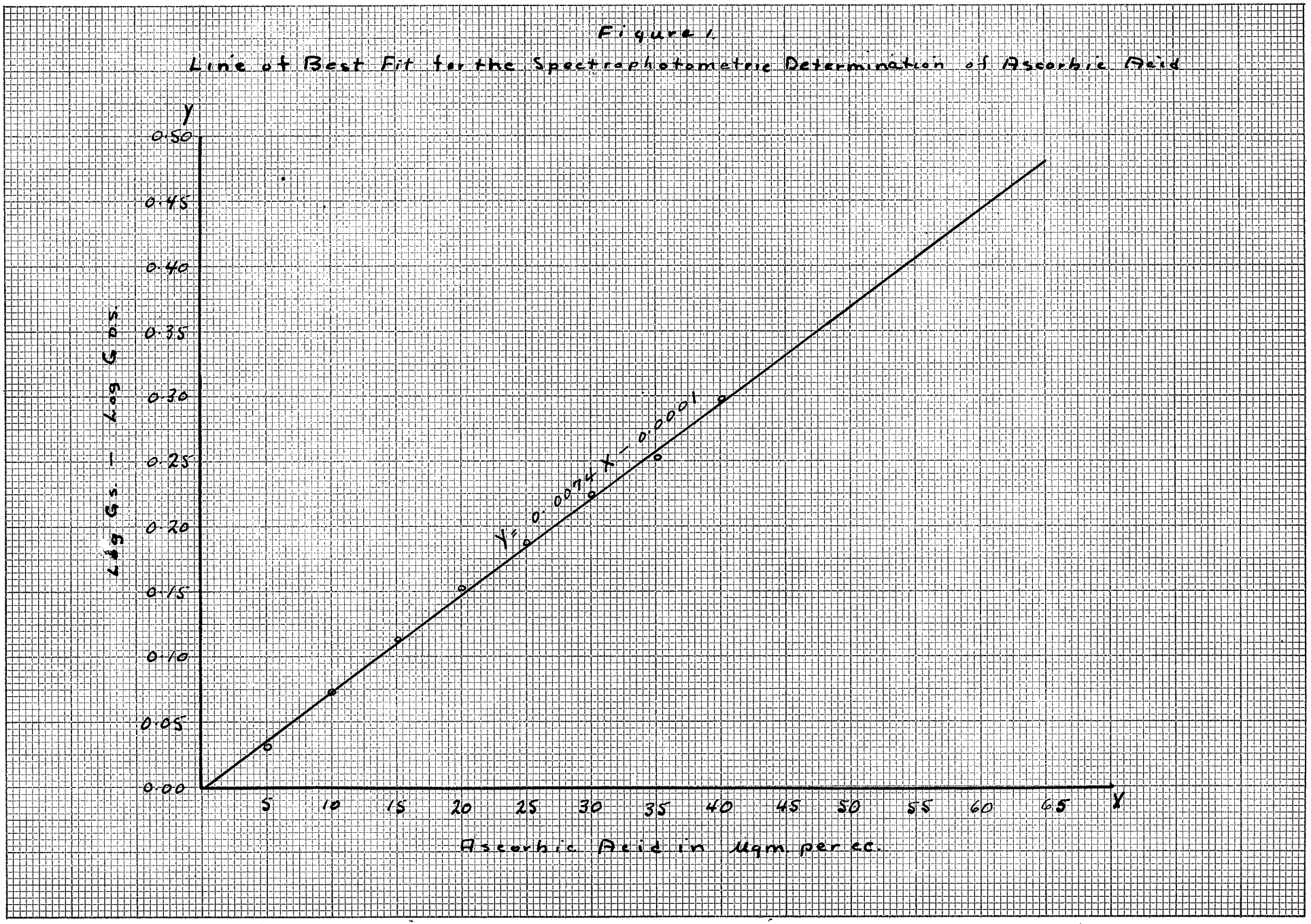
made on raw cabbage and found to check well with the tables. They were also made on canned peas, since the moisture content was not given in tables.

For the dehydroascorbic acid determinations, the method of Roe and Oesterling (62) was used, with a 540 M.μ. filter. A sample of approximately 5 gm. was ground in a Waring Blendor with 100 cc. of a solution of five per cent metaphosphoric acid and one per cent thiourea. The extract was then filtered through number twelve Whatman fluted filter paper. In each of two matching colorimeter tubes was placed 4 cc. of the filtered extract, and to one of the tubes 1 cc. of two per cent 2-4 dinitrophenylhydrazine in 9N. sulphuric acid was added. The other tube was left blank. Both were held for three hours in an incubator at 37° C, and then placed in an ice water bath. While in the ice water, 5 cc. of eighty-five per cent sulphuric acid was added to each tube, drop by drop, during not less than one minute, and to the blank tube only was added 1 cc. of 2-4 dinitrophenylhydrazine. The two tubes were then well agitated, removed and dried. The spectrophotometer was set at 100 with the blank tube and readings were taken within thirty and forty-five minutes after removal from the bath.

A series of known dehydroascorbic acid solutions containing from 0.5 to 9.0 μgm. per cc. were tested and a standard curve prepared. The dehydroascorbic acid solution was prepared by dissolving 25 mgm. of ascorbic acid crystals in 25 cc. of five per cent metaphosphoric acid. The solution was oxidized to dehydroascorbic acid by adding a drop or two of bromine until the color was yellow. Excess bromine was decanted, and the

Figure 1

Line of Best Fit for the Spectrophotometric Determination of Ascorbic Acid



solution aerated until colorless. From 0.5/10 to 9/10 cc. amounts of the solution were placed in 100 cc. volumetric flasks and made up to the mark with the solution of metaphosphoric acid and thiourea. The samples were prepared and determined by the method described above.

The line of best fit was calculated by the method of least squares, and the equation was $Y = -0.0311X + 1.9671$, where X equals the ugm. of dehydroascorbic acid per cc., and Y equals the log of the galvanometer reading. The data for the determination of the standard line are shown in Table IV and the graph of the line in Figure 2.

The vegetables used throughout this work, unless otherwise specified, were grown under the supervision of the Division of Plant Science at the University of Manitoba. Five varieties of cabbage - three summer and two winter, five varieties of peas and three varieties of potatoes were tested. The garden was planted later than usual and consequently the vegetables were late in reaching maturity with the first samples being determined about the beginning of August. The vegetables were of optimum maturity unless otherwise stated, and determinations were carried out on the day they were gathered.

To obtain a uniform cabbage sample the coarse outer leaves of the head were removed, the cabbage quartered and the core taken out. Cross-sectional slices were cut from opposite quarters, chopped coarsely, the shreds mixed and a representative sample of approximately twenty-five gm. selected. A second sample using the other two quarters was prepared in the same way. The peas of each lot to be tested were shelled and mixed together

TABLE IV

CALIBRATION DATA FOR THE SPECTROPHOTEMETRIC DETERMINATION OF DEHYDROASCORBIC ACID

µgm. per cc.	Galvanometric Reading (Gs)	Observed Log Gs	Calculated (a)
0.5	91.0	1.9590	1.9520
1.0	83.3	1.9206	1.9364
1.5	80.9	1.9079	1.9208
3.0	78.6	1.8954	1.8740
4.0	65.9	1.8189	1.8428
5.0	69.9	1.8445	1.8116
6.0	61.9	1.7917	1.7804
7.0	55.0	1.7404	1.7492
9.0	47.4	1.6758	1.6868

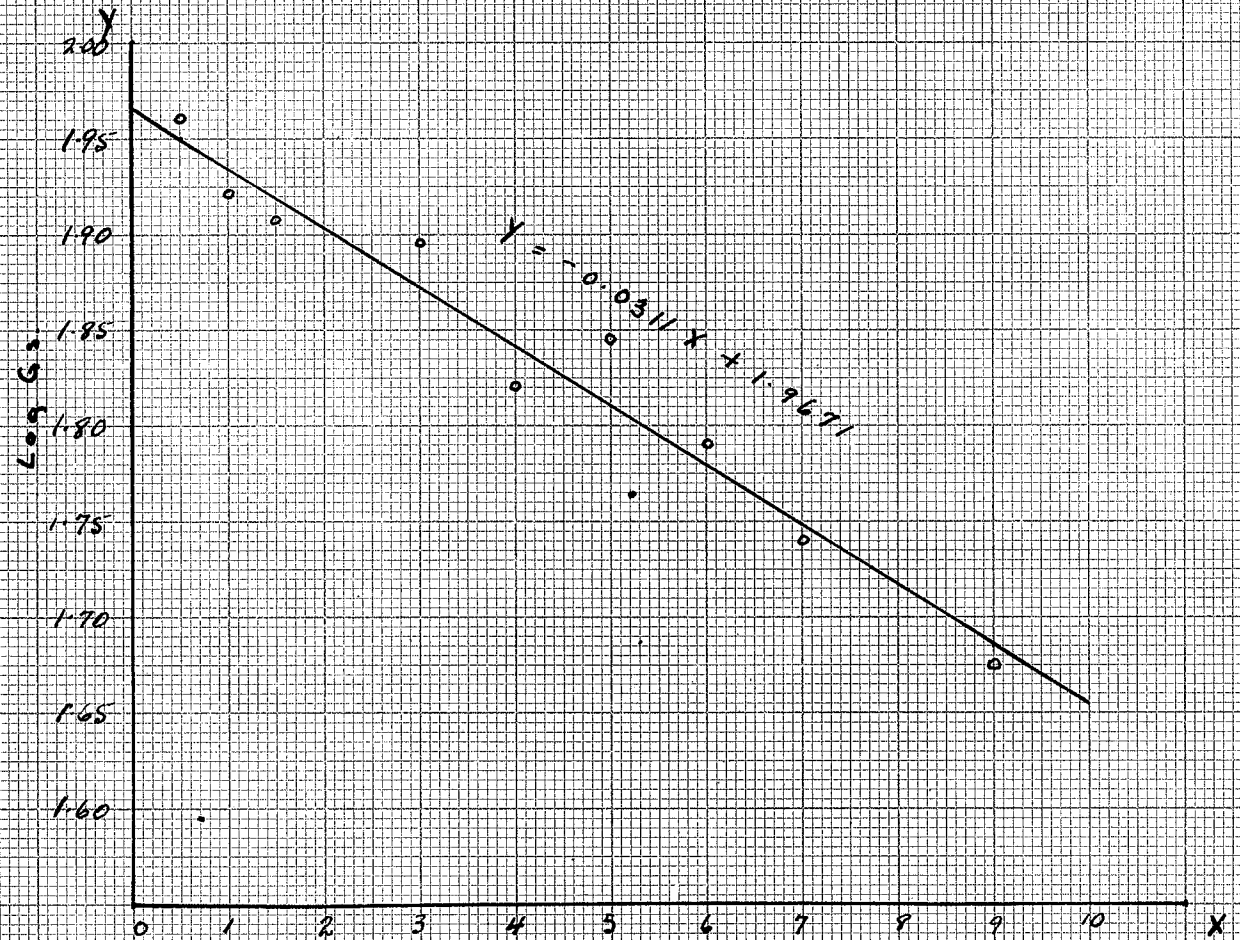
(a) Calculated from the line of best fit using the method of least squares.

$$Y = -0.0311X + 1.9671$$

The Standard Error of Estimate in per cent of the mean was 1.11 per cent.

Figure 2.

Line of Best Fit for the Spectrophometric Determination of Dehydroascorbic Acid



Dehydroascorbic Acid in γgm. per cc.

and duplicate samples of approximately twenty-five gm. selected and weighed. Two slices from each potato, weighing approximately 30 gm. each were tested. The vegetable was cut through the centre along the longitudinal axis, and the slices taken from either half.

Differences in ascorbic acid content between the five varieties of cabbage and between summer and winter varieties were tested. The heads selected were mature, and sampling was carried out in the manner described above. Five or six heads of each variety were tested over a period of two weeks to a month. In the case of peas, from eight to fourteen lots of each variety were analysed, over a period of three weeks to a month, as they reached maturity. Four potatoes of each of the three varieties were tested after being harvested. Since they were stored immediately, the variation in the concentration of the vitamin in vegetables grown in different parts of the province was tested by analysing cabbage and potatoes sent from dix districts of Manitoba. The Danish Ballhead variety of cabbage and Irish Cobbler and Warba potatoes were tested as they arrived by the above described procedure.

To find the effect of maturation on the ascorbic acid content of peas, duplicate samples of the Laxton's Progress variety in three stages of maturity were gathered and tested - when they were small tender and had not reached optimum maturity, when fully mature and over-mature. To determine the variation in ascorbic acid within the mature stage of peas and cabbage, a record was kept of the date and the daily average content of each variety over the experimental period.

The extent of variation in the vitamin concentration throughout the head of cabbage was tested. The coarse outer leaves of five heads were removed and samples of the core and inner and

outer tissues of each head analysed.

To determine how long vegetables may be kept in a refrigerator without losing ascorbic acid, refrigerator storage tests were carried out on cabbage and peas. Three varieties of cabbage were gathered, cut into quarters and four determinations made on each head immediately. The sections were wrapped in waxed paper and kept in the refrigerator for six days, and determinations made on each day except the third. Pods of the Laxton's Progress variety of peas were gathered and four determinations made immediately. The rest of the pods were stored in a refrigerator for four days, and samples were analysed daily.

Potatoes and winter cabbage were stored in a root-house about the end of September. They were analysed at the time of storage and then once every month until April. A minimum of four potatoes of each variety were analysed each time, but in the case of cabbage there were fewer heads so that only two Danish Ballhead and one Pennsylvania State Ballhead were tested at one time.

Lincoln variety peas were preserved when they reached optimum maturity in pint sealers using a pressure cooker. Tests were made on the peas before canning, and on the preserved product several times during the winter. To compare these values with those of commercially canned products, several brands of canned peas found on the retail market of Winnipeg were analysed. In each case two samples of the vegetable and two of the liquid were tested.

Cooking tests on stored cabbage were carried out according to the method suggested by Nobel and Waddell. (55) The cabbage was quartered and the core removed. Sections from opposite quarters were chopped coarsely, mixed together, and raw samples were ana-

lysed for ascorbic acid and dehydroascorbic acid. Three 40 gm. and one 5 gm. samples were weighed, tied in loose cheese-cloth bags and cooked together in 500 cc. of tap water in an uncovered enamel saucepan. The ratio of water to cabbage was therefore 4:1. The cheesecloth bags eliminated the cooling period necessary to weigh the sample accurately, during which time the ascorbic acid may be lost by oxidation. Also calculations may be made directly on the raw weight basis. The water was boiling when the samples were added and they were cooked for nine minutes after it returned to the boil. After cooking the water was poured off and measured, and samples of it determined for ascorbic acid and dehydroascorbic acid. One 40 gm. sample and the 5 gm. sample of the cooked cabbage were determined for ascorbic acid and dehydroascorbic acid respectively. The other two samples were kept hot in pyrex dishes in boiling water for thirty and sixty minutes, and then determined for ascorbic acid. Nine tests were used to obtain the mean figures for the cooking tests, five tests to obtain the values for the loss on standing and three to find the dehydroascorbic acid content.

Cooking tests were also carried out on fresh summer cabbage, using a ratio of water to cabbage of 4:1, to compare the retention of the vitamin in the cooked fresh vegetable with that of the cooked stored vegetable. The effect of adding salt to the cooking water was studied. Duplicate samples of cabbage were prepared and one was cooked without salt and the other with one-half a teaspoon of salt added to the cooking water. The mean values were obtained from the results of four tests.

One brand of frozen raw peas were analysed for ascorbic acid

and dehydroascorbic acid, and cooking tests were made on the frozen vegetable by adding them to boiling water before defrosting. Three 40 gm. and one 5 gm. samples were weighed, tied in loose cheesecloth bags, added to 500 cc. of boiling tap water and cooked for eight minutes after the water returned to the boil. The 5 gm. and one 40 gm. samples were analysed for ascorbic acid and dehydroascorbic acid respectively, and samples of the water were also tested for both forms of the vitamin. The other two samples were cooked for sixteen and twenty-four minutes and then analysed along with water samples for ascorbic acid only.

In the case of cooking tests on potatoes, the vegetables were peeled and raw samples tested for ascorbic acid and dehydroascorbic acid. Two pieces of approximately 40 gm. and one piece of 5 gm. were weighed for cooking, and the volume of cooking water used was four times the total weight of vegetable. The samples were added to boiling water in an enamel saucepan and cooked with the lid on. The small piece was cooked in fourteen minutes, and was removed and analysed for dehydroascorbic acid, while the larger pieces took eighteen minutes. The water was then poured off, measured and samples of it determined for ascorbic acid and dehydroascorbic acid. One of the large samples was analysed immediately after cooking for ascorbic acid.

The ascorbic acid retention in cooked freshly harvested potatoes was tested to compare it with the retention in cooked stored potatoes. The vegetables were peeled and cooked in a ratio of water to vegetable of 4:1. One-half of the vegetable was cooked immediately and the other half cooked in tap water for two hours. The water was then poured off, and the vegetables cooked in fresh

water in the manner described above. Three tests were used to obtain average values. The effect of soaking potatoes without cooking them was tested by soaking one-half of four potatoes in tap water for three hours and then testing for ascorbic acid. The other half was analysed immediately.

Results and Discussion

The ascorbic acid content of raw, mature freshly harvested cabbage, peas and potatoes grown on the University Campus at Fort Garry has been summarized in Table V.

A wide variation within each variety of cabbage was found, and the mean values for five varieties varied from 34.7 to 49.7 mgm. per 100 gm. This range is lower than that reported for a much larger number of varieties by Burell, Brown and Ebright (10) and Maynard and Beeson (46), as shown in Table I, but are more comparable to the results of Gould and Tressler (19) and Hollyman, Brodie and Willard. (24) The Danish Ballhead and Pennsylvania State Ballhead content of winter varieties, was consistently higher than that of summer varieties, Copenhagen Market, Garden Acre and Jersey Wakefield. This agrees with the results of Burell et al., (10) but is the reverse of those reported by Gould and Tressler. (19) The vitamin C content of the Ballhead varieties compares well with that found by Hollyman et al., (24) but was higher then the results of Gould and Tressler (19) and considerably lower than those of Burell et al. (10) Of the summer varieties, Jersey Wakefield was found to have the highest ascorbic acid content, while the content of the Golden Acre variety was higher than that of Copenhagen Market. This was also reported by Burell et al. (10)

The ascorbic acid content of fresh raw mature peas was found to vary more within a variety than between varieties. The mean content of five varieties showed a variation of 23.7 to 33.3 mgm. per 100 gm., which agrees with the variation reported in literature

TABLE V

THE ASCORBIC ACID CONTENT OF RAW CABBAGE PEAS AND POTATOES GROWN AT THE UNIVERSITY OF MANITOBA

Vegetable	Variety	Number of Vegetables or Lots	Ascorbic Acid mgm. per 100 gm.	
			Range	Mean
Cabbage	Copenhagen Market	5	30.4-40.4	34.7
	Golden Acre	6	30.7-44.4	38.4
	Jersey Wakefield	6	37.2-47.2	42.0
	Danish Ballhead	5	40.3-53.5	45.3
	Penn. State Ballhead	5	38.0-56.2	49.7
Peas	Laxton's Progress	10	18.3-32.2	23.7
	Little Marvel	14	19.1-31.7	25.0
	Telephone	11	22.6-34.9	28.5
	Wisc. Early Sweet	8	25.4-33.3	29.7
	Lincoln	11	22.2-38.9	33.3
Potatoes	Columbia Russet	4	11.8-15.3	13.7
	Irish Cobbler	4	18.0-23.3	18.6
	Warba	4	16.0-20.5	18.9

as shown in Table I. The Lincoln variety contained the highest average ascorbic acid content, while the values for Laxton's Progress and Little Marvel agree closely with those reported by Van Duyne, Bruckhart, Chase and Simpson. (76)

The variation within potato varieties was less than that noted in the other two vegetables because the vitamin changes over a period of time could not be considered. The mean varietal values vary from 13.7 to 18.9 which are within the range reported by Julen (30) and close to the mean value for six varieties found by Murphy. (52) They are higher than the values reported by Esselen, Lyons and Fellers (13) and lower than those of Lampitt, Baker and Parkinson (39) and Murphy, Dove and Akeley. (53) The Irish Cobbler and Warba varieties were consistently higher in ascorbic acid than the Columbia Russet, and compared well with the results reported in literature.

Samples of cabbage and potatoes were sent from a number of districts of Manitoba and analysed for ascorbic acid. The results of this study are shown in Table VI. Although the number of vegetables assayed was small and only one sample lot from each district tested, it can be seen that a great variation in ascorbic acid concentration exists within a variety of a vegetable. For Danish Ballhead cabbage a variation of 27.4 to 73.0 mgm. per 100 gm. was found with an average of 49.9 mgm. per 100 gm. Although the variation between districts is greater than that shown for cabbage grown on the University Campus at Fort Garry, the mean values agree well.

In the case of potatoes a variation of 7.0 to 22.0 mgm. per 100 gm. was found for the Warba variety, and 8.2 to 18.6 mgm. per

TABLE VI

THE ASCORBIC ACID CONTENT OF RAW VEGETABLES FROM A NUMBER OF DISTRICTS OF MANITOBA

Vegetable	Variety	District	Number of Vegetables Analysed	Ascorbic Acid	
				Range	Mean
Cabbage	Danish Ballhead	Gilbert Plains	2	41.5 - 45.4	43.5
		Lyleton	4 small	64.8 - 82.7	73.0
		Pipestone	1 heads	. . . .	61.5
		Dauphin	2	61.3 - 71.0	66.2
		Lenswood	1	. . . .	27.4
		Ericksdale	1	. . . .	32.7
		Fort Garry	5	40.3 - 53.5	45.3
		Districts Mean			49.9
Potatoes	Warba	Gilbert Plains	3	6.1 - 7.8	7.0
		Lyleton	4	15.2 - 24.7	19.2
		Pipestone	2	6.5 - 10.4	8.5
		Lenswood	4	13.6 - 16.3	14.4
		Crystal City	4	19.3 - 24.7	22.0
		Ericksdale	3	6.5 - 7.9	7.1
		Fort Garry	4	16.0 - 20.5	18.9
		Districts Mean			13.9
	Irish Cobbler	Crystal City	4	12.1 - 22.9	17.5
		Ericksdale	3	8.1 - 8.2	8.2
		Fort Garry	4	18.0 - 23.3	18.6
		Districts Mean			14.8

100 gm. for Irish Cobblers. Although large these variations agree well with those reported in literature as shown in Table I.

The results of this study and those of other investigators show that a very wide variation in ascorbic acid concentration exists within a variety of a vegetable. Maynard and Beeson (41) and Burrell, Brown and Ebright (10) reported that while genetic influences affected the ascorbic acid variation between varieties, environmental factors were influential in varying the content within a variety. Of these factors, light was reported to be the most effective. Karikka, Dudgeon and Hauk (32) and Murphy, Dove and Akeley (53) have reported that the average content of the same variety of potato varies with different years. These findings may partly explain differences in the ascorbic acid content of vegetables grown in various places. Another factor which is often neglected is the sampling technique used. A sufficient number of vegetable lots, numbers of vegetables within a lot and number of samples within a vegetable must be tested to obtain a true picture of varietal differences.

It has been reported by Bessey (4) and Mack, Tressler and King (74) that the ascorbic acid content of peas decreases with maturity. Table VII shows the average ascorbic acid content of the Laxton's Progress variety of peas, in the under-ripe, mature and over-ripe stages of maturity. The ascorbic acid content at each stage is significantly different and decreases with maturation. The difference in ascorbic acid between the under-ripe and over-ripe stages was fifty per cent. The Analysis of Variance to show the significance of difference between the stages of maturity is shown in Table VIII.

TABLE VII

THE EFFECT OF MATURATION ON THE ASCORBIC ACID CONTENT OF PEAS

Degree of Maturity	Number of Samples	Ascorbic Acid mgm. per 100 gm.
Tender	2	24.3
Mature	2	19.5
Over-mature	2	11.9

TABLE VIII

ANALYSIS OF VARIANCE TO SHOW THE SIGNIFICANT DIFFERENCE BETWEEN THE ASCORBIC ACID CONTENT OF THREE STAGES OF MATURITY IN PEAS

Source of Sum of Squares	Sum of Squares	Degrees of Freedom	Mean Square	F	5 per cent point
Stages	156.38	2	78.19	29.07	19.00
Duplicates	0.43	1	0.43		
Error	5.37	2	2.69		
Total	162.81	5			

It is therefore concluded that the differences between the stages of maturity are significant

Stages of Maturity

		A	B	C	
duplicates	1	24.8	19.8	10.3	54.9
	2	23.8	19.2	13.5	56.5
		48.6	39.0	23.8	111.4

Table IX shows the variations in the ascorbic acid content within two varieties of peas, in the mature stage, and Figure 3 shows the graphs of these variations. The ascorbic acid concentration of the Lincoln variety decreased twenty-five per cent in twenty-one days, while that of the Little Marvel variety decreased thirty per cent in eleven days.

Table X shows a similar decrease in the ascorbic acid concentration of mature cabbage, and Figure 4 shows the graphs of these decreases. In one month the content of the Golden Acre variety decreased twenty per cent, while that of the Jersey Wakefield decreased fifteen per cent in three weeks, and the Copenhagen Market twenty per cent in two weeks.

The variations within the head of a cabbage were also determined, and the results are summarized in Table XI. The ascorbic acid concentration in the core was forty per cent higher than in other parts of the cabbage. The content of the outer tissues tended to be a little lower than that of the inner tissue but the difference was small.

The results of refrigerator storage tests are shown in Table XII. There was no change in the ascorbic acid content of the peas for three days and then an abrupt loss of twenty-five per cent on the fourth day. For each of the three varieties of cabbage there was a rise in ascorbic acid value during the first and second day. A similar rise was reported by Lampitt, Baker and Parkinson (37) and Van Duyne, Chase and Simpson (77). The former suggested that weight changes in the head caused the apparent increase in the vitamin. After six days storage, there was a loss of only ten per cent for the Golden Acre variety. These results show that unshelled

TABLE IX

THE VARIATION IN THE ASCORBIC ACID CONTENT OF PEAS WITHIN THE MATURE STAGE

Variety	Day	Mean Ascorbic Acid mgm. per 100 gm.
Lincoln	1	29.7
	3	31.3
	19	29.5
	21	24.1
Little Marvel	1	27.8
	4	28.7
	7	22.6
	9	23.2
	11	20.1

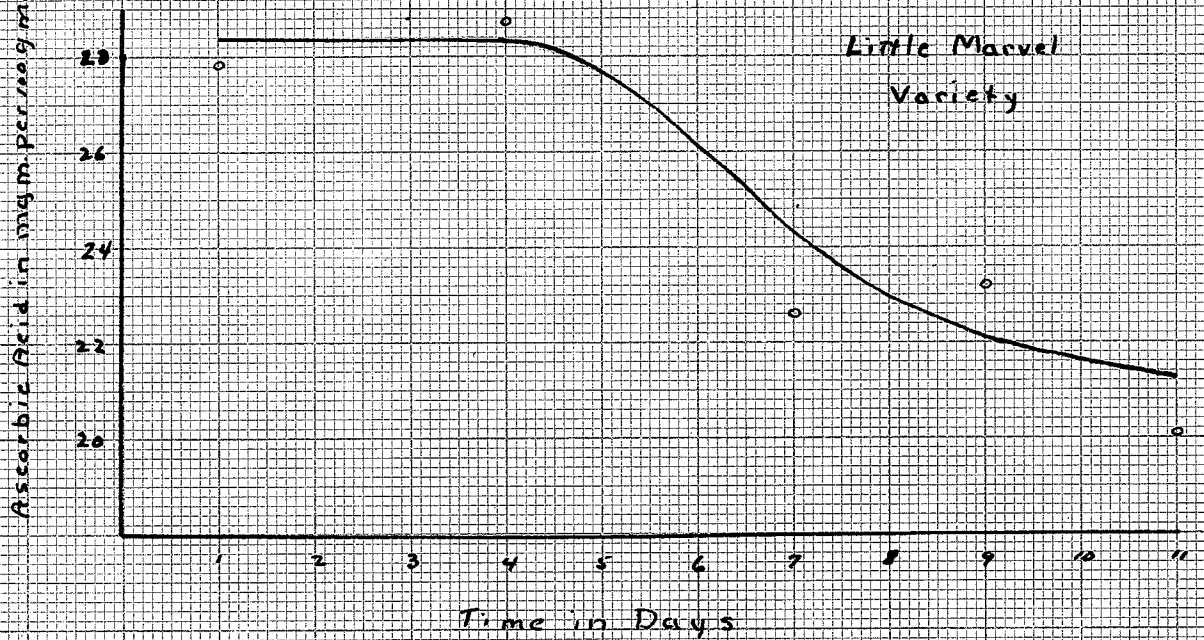
TABLE X

THE VARIATION IN THE ASCORBIC ACID CONTENT OF CABBAGE WITHIN THE MATURE STAGE

Variety	Day	Mean Ascorbic Acid mgm. per 100 gm.
Golden Acre	1	39.1
	13	32.3
	29	30.7
Jersey Wakefield	1	46.2
	14	38.3
	21	37.2
	24	39.4
Copenhagen Market	1	39.0
	14	30.4
	16	30.6

Figure 3.

Graphs to Show the Decrease in the Ascorbic Acid Content of Peas Within the Mature Stage



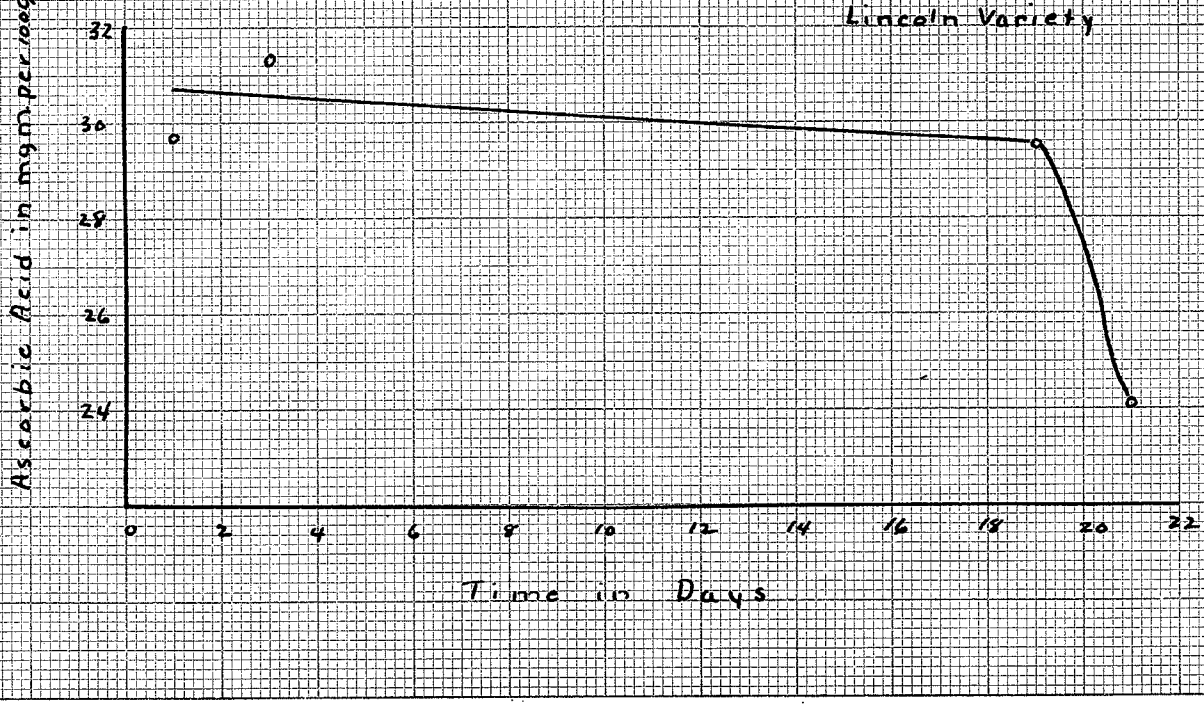


Figure 4.

Graphs to Show the Decrease in the Ascorbic Acid Content of Cabbage Within the Mature Stage

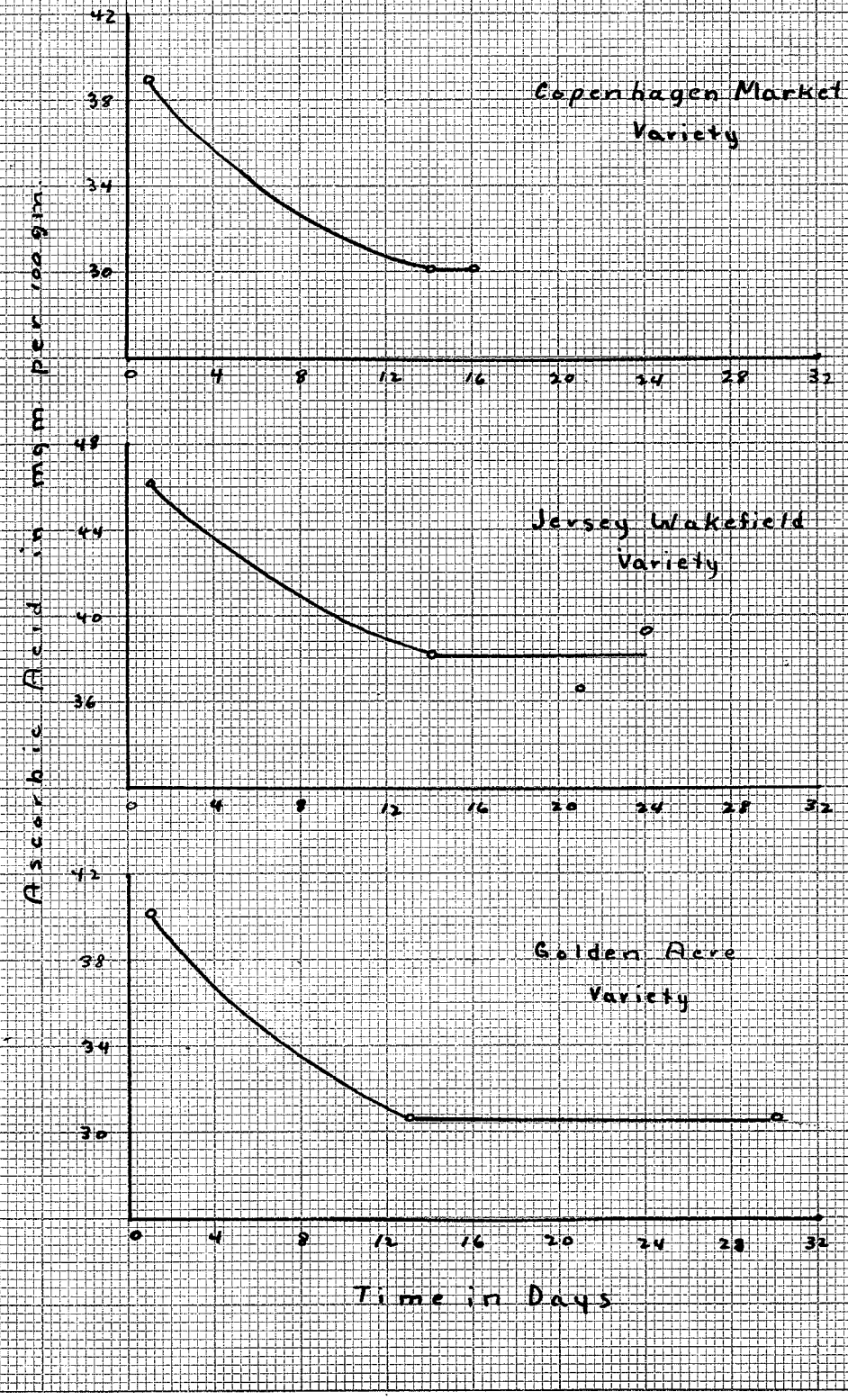


TABLE XI

THE VARIATION IN THE ASCORBIC ACID CONCENTRATION WITHIN FIVE CABBAGE HEADS

Part of Cabbage	Ascorbic Acid mgm. per 100 gm.	
	Range	Mean
Core	78.0 - 101.9	88.1
Inner TIssues	39.7 - 59.9	52.2
Outer Tissues	40.9 - 57.8	48.5

TABLE XII

THE EFFECT OF REFRIGERATOR STORAGE ON THE ASCORBIC ACID CONTENT OF PEAS AND CABBAGE

Vegetable	Variety	Day	Mean Ascorbic Acid mgm. per 100 gm.
Peas	Little Marvel	1 - Fresh	22.6
		2	22.8
		3	22.4
		4	16.9
Cabbage	Golden Acre	1 - Fresh	20.7
		2	34.3
		4	31.0
		5	31.3
		6	27.6
	Jersey Wakefield	1 - Fresh	39.4
		2	41.7
		4	43.7
		5	42.1
		6	39.3
	Copenhagen Market	1 - Fresh	34.6
		2	32.0
		4	41.0
		5	31.9
		6	31.8

peas can be kept in a refrigerator for three days with no loss in ascorbic acid, and cabbage wrapped in waxed paper will lose little or no ascorbic acid in six days.

The effect on the ascorbic acid content of cabbage and potatoes of roo-house storage for six months was summarized in Table XIII. There was little change in the ascorbic acid content of either variety of cabbage during that time. Both Bessey (5) and Van Duyne, Chase and Simpson (77) reported a loss of 10 per cent in one month's storage and the latter group of investigators reported a lost of 21 per cent in three months. In spite of the fact that a small number of heads were analysed each time,-only one in the case of Pensylvania State Ballhead - the variation was small showing that the wide discrepancies found between freshly harvested cabbage tends to lessen on storage. The high value for the ascorbic acid content of the Danish Ballhead variety in the month of November and the Pennsylvania State Ballhead in December may have been due to the small number of vegetables analysed, or to an increase in other dye-reducing substances as suggested by Wokes, Organ and Jacoby. (83) Graphs showing the rate of loss in ascorbic acid in potatoes during storage is shown in Figure 5.

The loss in ascorbic acid during the storage of potatoes for six months was 54 per cent for Columbia Russets and 62 and 67 per cent for Irish Cobblers and Warbas respectively. These losses agree fairly well with those reported in literature. Esselen, Lyons and Fellers (13) and Julen (29)

The effect of canning on the ascorbic acid concentration of peas has been shown in Table XIV. Approximately one-third of the original ascorbic acid content was retained by the vegetable, one-

TABLE XIII

THE EFFECT OF ROOT-HOUSE STORAGE ON THE ASCORBIC ACID CONTENT OF CABBAGE AND POTATOES

Vegetables and Variety		Ascorbic Acid mgm. per 100 gm.					
		Oct.	Nov.	Dec.	Jan.	Feb.	March
Cabbage							
Danish Ballhead	No. of Samples	5	2	2	4	4	3
	Range	40.3-53.5	52.2-61.3	43.6-51.8	45.9-54.6	40.5-57.1	43.0-53.5
	Mean	45.3	56.8	47.7	49.5	49.8	49.8
Penn. State Ballhead	No. of Samples	5	1	1	1	1	1
	Range	38.0-56.2	...	...	...	...	...
	Mean	49.7	46.9	63.4	49.9	47.7	46.4
Potatoes							
Columbia Russet	No. of Samples	4	3	3	3	...	3
	Range	11.8-15.3	12.1-13.3	4.4-7.1	4.1-7.0	...	5.3-7.4
	Mean	13.7	12.7	6.0	5.9	...	6.3
Irish Cobbler	No. of Samples	4	3	3	3	...	9
	Range	18.0-23.3	5.9-11.7	8.5-10.0	8.3-9.9	...	5.1-10.6
	Mean	18.6	8.6	9.3	9.0	...	7.1
Warba	No. of Samples	4	3	3	3	...	4
	Range	16.0-20.5	4.1-9.3	7.7-7.9	5.9-7.5	...	3.9-7.9
	Mean	18.9	6.9	7.8	6.4	...	6.1

Figure 5.

Graphs to Show the Decrease in the Ascorbic Acid Content of Potatoes During Root-House Storage.

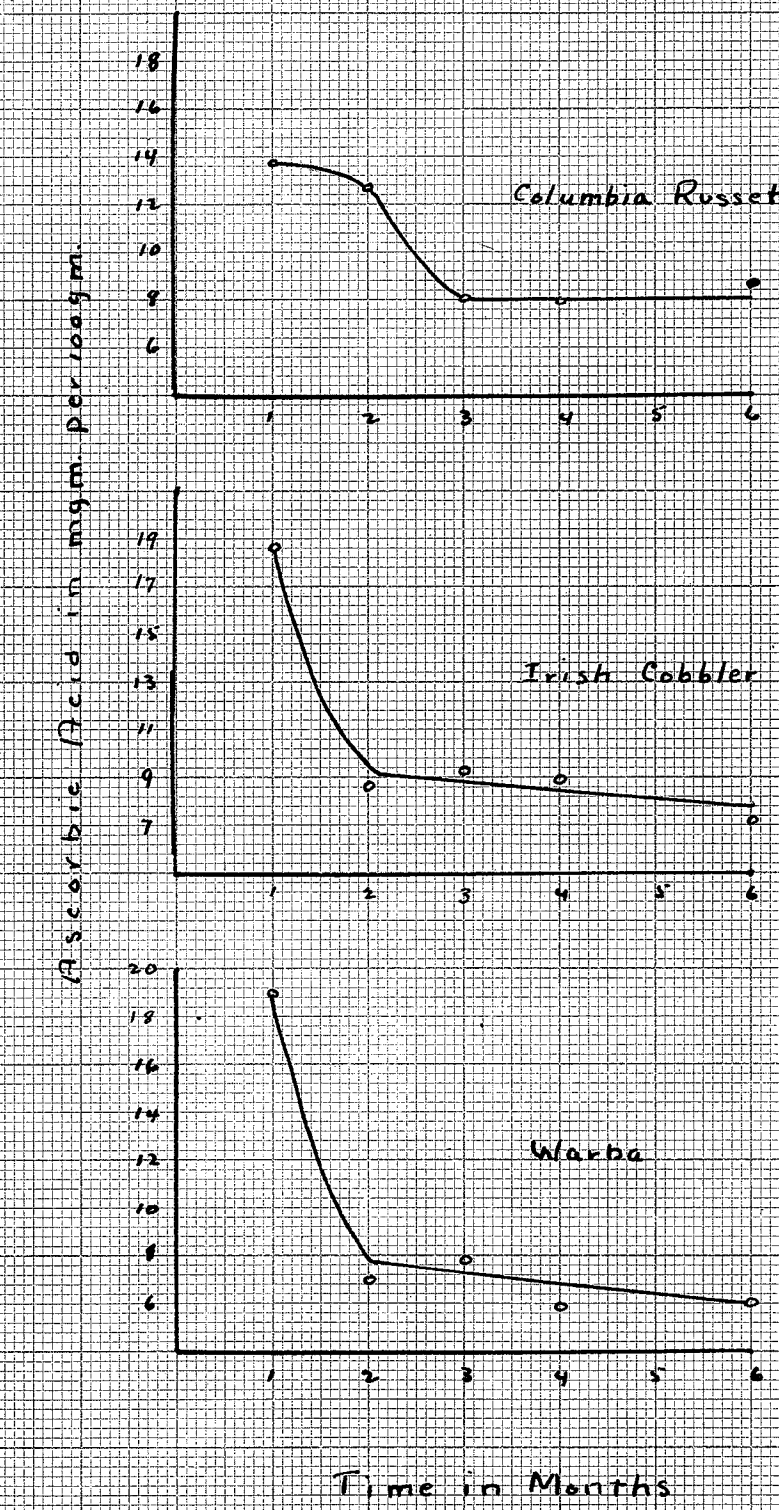


TABLE XIV

THE EFFECT OF CANNING ON THE ASCORBIC ACID CONTENT OF PEAS

	Ascorbic Acid mgm. per 100 gm.			Ascorbic Acid Per Cent.		
		Canned		Retained		Destroyed
	Raw	Peas	Liquid	Peas	Liquid	
No. of Samples	4	3	3	3	3	3
Range	21.9-25.6	7.9-8.9	8.8-14.8	33.0-37.0	25.5-42.7	20.3-39.5
Mean	24.1	8.4	11.1	35.0	31.9	33.1

third dissolved in the liquid, and one-third destroyed. This is a little lower than the destruction reported by Fellers and Stepat (13) but within the range given by Bessey (5). The ascorbic acid and dehydroascorbic acid content of the canned product has been summarized in Table XV. The average dehydroascorbic acid content of the peas was approximately two-thirds as great as the ascorbic acid concentration, while the amount in the liquid was relatively small. A comparison of commercially-canned and home-canned peas, in relation to the ascorbic acid is shown in Table XVI. Since the size of the pea, and the grade as well as the brand of the commercial products varied, the average figures for the whole group have been used. Slightly more ascorbic acid was found in the home-canned product than in commercially canned peas. No dehydroascorbic acid was found in either the vegetable or the liquid of the commercially-canned product. The total ascorbic acid, which includes the ascorbic acid plus the dehydroascorbic acid concentration for the home-canned peas has also been shown. The percentage of ascorbic acid found in the peas was approximately fifty for both types of canning, while the percentage of total ascorbic acid in the home-canned peas was sixty per cent.

The effect of cooking on the ascorbic acid content of cabbage has been summarized in Table XVII. The retention of the vitamin in the cooked vegetable varied from 37.4 to 53.5 per cent, and the amount dissolved in the cooking water ranged from 25.6 to 50.3 per cent. These results agree well with those reported in literature as shown in Table II. The amount of ascorbic acid destroyed during cooking varied from 1.3 to 33.2 per cent, and a similarly wide variation of 4 to 35 per cent has been reported

TABLE XV

THE ASCORBIC ACID AND DEHYDROASCORBIC ACID CONTENT OF HOME-CANNED PEAS

	Ascorbic Acid mgm. per 100 gm.		Dehydroascorbic Acid mgm. per 100 gm.	
	Peas	Liquid	Peas	Liquid
No. of Samples	2	2	2	2
Range	7.9-8.9	8.8-14.8	4.7-6.7	0-2.7
Mean	8.4	11.1	5.7	1.4

TABLE XVI

A COMPARISON OF THE ASCORBIC ACID CONTENT OF COMMERCIALLY-CANNED AND HOME-CANNED PEAS

Type of Canning		Ascorbic Acid mgm. per 100 gm.		Ascorbic Acid Percent	
		peas	Liquid	Peas	Liquid
Commercial	No. of Samples	9	9	9	9
	Range	2.7-7.3	6.0-14.2	43.2-64.3	41.9-54.1
	Mean	6.2	11.1	51.5	48.5
Home-Canned	No. of Samples	3	3	3	3
	Range	7.9-8.9	8.8-14.8	46.0-58.0	42.0-53.6
	Mean	8.4	11.1	52.8	47.2
Home-Canned Total Asc.Ac.	No. of Samples	2	2	2	2
	Range	13.1-15.6	11.5-14.8	59.7-60.2	39.8-40.3
	Mean	14.4	13.2	60.0	40.0

TABLE XVII

THE ASCORBIC ACID CONTENT OF COOKED CABBAGE

	Ascorbic Acid mgm. per 100 gm.			Ascorbic Acid Per Cent		
	Raw	Cooked	Water	Retained	Dissolved	Destroyed
No. of Samples	9	9	9	9	9	9
Range	40.5-54.6	15.2-27.4	5.2-9.2	37.4-53.5	25.6-50.3	1.3-33.2
Mean	51.7	23.6	7.2	45.6	40.1	14.4

in literature.

A comparison was made between the retention of ascorbic acid in cooked fresh cabbage and cooked stored cabbage, and the results summarized in Table XVIII. There was no difference between the retention of the vitamin in the cooked fresh vegetables and that retained by cooked stored cabbage. This shows that if "apparent vitamin C" was formed during storage, it does not affect the retention of ascorbic acid in the cooked product.

The dehydroascorbic acid content of cabbage has been summarized in Table XIX. In both the raw and the cooked vegetable the concentration of dehydroascorbic acid was about twenty per cent of the ascorbic acid content, while very little or none at all was found in the water.

The effect of keeping cooked cabbage hot for thirty and sixty minutes after cooking has been summarized in Table XX. The additional loss in thirty minutes was 9.2 per cent, and in sixty minutes it was 21.3 per cent. The total destruction during the cooking and holding for thirty minutes was 67.3 per cent, and 79.4 per cent in sixty minutes. This shows the great destruction of ascorbic acid which would be encountered when the vegetable was kept hot on a steam-table. The destruction was greater than the 60 per cent in one hour reported by Lampitt, Baker and Parkinson (31), Allen and Mapson (1) and Olliver, (56) but agrees with the results of Hollyman Brodie and Willard. (24)

The effect of adding salt to the cooking water of cabbage has been summarized in Table XXI. The retention of ascorbic acid in the vegetable was fourteen per cent higher when salt was used. Table XXII shows the effect of salt in the retention of ascorbic

TABLE XVIII

THE RETENTION OF ASCORBIC ACID IN COOKED FRESH AND STORED CABBAGE

Cabbage		Ascorbic Acid mgm. per 100 gm.		Ascorbic Acid
		Raw	Cooked	Retention Per Cent
Fresh	No. of Samples	5	5	5
	Range	32.2-38.8	14.7-15.8	38.1-48.9
	Mean	34.3	15.1	44.2
Stored	No. of Samples	9	9	9
	Range	40.5-57.1	15.2-27.4	37.5-51.2
	Mean	49.7	21.1	45.6

TABLE XIX

THE DEHYDROASCORBIC ACID CONTENT OF CABBAGE

	Dehydroascorbic Acid mgm. per 100 gm.		
	Raw	Cooked	Water
No. of Samples	3	3	3
Range	3.5-12.6	2.4-7.5	0.0-0.6
Mean	8.0	5.0	0.1

TABLE XX

THE EFFECT OF HOLDING CABBAGE AFTER COOKING ON THE ASCORBIC ACID CONTENT

	Ascorbic Acid mgm. per 100 gm.				Ascorbic Acid Retained Per Cent		
	Raw	Cooked	Held 30 Min.	Held 60 Min.	Cooked	Held 30 Min.	Held 60 Min.
No. of Samples	6	5	5	5	5	5	5
Range	40.5-57.1	15.2-27.2	10.1-24.5	2.8-17.2	37.5-51.2	24.9-45.7	7.2-30.1
Mean	49.7	21.1	16.6	10.8	41.9	32.7	20.6

TABLE XXI

THE EFFECT OF SALT ON THE RETENTION OF ASCORBIC ACID IN COOKED CABBAGE

		Ascorbic Acid mgm. per 100 gm.			Ascorbic Acid
		Raw	Cooked	Water	Retained Per Cent
No Salt	No. of Samples	4	4	4	4
	Range	32.2-38.8	14.7-15.8	5.9-7.4	38.1-48.9
	Mean	34.5	15.1	6.6	44.2
Salt	No. of Samples	4	4	4	4
	Range	32.3-38.8	16.3-19.1	2.8-5.4	42.0-59.1
	Mean	34.5	17.7	4.1	50.5

TABLE XXII

THE EFFECT OF SALT ON THE RETENTION OF ASCORBIC ACID IN COOKED PEAS

		Ascorbic Acid mgm. per 100 gm.			Ascorbic Acid
		Raw	Cooked	Water	Retained Per Cent
No Salt	No. of Samples	3	3	3	3
	Range	25.0-26.4	7.8-11.2	0.9-6.5	35.2-43.0
	Mean	25.5	9.9	3.9	38.7
Salt	No. of Samples	3	3	3	3
	Range	25.0-26.4	9.1-12.9	1.2-7.1	40.4-50.6
	Mean	25.5	11.6	3.4	45.2

acid in cooked fresh peas. The peas cooked with salt retained an average of seventeen per cent more ascorbic acid than those cooked without salt. The retention in unsalted peas varied from 35.2 to 43.0 per cent which is a little lower than the retention reported by Bessey (5) and Fenton, Tressler and King. (17)

The ascorbic acid content of frozen peas was summarized in Table XXIII. The concentration of the vitamin in the raw frozen vegetable was very small, and much lower than that reported in literature as shown in Table I. The retention of ascorbic acid in the cooked peas varied between 48.2 and 70.3 per cent, which agrees with the results reported in the literature as summarized in Table II. The ascorbic acid dissolved in the cooking water, however, was found to be very high which led to an apparent gain in ascorbic acid rather than a destruction. The cause of this apparent increase is not known, but it is suggested that it may be due to the formation of "apparent vitamin C" during cooking as reported by Tuba, Hunter and Steele. (75)

The effect of cooking on the ascorbic acid concentration of stored potatoes has been summarized in Table XXIV. The retention of ascorbic acid by the cooked vegetable varied from 50.4 to 87.2 per cent. This agrees well with the results reported in the literature as shown in Table II, which vary from 53 to 87 per cent. The amount of the vitamin dissolved in the cooking water was found to be very high which led to an apparent gain in ascorbic acid, such as was found in the case of frozen peas.

The ascorbic acid content of freshly harvested potatoes was summarized in Table XXV. The average retention by the uncooked vegetables was considerably lower than the average retention for

TABLE XXIII

THE ASCORBIC ACID CONTENT OF COOKED FROZEN PEAS

	Ascorbic Acid mgm. per 100 gm.			
	Raw	Cooked	Water	Ascorbic Acid Retained Per Cent
No. of Samples	5	5	5	5
Range	2.7-4.4	1.3-3.1	0.0-2.0	48.2-70.5
Mean	3.5	2.2	1.3	60.7

TABLE XXIV

THE ASCORBIC ACID CONTENT OF COOKED POTATOES

	Ascorbic Acid mgm. per 100 gm.			Ascorbic Acid
	Raw	Cooked	Water	Retained Per Cent
No. of Samples	7	7	7	7
Range	5.2-13.9	3.2-9.0	1.2-4.4	50.4-87.2
Mean	7.8	5.2	3.0	70.1

TABLE XXV

THE EFFECT OF SOAKING AND COOKING ON THE ASCORBIC ACID CONTENT OF POTATOES

Potatoes		Ascorbic Acid mgm. per 100 gm. Raw	Ascorbic Acid mgm. per 100 gm. Cooked	Ascorbic Acid Retained Per Cent
Unsoaked	No. of Samples	3	3	3
	Range	6.1-8.9	3.0-5.2	49.2-58.4
	Mean	7.4	3.9	52.5
Soaked	Range	6.1-8.9	3.8-5.2	58.4-62.3
	Mean	7.4	4.4	60.1

stored vegetables, but within the range found. There was also an apparent gain in ascorbic acid similar to the one found in stored potatoes.

The effect of soaking potatoes in tap water has been summarized in Table XXVI. No difference in the ascorbic acid content between soaked and unsoaked potatoes was noted. However Table XXV shows the effect of cooking potatoes after soaking. The percentage retention of ascorbic acid by the vegetable was found to be fourteen per cent higher in the soaked potatoes than in the unsoaked ones.

Table XXVII shows the effect of peeling raw potatoes and exposing them to the air. There was no change in the ascorbic acid content after forty-five minutes exposure.

The dehydroascorbic acid content of potatoes was found to be very low with a variation of from 0 to 3.5 mgm. per 100 gm. in the raw vegetable, and none at all in the cooked vegetable and cooking water.

TABLE XXVI

THE EFFECT OF SOAKING POTATOES IN TAP WATER

	Ascorbic Acid mgm. per 100 gm.	
	Unsoaked	Soaked
No. of Samples	4	4
Range	5.0-8.9	4.8-9.2
Mean	7.0	7.1

TABLE XXVII

THE EFFECT OF EXPOSING PEELED RAW POTATOES TO THE AIR

	Before Exposure	Ascorbic Acid mgm. per 100 gm.	
		15 Min.	45 Min.
No. of Samples	4	4	4
Range	2.3-10.6	3.3-9.8	4.8-9.6
Mean	6.8	7.0	7.2

SUMMARY

A very wide variation exists in the ascorbic acid content of raw vegetables, not only between varieties but also within a variety. There is a gradual decrease in the vitamin concentration during maturation of both peas and cabbage. The highest concentration found in peas was when they were small, tender and had not reached full maturity. Although differences in the vitamin concentration throughout the cabbage head was noticed the average content of the inner and outer tissues differed very little, while the content of the core was forty per cent higher than that of other tissues.

There was no loss during refrigerator storage of peas for three days, but an abrupt decrease of twenty-five per cent was noticed on the fourth day. Cabbage was found to keep for six days with very little or no loss in the vitamin. There was no loss in the ascorbic acid content of two varieties of cabbage during root-house storage for six months, while potatoes, on the other hand, lost from fifty-four to sixty-seven per cent during this time, with the greatest decrease during the first two months.

During the canning of peas approximately one-third of the original vitamin content was retained by the vegetable, one-third dissolved in the liquid and one-third destroyed. The vitamin content of the home-canned peas was found to be a little higher than the average content of a group of commercially-canned products found on the Winnipeg retail market. In both types fifty per cent of the vitamin was retained by the peas and fifty per cent dissolved in the liquid.

The retention of ascorbic acid in potatoes after cooking was the highest of the three vegetables, averaging seventy per cent. Cabbage retained an average of thirty-nine per cent of the original raw ascorbic acid content. The average amount of the vitamin in the cooking water of cabbage was forty per cent, and the amount destroyed fourteen per cent. Frozen peas retained an average of sixty-one per cent of the content of the raw frozen state. In the case of both potatoes and frozen peas, the amount of the vitamin dissolved in the cooking water was high, which led to an apparent gain in ascorbic acid during cooking. It is suggested that this may have been due to an increase in "apparent vitamin C". The phenomenon may have been present also in cabbage tests, but because the original ascorbic acid content was high, and the loss in cooking large, it would not be evident.

There was no difference in the retention of ascorbic acid during the cooking of stored or fresh cabbage and potatoes. This suggests that no "apparent vitamin C" was formed during the storage of the raw vegetables.

No change in the ascorbic acid concentration was found during the soaking of potatoes for three hours in tap water. However when the soaked vegetables were cooked, the retention of the vitamin in the cooked product was consistently higher than that of the unsoaked samples. Exposing potatoes for forty-five minutes in the air caused no loss in the ascorbic acid concentration, even though the vegetables were badly discolored.

BIBLIOGRAPHY

(1) Allen, R.J.L. and Mapson, L. W. J. Soc. Chem. Indus. 63:78-83. 1944.

"The Drying of Vegetables. II. The Loss of Ascorbic Acid During the Cooking of Fresh and Dried Cabbage."

(2) American Medical Association. Am. Med. Assoc. Chicago. 1939.

"The Vitamins."

(3) Bacharach, A.L. and Coates, M.E. Chem. and Indus. 64:10. 1945.

"A Note on Day to Day Variations in Vitamin-C Content of Bought and Culled Vegetables."

(4) Bessey, O.A. J. Biol. Chem. 126:771-784. 1938.

"A Method for the Determination of Small Quantities of Ascorbic Acid and Dehydroascorbic Acid in Turbid and Colored Solutions in the Presence of Other Reducing Substances."

(5) Bessey, O.A. J. Am. Med. Assoc. 111:1290. 1938.

"Vitamin C: Method of Assay and Dietary Sources."

(6) Bessey, O.A. and King, C.G. J. Biol. Chem. 103:687-698. 1933.

"The Distribution of Vitamin C in Plant and Animal Tissues, and its Determination."

(7) Birch, T.W., Harris, L.J. and Ray, S.N. Nature, 131:273-274. 1933.

"Hexuronic (Ascorbic) Acid as the Antiscorbutic Factor, and its Chemical Determination."

(8) Borsook, H. The Viking Press. New York. 1941.

"Vitamins - What They Are and How They Can Benefit You."

(9) Brinkman, E.V.S., Halliday, E.G., Hinman, W.F. and Hamner, R.J. Food Research, 7:301-305. 1942.

"Effect of Various Cooking Methods upon Subjective Qualities and Nutritive Values of Vegetables."

(10) Burell, R.C., Brown, H.D. and Ebright, V.R. Food Research, 5:247. 1940.

"Ascorbic Acid Content of Cabbage as Influenced by Variety, Season and Soil Fertility."

(11) Cohen, B. and Mendel, L.B. J.Biol. Chem. 35:425-453. 1918.

"Experimental Scurvy of the Guinea Pig in Relation to the Diet."

(12) Canadian Council of Nutrition. Can. J. Pub. Health, 36:272. 1945.

"The Construction and Use of Dietary Standards."

(13) Esselen, W.B. Jr., Lyons, M.E. and Fellers, C.R. Mass. Ag. Exp. Sta. Bull. 390:2-19. 1942.

"The Composition and Nutritive Value of Potatoes with Special Emphasis on Vitamin C."

(14) Euler, H. v. and Klussmann, E. Ark. f. Kemi. Min. Geol. 11b. (7). 1932-33. Abstracted in : Nut. Abst. and Rev. 3:89. 1933.

"Biochemical Experiments on Vitamin C and Sugar Derivitives."

(15) Fellers, C.R. and Stepat, W. Am. Soc. Hort. Sc. Proc. 33:627. 1936.

"Effect of Shipping, Freezing and Canning on the Ascorbic Acid (Vitamin C) Content of Peas."

(16) Fenton, F. and Tressler, D.K. Food Research, 3:409-416. 1938.

"Losses of Vitamin C During Commercial Freezing, Defrosting and Cooking of Frosted Peas."

(17) Fenton, F., Tressler, D.K. and King, C.G. J. Nut. 12:285-295. 1936.

"Losses of Vitamin C. During the Cooking of Peas."

(18) Fitzgerald, G.A. and Fellers, C.R. Food Research, 3:109-120. 1938

"Carotene and Ascorbic Acid Content of Fresh Market and Commercially Frozen Fruits and Vegetables."

(19) Gould, S. and Tressler, D.K. Food Research, 1:427-434. 1936.

"Vitamin-C Content of Vegetables. V. Cabbage."

(20) Harris, L. J. University Press. Cambridge. 1937.

"Vitamins in Theory and Practise."

(21) Harris, L.J. P. Blakiston's Son and Company Inc. Philadelphia. 1938.

"Vitamins and Vitamin Deficiencies."

(22) Haworth, W.N. Chem. and Indus. 52:482-485. 1933.

"The Constitution of Ascorbic Acid."

(23) Hirst, E.L. Chem. and Indus. 52:221. 1943.

"The Structure of Ascorbic Acid."

(24) Hollyman, B.F., Brodie, J.B. and Willard, A.C. J. Can. Diet. Assoc. 5:123-130. 1944.

"The Influence of Storage and of Cooking on the Vitamin C Content of Vegetables."

(25) Holst, A. and Frölich, L. Zentr. Biochem. Biophys. 10:231. 1910.

"Antiscorbutic Properties of Some Vegetables."

(26) Holst, A. and Frölich, L. Z. Hyg. 72:1-120. 1912. Abstracted in: Chem. Abst. 6:2456. 1912.

"Experimental Scurvy."

(27) Jenkins, G.N. Nature, 151:473. 1943.

"Ascorbic Acid in Mashed Potatoes."

(28) Jenkins, R.R., Tressler, D.K. and Fitzgerald, G.A.

"Vitamin Content of Vegetables. VIII. Frozen Peas."

(29) Julen, G. Lantbruks-Hogsk. Ann. 9:294-309. 1941. Abstracted in: Nut. Abst. and Rev. 13:394. 1944.

"The Potato as a Source of Vitamin C."

(30) Julen, G. Expt. Sta. Rec. 93:377-78. 1945.

"The Potato as a Source of Vitamin C?

(31) Kahn, R.M. and Halliday, E.G. J. Am. Diet. Assoc. 20:220-222. 1944.

"Ascorbic Acid Content of White Potatoes as Affected by Cooking and Standing on a Steam-Table."

(32) Karikka, K.J., Dudgeon, L.T. and Hauk, H.M. J. Ag. Research, 68:49. 1944.

"Influence of Variety, Location, Fertilizer and Storage on Ascorbic Acid Content of Potatoes Grown in New York State."

(33) Karrer, P., Solomon, H., Schöpp, K. and Morf, R. Helv. chim. Acta. 16:181-183. 1933. Abstracted in: Nut. Abst. and Rev. 3:86. 1933.

"Antiscorbutic Vitamin C."

(34) Karrer, P., Schöpp, K. and Zehender, F. Helv. chim. Acta. 16: 1161-1163. 1933. Abstracted in: Nut. Abst. and Rev. 3:997. 1934.

"Vitamin C."

(35) King, C.G. Indus. Eng. Chem. Anal. Ed. 13:225-227. 1941.

"Chemical Methods for the Determination of Vitamin C."

(36) Lampitt, L.H., Baker, L.C. and Parkinson, T.L. J. Soc. Chem. Indus. 62:61-67. 1943.

"Vitamin-C Content of Raw and Cooked Vegetables."

(37) Lampitt, L.H., Baker, LC. and Parkinson, T.L. J. Soc. Chem. Indus. 64:200-202. 1945.

"Vitamin-C Content of Vegetables. Part II. Effect of Storage on Raw Vegetables."

(38) Lampitt, L.H., Baker, L.C. and Parkinson, T.L. J. Soc. Chem. Indus. 64:22-26. 1945.

"Vitamin-C Content of Potatoes. II. The Effect of Variety, Soil and Storage."

(39) Lampitt, L.H., Baker, L.C. and Parkinson, T.L. J. Soc. Chem. Indus. 64:202-203. 1945.

"Vitamin-C Content of Vegetables. Part III. Average Figures for Raw Vegetables."

(40) Levy, E.F. Biochem. J. 37:714-716. 1943.

"The Determination of Ascorbic Acid in the Presence of Interfering Substances, Notably Reductones."

(41) Loeffler, H.J. and Ponting, J.D. Indus. Eng. Chem. Anal. Ed. 14:846-849. 1942.

"Ascorbic Acid: Rapid Determination in Fresh, Frozen or Dehydrated Fruits and Vegetables."

(42) Lugg, J.W.H. Nature, 150:577. 1942.

"The Use of Formaldehyde in the Estimation of Ascorbic Acid and Dehydro-ascorbic Acid."

(43) Mack, G.L., Tressler, D.K. and King, C.G. Food Research, 1:231-235. 1936.

"Vitamin-C Content of Vegetables. II. Peas."

(44) Mapson, L.W. Chem. and Indus. 60:802. 1941.

"The Determination of Ascorbic Acid in Food-stuffs Containing SO_2."

(45) Mapson, L.W. J. Soc. Chem. Indus. 62:223-232. 1943.

"Vitamin Methods: VI. The Estimation of Ascorbic Acid in the Presence Reductones and Allied Substances."

(46) Maynard, L.A. and Beeson, L.C. Nut. Abst. and Rev. 13:155. 1943.

"Some Causes of Variation in the Vitamin Content of Plants Grown for Food."

(47) McCollum, E.V., Orent-Keiles, E. and Day, H.G. The MacMillan Company, New York. 1939.

"The Newer Knowledge of Nutrition."

(48) McIntosh, J.A., Tressler, D.K. and Fenton, F.J. Home. Econ. 34:314-318. 1942.

"Ascorbic Acid Content of Five Quick-Frozen Vegetables."

(49) Micheel, F. and Kraft, K. Ztschr. f. physiol. Chem. 222:235-249. 1933. Abstracted in: Nut. Abst. and Rev. 3:997. 1934.

"The Constitution of Vitamin C.".

(50) Morell, S.A. Indus. Eng. Chem. Anal. Ed. 13:793-794. 1941.

"Rapid Photometric Determination of Ascorbic Acid in Plant Materials."

(51) Morgan, A.F., MacKinney, G. and Cailleau, R. Food Research, 10:5-15. 1945.

"Losses of Ascorbic Acid and Four B Vitamins in Vegetables as a Result of Dehydration, Storage and Cooking."

(52) Murphy, E.F. Maine Ag. Expt. Sta. Bull. 426. 1944.

"The Vitamin C Content of Maine Foods."

(53) Murphy, E.F., Dove, W.F. and Akeley, R.V. Am Potato J. 22:62-81 1945.

"Observations on Genetic, Physiological and Environmental Factors Affecting the Vitamin C Content of Main Grown Potatoes.

(54) National Research Council of the United States. J. Am. Diet. Assoc. 17:565. 1941.

"Recommended Allowances for Various Dietary Essentials."

(55) Noble, I. and Waddell, E. Food Research 10:246-254. 1945.

"Effects of Different Methods of Cooking on the Ascorbic Acid Content of Cabbage."

(56) Olliver, M. Chem. and Indus. 60:586-596. 1941.

"The Effect of Cooking on the Nutritive Value of Vegetables."

(57) Pett, L.B. J. Am. Diet. Assoc. 21:220. 1945.

"Canadian Trends in Food and Nutrition."

(58) Pett, L.B. Can. J. Public Health, 36:69-73. 1945.

"Errors in Applying Nutrient Allowances to Dietary Surveys or Food Policies."

(59) Reichstein G. and Grussner, A. Helv. chim. Acta. 17:311-328. 1934. Abstracted in: Nut. Abst. and Rev. 4:63. 1934.

"The Productive Synthesis of l-Ascorbic Acid, Vitamin C."

(60) Reichstein, T., Grussner, A. and Oppenauer, R. Nature, 132:280. 1933.

"Synthesis of d-and l-Ascorbic Acid."

(61) Roe, J.H. and Keuther, C.A. J. Biol. Chem. 147:399-407. 1943.

"The Determination of Ascorbic Acid in Whole Blood and Urine Through the 2-4 Dinitrophenylhydrazine Derivitive of Dehydroascorbic Acid."

(62) Roe, J.H. and Oesterling, M.J. J. Biol. Chem. 152:511-517. 1944.

'The Determination of Dehydroascorbic Acid and Ascorbic Acid in Plant Tissues by the 2-4. Dinitrophenylhydrazine Method."

(63) Sherman, H. C. The MacMillan Company. New York. 1941.

"Chemistry of Food and Nutrition."

(64) Sherman, H. C., LeMar, V. K. and Campbell, H.L. J. Am. Chem. Soc. 44:165-172. 1922.

"The Quantitative Determination of the Antiscorbutic Vitamin (Vitamin C)."

(65) Sherman, H. C. and Smith S.L. Chemical Catalogue Company, Inc. New York. 1922.

"The Vitamins."

(66) Stepp, W. O., Kuhnau, and Schroeder, H. Translate by: Baumann, A.H. The Vitamin Products Company. Milwaukee. 1938.

"The Vitamins and Their Clinical Applications."

(67) Szent-Györgyi, A. Biochem. J. 22:1387-1409. 1928. Abstracted in: Chem. Abst. 23:1423. 1929.

"Observations on the Function of Peroxidose Systems and the Chemistry of the Adrenal Cortex. Description of a New Carbohydrate Derivitive."

(68) Szent-Györgyi, A. Nature, 129:943. 1932.

"The Identity of Hexuronic Acid as Vitamin C."

(69) Szent-Györgyi, A. and Haworth, W. N. Nature, 131:24. 1933.

"Hexuronic Acid (Ascorbic Acid) as the Antiscorbutic Factor."

(70) Tillmans, J. and Hirsch, P. Biochem. Ztschr. 250:312-320. 1932. Abstracted in: Nut Abst. and Rev. 2:505. 1933.

"Vitamin C."

(71) Todhunter, E.N. and Robbins, R.C. Wash. Ag. Expt. Sta. Bull. 408. 1941.

"Ascorbic Acid Content of Garden-Type Peas Preserved by the Frozen Pack Method."

(72) Todhunter, E.N. and Sparling, B.L. Food Research, 3:489-498. 1938.

"Vitamin Values of Garden-Type Peas Preserved by the Frozen-Pack Method. I. Ascorbic Acid (Vitamin C).

(73) Tressler, D.K. Ice and Cold Storage, 41:141. 1938.

"Importance of Refrigeration in Conserving the Vitamin

C Content of Fresh Vegetables." Taken from: Fenton, F. J. Am. Diet. Assoc. 16:524-535. 1940.

"Vitamin C. Retention as a Criterion of Quality and Nutritive Value in Vegetables."

(74) Tressler, D.K., Mack, G.L. and King, C.G. Am. J. Public Health. 26:905-909. 1936.

"Factors Influencing the Vitamin C Content of Vegetables."

(75) Tuba, J., Hunter, G. and Steele, H.R. Can. J. Research, B, 24:1-37. 1946.

"On the Specificity of Dye Titration fo Ascorbic Acid."

(76) Van Duyne, F.O., Bruckhart, S.M., Chase, J.T. and Simpson, J. E. J. Am. Diet. Assoc. 21:153-154. 1945.

"Ascorbic Acid Content of Freshly Harvested Vegetables."

(77) Van Duyne, F.O., Chase, J.T. and Simpson, J.I. Food Research 9:164-173. 1944.

"Effect of Various Home Practises on the Ascorbic Content of Cabbage."

(78) Van Duyne, F.O., Chase, J.T. and Simpson, J.I. Food Research 10:72-81. 1945.

"Effect of Home Practises on the Ascorbic Acid Content of Potatoes."

(79) Waugh, W.A. and King C.G. J. Biol. Chem. 97:325-331. 1932.

"Isolation and Identification of Vitamin C."

(80) Wellington, M. and Tressler, D.K. Food Research, 3:311-316. 1938.

"Vitamin C Content of Vegetables. I. Influence of Method of Cooking on Vitamin C Content of Cabbage."

(81) Wokes, F. Nature, 154:669-670. 1944.

"Apparent Vitamin C as a Possible Precursor of True Vitamin C in Walnuts."

(82) Wokes, F., Organ, J. G. and Jacoby, F.C. J. Soc. Chem. Indus. 62:232-236. 1943.

"The Estimation of Apparent Vitamin C in Foods."

(83) Young, E.G., Sylventre, J.E. and Nadeau, H.; Patterson, J.M. and McHenry, E.W.; Hunter, G. and Pett, L.B. Can. J. Public Health, 32:6-11, 11-21, 21-29. 1941. Hiltz, M.C. Can. J. Public Health, 34:6-9. 1943.

"Canadian Studies on Nutrition."

(84) Zilva, S.S. Biochem. J. 18:632-637. 1924. Abstracted in: Chem. Abst. 18:3411. 1924.

"Antiscorbutic Fraction of Lemon Juice."