CERTAIN EFFECTS OF PACKING FRESH VEGETABLES AND FRUITS IN CRACKED ICE

by

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INTRODUCTION

Nutrition research has shown that a certain amount of vitamin C is required regularly by each individual as a physiological aid to good health. Fruits and vegetables are the principal sources of vitamin C for the human diet and frequently they are purchased on this account. The value of any vegetable or fruit as a food product depends primarily upon its composition and palatability. Both are generally influenced by the stage of maturity at which the material is prepared for use.

While a vegetable is growing and coming to its optimum state of ripening or maturity there is a continuous and rapidly increasing development of ascorbic acid or vitamin C. This vitamin is most susceptible to adverse conditions of storage. Much emphasis is placed at the present time on conservation methods which may be used for preventing food losses and destruction of valuable nutrients in fresh plant products. In vegetables, losses of vitamin C might well be used to indicate general decline in nutritive value and in other attributes such as aroma, color, flavor, and texture, which contribute to quality or taste appeal.

The time factor influences the extent and rate of vitamin loss from fresh produce. Transportation and distribution of fresh fruit and vegetable supplies from the areas where grown to regions where consumed require time. Conditions of temperature, humidity, and time of holding during marketing may be responsible for additional losses of this vitamin.

There are many factors which cause variation in food value, particularly vitamin C before vegetables and fruits reach the kitchen. Difference in variety, cultural conditions and stage of maturity at harvest cause variation in the ascorbic value at the time when produce leaves the field. Careless handling at the farm, such as permitting vegetables to stand exposed to the sun, or holding them overnight in warm quarters, may make them lose over half of their vitamin C in a few hours.

Few results have been reported as to the protection which ice, in direct contact with vegetables and fruits, may have on nutritive value and quality.

It is the purpose of the present study to determine the changes during temporary storage of fresh produce which had been kept at room temperature as compared with duplicate lots which had the protective effect of cracked ice from time of harvest and during the period of time in which the testing was being done.

The program of research work on retention of vitamin content and marketability of fresh fruits and vegetables was initiated by the National Association of Ice Industries. Projects are being sponsored by various state and regional unit associations.

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REVIEW OF LITERATURE

Many investi ators have studied the source and magnitude of the factors causing variations in vitamin content. Results indicate that there are several stages during which the vitamin C content of a food is subject to variation. Natural variations in the vitamin content of the food as harvested have been shown to result from the effects of various factors during the time the crop is growing. These factors include climate and soil, variety and degree of maturity and selective concentration in different parts of the plant. Adams and Smith (1944) discussed these factors in detail.

Fenton (1940) has found a close correlation existing between the nutritive value of fruits and vegetables and other attributes such as aroma, color, flavor, and texture which contribute to quality or taste appeal. Once harvested, fruits and vegetables are subjected to ascorbic acid losses when they are being shipped, while they are held in the market and while they are held in the home until prepared for table use. Vitamin C content frequently is used as the index for determining quality in fresh produce. This vitamin is probably not only the most readily destroyed but also the most readily dissolved of all the vitamins.

For years, many common fruits and vegetables have been investigated to learn of ascorbic acid content. Tomatoes have been the subject of extensive research.

McHenry and Graham (1935) found there was an inverse relationship between size and vitamin C content of ripe tomatoes. They concluded there was no apparent advantage, so far as preservation of vitamin C content is concerned in holding tomatoes at cold storage temperatures.

Maclinn, Buck and Fellers (1939) were able to find no correlation between size and vitamin C content in tomatoes. They were in agreement with McHenry and Graham (1935) in their findings that storage of tomatoes at room temperature caused no apparent loss in vitamin C after ten days. Results reported by Currence (1939) were to the effect that tomatoes grown in the greenhouse contained significantly less vitamin C than the same varieties grown in the open field.

The literature shows some disagreement as to whether vitamin C content is influenced by degree of ripeness. Krauss et al. (1937) found a rapid increase in vitamin C content during final softening of ripe tomato fruit but Maclinn and Fellers (1938) concluded that the degree of ripeness did not influence vitamin C content. Tripp and Satterfield (1937) found that soft and overripe tomatoes were lower in ascorbic acid value than firm, ripe ones. Brown and Moser (1941) had consistent results and reported that as the firmness of tomatoes decreased the titration values for ascorbic acid increased.

With acidic vegetables as tomatoes, Tressler, Mack and King (1936) found slight losses of ascorbic acid from vegetables kept at room temperature for a week. Since certain vegetables lose half their vitamin C content when held at room temperature for three days with rate of loss much lower when iced, these workers suggested prompt cooling of all except the more acidic vegetables for retaining full nutritive value of the product. They also suggested that similar studies be continued in order to determine the optimum storage conditions of all vegetables necessary to obtain maximum retention of nutrients.

Hamner et al. (1945) reported that neither the nature of the soil nor fertilizers exerted marked effect on vitamin C content of tomatoes. Variations in ascorbic acid content associated with differences in light intensity were relatively great. The authors inferred from their results that the light intensity to which plants have been exposed just prior to harvest may be the dominant factor in determining ascorbic acid content of tomatoes.

With carrots it has been found that the vitamin C content varied in different portions of the same root. Smith et al. (1944) also reported that the very young pencil size carrots had a higher vitamin C content than those of market size. They found the smaller size to contain five to eight milligrams of ascorbic per 100 grams while those of marketable size contained three to six milligrams per 100 grams. No significant difference was observed in content of ascorbic acid for carrots planted in different months.

Work with asparagus done by Olliver (1936, 1938) showed that the concentration of ascorbic acid decreases progressively from the tips down the stem. Also that the tips of the asparagus shoots are consistently richer in ascorbic acid, even before chlorophyll or any other pigment is produced. The high concentration of ascorbic acid found in green tissues had suggested the association of chlorophyll with the production of the vitamin. It seems probable that ascorbic acid is connected rather with metabolic activity than with pigment formation. Fitzgerald and Fellers (1938) found that the freshness of the asparagus affects the vitamin C potency of the product. Overmaturity, which may be caused by holding after cutting, may also be a deleterious factor.

King (1936) found that ascorbic acid reaches a high concentration in all rapidly growing stem or root tips, green leaves, seeds and pods. Its relatively higher concentration in the tissues where metabolism is highest is further evidence of an essential metabolic role. The close correlation between photosynthetic activity and vitamin concentration points toward an essential relationship, but since the vitamin precedes the appearance of chlorophyll and other carotenoid pigments in the growing plant, it is concluded that vitamin synthesis is only indirectly dependent upon photosynthesis.

For lettuce, Munsell and Kennedy (1935) reported that the outer green leaves of the Iceberg variety contained slightly less vitamin C than the inner bleached ones.

Wheeler, Tressler and King (1939) found that lettuce lost ascorbic acid rapidly when held at common room temperatures in summer. With Iceberg lettuce the loss was rapid even during low temperature storage. Zepplin and Elvehjem (1944) found that packing lettuce directly in ice when harvested was effective in preventing any loss of vitamin C during the first day. When the ice packed container was kept in a cold room, less than ten per cent loss of vitamin C after six days storage was reported. The practice in retail markets of sprinkling the room stored lettuce to keep it fresh was not effective in preserving vitamin content; losses were 50 per cent after 24 hours, and 70 per cent after 48 hours. No conclusive evidence of superiority of either mechanical or ice refrigeration on vitamin retention could be given. The retention of vitamin C in lettuce stored in the hydrator pan was no greater than when stored on the open shelf of the mechanical refrigerator.

For all vegetables studied, Zepplin and Elvehjem (1944) reported ascorbic acid losses proceeding at a rapid rate after harvest if measures were not taken to prevent this loss. They found the rate at which losses occur to vary; relatively slow for peppers, tomatoes, cabbage and root crops, and rapid for leafy vegetables. Since the loss of ascorbic acid from plant tissues is an oxidation process any means used for reducing the rate of oxidation should be effective in inhibiting the destruction of ascorbic acid.

Chappell (1940) concluded that the degree of metabolic activity in the tissues greatly influenced the amount of ascorbic acid found in green vegetables. All heart stems, leaves and developing tissues gave a higher result than outer stems or leaves. Such experimental results indicate that there is a higher vitamin content in the meristematic parts of the plant than in the older tissues.

Green beans have received and continue to receive much attention. It has already been shown by many workers that storage affects the concentration of ascorbic acid in plant tissues. Tressler, Mack and King (1936) reported greater losses of vitamin C from beans held three days at room temperature than from beans held at one to three degrees Centigrade. It was found by Mack, Tapley and King (1939) that the seeds of beans contained three to four times as much ascorbic acid as the seed pods themselves when considered on the fresh basis. Their storage tests confirm results reported by Tressler, Mack and King (1936) in which the rate of loss was less at lower temperatures. Mack, Tapley and King (1939) reported 46 per cent losses at 24 hours, increasing to a maximum of 78 per cent for beans stored six days at room temperature. In comparison with other vegetables, snap beans lose their vitamin C very rapidly in storage except at low temperatures.

Heinze et al. (1944) found pods from spring harvested beans to be significantly higher in ascorbic acid content than those of fall harvest. Similar findings were also reported by Wade and Kanapaux (1943). It also was reported by Wade and Kanapaux (1943) that a slight but highly significant decline was found in the ascorbic acid content of spring crop for the first two pickings over that contained in the third and fourth pickings.

Zepplin and Elvehjem (1944) found small losses in ascorbic acid from green beans stored either at room temperature or in the refrigerator. With the use of cracked ice, Brison (1945) reported slight loss from beans as compared with a loss of 42 per cent for beans held at room temperature for three days.

With the small fruits, Lineberry and Burkhart (1942) found that strawberries grown in direct sunshine were consistently higher in ascorbic acid than those ripened in the shade. Satterfield and Yarbrough (1940) reported that the half of the fruit most exposed to the sun's rays and consequently more highly colored, gave a higher vitamin C value than the other half. It was also found by these workers that the ascorbic acid contents of strawberries show a definite varietal difference.

Hansen and Waldo (1944) reported that blackberries picked during periods of prevailing sunshine generally tended to be higher in ascorbic acid than those picked during periods of cloudy weather. In some cases with blackberries there was a decrease in ascorbic acid content as the season advanced.

Vitamin C content of sweet corn is little mentioned in the literature. From limited data secured by Dunker, Fellers and Fitzgerald (1937), it was found that sweet corn picked early in the season had a somewhat higher ascrobic acid content than that picked at a later date. The practice of holding sweet corn in the husk for several days after picking caused ascorbic acid loss as follows: less than ten per cent at room temperature for 24 hours; 20 per cent after three days and less than 50 per cent loss after four days.

Work with cantaloup done by Wheeler, Tressler and King (1939) included vitamin C determinations on melons which had been stored at different temperatures for varying periods of time. The greatest amount of vitamin C was present at optimum maturity. The green portion of cantaloup contained less vitamin C than the edible portion.

Similar findings by Smith et al. (1944) in Arizona likewise suggest that variability in ascorbic acid content of cantaloup is associated with degree of ripeness and changes during storage. Some evidence which they obtained showed that the soft inside portion of the cantaloup next to the seeds was somewhat higher in both ascorbic acid and carotene than the harder firmer portion next to the rind.

Floyd and Fraps (1939) found cantaloup to contain 24 to 37 milligrams per 100 grams, a larger amount of vitamin C than figures reported by Daniel and Munsell (1937). Wheeler, Trossler and King (1939) reported vitamin C content to be 23 to 48 milligrams per 100 grams for cantaloup.

Testing of peppers by Floyd and Fraps (1939), when working with vegetables and fruits in Texas, showed some striking variations in ascorbic acid content of the same fruit and vegetable. Peppers were high in ascorbic acid content, having over 100 milligrams per 100 grams of vegetable. Ruby King was the highest for all varieties of peppers studied. Their results compared with Daniel and Munsell (1937) on ascorbic acid content of green peppers.

It seemed justifiable, according to Maynard and Beeson (1943), to conclude that the accumulation of ascorbic acid in plants is a characteristic of species and variety and that this genetic influence may overwhelm any differences due to climate, soil or fertilization. Of climatic factors, light seemed to have the greatest influence.

MATERIALS AND METHODS

Supplies of fresh fruit and vegetable products grown near Manhattan, Kansas were secured direct from the grower at the place of production. Advance arrangements were made so that freshly gathered food samples, uniform in quality, would be available. When necessary, a washing and drying treatment was done preliminary to weighing for test use. All products used for these experiments were obtained direct from the fields at the stage of maturity considered suitable for harvesting and marketing. The men who gathered the fresh produce were growers familiar with judging whether the products were ready for market.

Carrots, cantaloup and asparagus were secured from local market-garden growers and obtained direct from the fields.

Berries, green peppers, corn and string beans were supplied from the Department of Horticulture field gardens maintained by the college.

Leaf lettuce and tomatoes were grown in greenhouses on the college campus.

A test series consisted of 19 samples examined in duplicate or replicate for securing data for this study. The first sample which was placed in metaphosphoric acid solution at the field was assayed upon return to the laboratory. This served as the standard possessing the nutritive valus and qualities with which the remaining samples were compared. Two equal portions of the produce were made up into samples of uniform weight when practical. One-half of these samples were placed in ordinary trays or crates for storage on the laboratory counter, but having no protection of ice. The other lot of samples were packed immediately in ice after being weighed. A supply of cracked ice was always taken to the field for this uss. These samples had the protection of ice from the time of harvest and through ths experimental period; the un-iced samples were exposed to ordinary room conditions without undue exposure to strong sunlight or to direct air currents. Records of room temperature were kept.

Weights were again taken for each test sample of fruit or vegetable used before final cutting and analysis. Calculations which are reported represent computations made on the moist weight basis of the fruit and vegetable produce used. As all of the products used contained a low content of dehydroascorbic acid, the same testing technique was employed throughout the series.

Time intervals for the tests were suggested by the National Association of Ice Industries. The first sampling was done at six hour intervals during the first 24 hours and once daily thereafter for a total of six days (See sample data sheet).

Asparagus, Mary Washington variety, was harvested according to the custom of the grower for the local market. Samples for the test series were made up into bundles weighing 100 grams and containing a uniform number of spears of freshly cut asparagus.

Carrots, Chantenay variety, were stored without removing the tops. Three medium or two large carrots were used for each test sample. These were sectioned into eighths from top to tip. Alternate sections from each carrot were used for the test portion. It was not practical to try to follow weights of carrots as previously bunched due to inedible part which was discarded.

Radial sectors were cut from each quarter section of an entire Hale's Best cantaloup for the test sample used. The edible portion was taken down to the green part of the rind after removing seed.

Strawberry, Howard variety; blackberry, El Dorado variety; dewberry, Boysen variety; were weighed at the field and placed in individual chip board baskets in 50 gram amounts. Caps were left on the strawberries until time of using. Berries uniform in size and degree of maturity were used.

Sweet corn, Tender Gold and Trinoka varieties, was prepared for storage by using the custom commonly employed in retail market; that of cutting a short portion from tip of ear. Two ears of corn were used for each test sample. Alternate two row sections were cut from tip to base of each ear, cutting just deeply enough to use the entire kernel. Husks were left on the corn until testing time for each sample lot.

An entire Ruby King green pepper was used for each test sample, having a circular cut made around base of stem to remove core and seeds. Weights were taken after removal of the inedible part.

Lettuce, Grand Rapids variety, was prepared for sampling by using leaves taken from the outer and middle portion of the plant. The small, immature inner leaves were not included. Five leaves were allowed for each sample. Weights of lettuce bundles at time of harvest ranged from 30 to 37 grams. At time of assay, weights were recorded only on samples held at room temperature.

Three medium or two large tomato fruit were allowed for each sample. Cores were cut from the tomato similar to amount discarded when preparing tomatoes for table use. Tomatoes were sectioned into vertical quarters after removal of core. Alternate sections were used to have representative maturity. The two varieties used were Michigan State and Waltham.

String beans of uniform size and maturity were made up into bundles weighing 50 grams which were weighed again at time of using for the test. The six varieties used were: Tender Green, Stringless Green Pod, Bountiful, Pencil Pod, Unrivalled Wax, and Golden Bountiful Wax.

Ascorbic acid concentration was determined by the extensively used 2,6 dichlorophenol-indophenol technique described by Bessey and King (1933), modified by Mack and Tressler (1937) as described by Bessey (1939).

All determinations for vegetables and fruits were made on raw products. In carrying out an analysis the food product was prepared according to description given as to method of sampling. Metaphosphoric acid was used for each sample, which, when made up to 500 milliliter volume represented a three per cent concentration. A thorough blending of the acid and food sample was generally completed in one to two minutes in the Waring blendor and was never prolonged to the point of heating of the mixture. When the blending was complete, the material clinging to the sides of the mixing cylinder was washed down with distilled water; transferred to a flask and made up to

500 milliliter volume before filtering. A five or ten milliliter aliquot of the filtrate was used in duplicate or triplicate for titration. In this study all titrations were made rapidly on the acidified samples, in no case using a maximum of more than two minutes so the total titration value is reported as ascorbic acid content. A faint pink coloration which persisted for ten seconds was the end point to which the titrations were made.

The dye solution was prepared by dissolving 0.1 gram of 2,6 dichlorophenol-indophenol (Eastman Kodak) with successive portions of hot distilled water, filtering and diluting to 200 milliliters with thorough blending and cooling before use. Dye solutions were freshly made every three days; refrigerator storage was used for the dye solutions.

The dye solution was standardized by titration against aliquots of pure ascorbic acid solution of known concentration, prepared in the same acid medium as that used for the extracts of food. The standard solution of ascorbic acid was made fresh each week. A five milliliter aliquot of the prepared pure ascorbic acid solution was titrated with 0.01 normal iodine solution until a permanent bluing of the starch indicator resulted. The iodine solution was standardized with arsenious oxide made according to Association of Agricultural Chemists standards. Since one milliliter of the 0.01 normal iodine solution reacts with 0.88 milligram of ascorbic acid, the ascorbic equivalent of the dye solution was readily calculated.

Titrations for standardization were carried out so that the end point was reached in ten seconds or less.

All samples were analyzed in duplicate or triplicate according to the above procedure and the results of the analysis were averaged. Calculations were made to show milligrams of ascorbic acid per 100 grams of vegetable or fruit as harvested.

Determinations for dehydro-ascorbic were deemed unnecessary because no foods studied contained appreciable amounts as reported by Roe and Oesterling (1944).

Results of each test assay were recorded on data sheets which were a modification of ones suggested by T. B. Gilliam, Research Director of National Association of Ice Industries (See sample data sheet).

In each case the freshly harvested vegetable packed in cracked ice at the field was compared with the same vegetable not iced which had been stored at room temperature.

Supplementary Tests

Variability in ascorbic acid values for the peppers tested suggested the possibility that environmental factors as well as plant yield might influence vitamin C content. More than 125 peppers were examined from various aspects.

Additional experiments were conducted as follows:

1. All peppers from a single plant which were considered of marketable maturity were tested.

2. Plants yielding many peppers were compared with plants having but a few to ascertain whether those plants bearing few peppers might store greater amounts of vitamin C per individual pepper than plants supporting greater yields.

3. Investigations were made to determine the effect on ascorbic value which intensity of sunlight might have according to position of peppers on the plant. Peppers matched as to size and maturity from the same plant and having equal amount of exposure to sunlight were tested.

4. Stem end and blossom end portions of peppers were tested as this might be representative of portions of pepper which would be an individual serving for meal use.

In a single lettuce plant there could be noted differences in size of leaves as well as intensity of coloring. Additional experiments were conducted as follows:

1. Using all of the leaves from a single plant.

2. Using leaf portions selected according to the position of growth. This latter grouping consisted of:

a. Large size leaves representing the outside darker green colored ones.

b. Medium sized leaves which were intermediate in position according to plant location, development, and with much lighter coloring.

c. Small leaves representing the immature, almost colorless leaves of the innermost portion of the plant. These likely would be discarded due to size and color if leaf lettuce were being used principally as a base for salad use.

With string beans a study of three green pod varieties were made. Harvesting of beans was done at three different periods.

DISCUSSION

A report of temperature and rainfall for the six months period was obtained from the local station of the United States Weather Bureau maintained by the College Physics Department. For the six-month growing period the following information is submitted:

	Inches rainfall	Fahrenheit Mean maximum temperature	Fahrenheit Mean minimum temperature
April	7.47	66.06	43.77
May	4.45	73.40	48.93
June	7.93	78.76	59.16
July	7.53	87.93	65.51
August	2.25	90.54	66.45
September	4.58	81.70	57.27

The 1945 growing season was abnormal, rainfall was approximately 50 per cent greater than normal. Excessive rainfall and cool weather delayed the growth and development of plant products; harvesting was done at dates later than normal for such products.

A soil survey map of Riley County supplied data for areas from which crops were secured. Laurel silt loam was the soil type at the Horticulture farm where supplies of dewberries, strawberries, blackberries, green beans and sweet corn were obtained. Marshall silt loam was the soil type in the campus garden where green peppers, and snap beans were grown. Wabash silt loam was soil type on the farm which supplied the asparagus. Laurel fine sandy loam was soil type of truck garden producing the carrots and cantaloup. It was not possible to classify the soil type used in the greenhouse vegetable beds.

Carrots were considered to be of marketable size three weeks before they were harvested for testing. Delayed harvesting was considered advisable due to lack of sufficient moisture during August for carrots to be taken easily from the ground. The truck farmer who raised the cantaloup reported that the seed secured in 1945 was an impure strain. This lack of uniformity of seed also resulted in a lack of uniformity of maturity when the crop was harvested.

Storage in cracked ice kept the products at not to exceed 34° F. Room temperatures as recorded by a Taylor thermograph ranged from 66.5° F. to 87.8° F. Ordinarily the temperatures did not drop below 70° F. There was no really hot weather during the course of these experiments.

Data in the tables give the ascorbic acid content for each vegetable and fruit used on the fresh weight basis. Comparisons are shown for each product tested when (a) freshly harvested, (b) stored at room temperature, and (c) packed in cracked ice.

Data, Table 1, show initial ascorbic acid contents for asparagus cut on two different dates to be similar. For room temperature storage, the per cent of loss at the 18 hour time period was double that occurring at 12 hours. The rate of loss of ascorbic acid was rapid, with less than 50 per cent remaining by the end of the second day. The rate of loss was consistent for both series during the first 48 hours. Average losses of ascorbic acid were as high as 80 per cent by the end of the fourth day when asparagus was considered inedible.

The asparagus stored in ice retained most of its ascorbic acid for the first three days. The average apparent gains made any time during the test week never exceeded four per cent. During the last three days both series were making consistent losses with maximum losses reaching over 40 per cent by the end of the test week. The average amount of ascorbic acid retained by the end of the experiment for asparagus stored in ice was approximately the same as that found in the room stored asparagus at the end of 24 hours.

Asparagus stored in ice for eight days was considered to be in better condition than sample which had been stored in a mechani al refrigerator for the corresponding time. After 14 days storage in ice the vegetable had good color, was fresh in appearance and crisp.

Plate I shows asparagus after eight days' storage.

EXPLANATION OF PLATE I

Mary Washington Asparagus

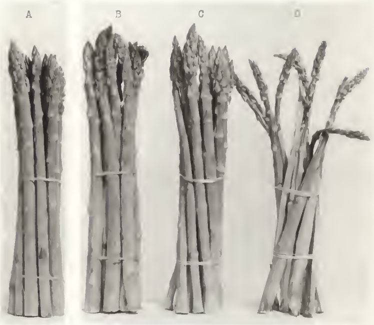
A - Initial sample.

B - Sample after eight days' storage in cracked ice.

C - Sample after eight days'storage in mechanical refrigerator.

D - Sample after eight days' storage at room temperature.

PLATE I



Data for snap beans, Table 2, were analyzed by statistical methods. The variables included: three varieties each of yellow and of green pod beans, three harvest dates, and two storage treatments.

Ice storage significantly retarded the loss of ascorbic acid for all varieties; and likewise for all periods.

The sampling variation changed significantly from one date to another. This may be due to the number of pickings gathered prior to the experiment.

Varieties and periods produced significant differences in reduction of ascorbic acid content; but those differences were not consistent between the two types of treatment: room temperature and ice storage. Varieties, for example, showed significantly different losses of ascorbic acid under room temperature and also under ice storage; but the varietal comparisons were quite different under the two different treatments.

Rankings made of varieties for each testing period show:

Total per cent ascorbic acid lost per nine units testing time

	Room temperature		Iced	
July 20, 1945	Bountiful	320	Stringless Green Pod	74
	Stringless Green Pod	335	Bountiful	115
	Unrivalled Wax	360	Pencil Pod	190
	Golden Bountiful Wax	372	Unrivalled Wax	292
	Pencil Pod	434	Tender Green	273
	Tender Green	456	Golden Bountiful Wax	283
August 2, 1945	Tender Green	304	Tender Green	59
	Stringless Green Pod	303	Stringless Green Pod	100

	Room temperature		Iced	
	Stringless Green Pod	228	Stringless Green Pod	-13
August 8,	Bountiful	248	Tender Green	26
1945	Tender Green	302	Bountiful	41

Varietal rankings are not consistent. Difference in vitamin C content between green and yellow beans is not significant for either iced or room temperature storage, which may be due to irregularity of ranking of Tender Green variety. Tender Green is significantly poorer than other green varieties of snap beans.

Beans stored at room temperature deteriorated greatly in quality by the end of three days. Dark spots were developing on the pods, and considerable shrinkage in weight had resulted due to dehydrated condition of the beans. The smaller, less matured beans wilted more readily than those more matured.

Accompanying the vitamin losses were fading of color and development of hay-like flavor in the beans when cooked. Beans stored in cracked ice retained crispness, bright green color and characteristic flavor. Their condition was acceptable after two weeks storage in ice.

Reduction of ascorbic acid content of beans

Analysis of Variance[1]

Sources of variation	Degree of freedom	Variance	Probability
		7/20	
Varieties	5	883.13	>.050 <.001
Treatment	1	12,214.00	<.001
Periods	8	2,982.13	<.001 ≐.003
VxT	5	208.88	<.001
VxP	40	45.97	<.050
TxP	8	273.72	<.001
Remainder	40	24.29	
Total	107		
		8/2	
Varieties	1	110.37	ns ns
Treatment	1	13,459.00	<.001 <.001
Periods	8	1,202.70	<.001 <.010
VxT	1	112.96	ns
VxP	8	79.06	ns
TxP	8	172.39	<.050
Remainder	62	73.19	
Total	89		
		8/8	
Varieties	2	187.54	>.500 <.050
Treatment	1	19,087.00	<.050 <.001
Periods	8	2,621.23	<.001 <.050
VxT	2	226.50	.010
VxP	16	33.18	ns
TxP	8	619.25	<.001
Remainder	70	47.71	
Total	107		

[1] Analysis of Variance worked by Dr. H. C. Fryer, Professor of Mathematics, Kansas State College.

Results for carrots, Table 3, show as much as 20 per cent difference in ascorbic acid content for initial testing. By the end of the experimental week there were large differences for the series held at room temperature. One test series showed an apparent gain at the end of the test period. Losses were noted for each of the other two series after only 12 hours of storage. The results representing averages for three series show losses to be increasing for the carrots held at room temperature. For the two series harvested on the same date there was uniformity in vitamin C content at time of initial sampling with a difference as great as 26 per cent at the end of the test period.

For carrots stored in ice there were apparent gains in ascorbic acid content by the end of the test period, with an average gain of 18 per cent. For all test series a loss in ascorbic acid content was noted at the 72 hour testing time with no regularity in losses for any other period tested.

Carrots packed in ice retained flavor, crisp condition and firm texture with no withering of the tops during the period of storage. Carrots without ice protection were too wilted and tough for use after four days; decline in flavor was quite evident after three days storage.

Results for sweet corn, Table 4, show that the one lot of Tender Gold variety contained approximately 20 per cent more initial vitamin C than did the one of Trinoka variety. Irregular losses in ascorbic acid content occurred at room temperature storage for both varieties during the first 18 hours with great increase in losses during the remaining periods. At the stage deemed inedible the Tender Gold variety had approximately 66 per cent higher vitamin C content than did the Trinoka variety. Although the percentage differences are great for the two varieties, the ascorbic acid content is low. By the end of the experiment the ascorbic acid figures were in close agreement for the two varieties. Tender Gold variety of sweet corn was consistently higher in ascorbic acid content than the Trinoka sweet corn throughout the test week.

For corn packed in ice, the Tender Gold also showed superior vitamin C retention qualities over Trinoka corn. Losses of ascorbic acid occurred for each time period but with no regularity. Slight differences existed in the retention of vitamin C for iced corn as compared with that at room temperature by the end of three days. Tender Gold corn contained a higher initial ascorbic acid content than was found in Trinoka as well as greater content at the end of the experimental week. With continued storage corn protected with ice showed higher retention of ascorbic acid than that at room temperature.

The corn stored at room temperature was inedible by the end of three days. A dented condition of kernels was evident by the second day with noticeable flavor change by the end of

12 hours. Iced corn contained some characteristic sweet flavor after five days of storage, kernels remaining plump and with no dents at the end of the test period.

Data in Table 5 for six test lots of greenhouse grown lettuce show considerable variation in initial vitamin C content, the highest being about 50 per cent greater than the lowest. After storage at room temperature there was also great variation at the end of the experiment but not in the same order. For most of the series there were losses at the end of six hours; with losses reaching 15 per cent after 24 hours storage.

Ice packed lettuce showed apparent gains in ascorbic acid content at the end of six hours, such gains continuing during the first day. With increase in storage time the rate of apparent gain decreased. An average maximum loss of ten per cent occurred at the third day. For two series there were apparent gains in ascorbic acid content at each of the testing periods. The final content of ascorbic acid was approximately the same as the initial content.

Lettuce was the only leafy vegetable studied. The rate of vitamin C loss agreed with that reported by Zepplin and Elvehjem (1944); at no time did losses exceed ten per cent. While the practice of sprinkling with water to retard wilting was effective, it failed to prevent vitamin losses. In the present experiment a 50 per cent loss had occurred in lettuce held at room temperature by the end of four days. By the end of the third day when considered too wilted to be edible the vitamin losses were approximately 40 per cent. The apparent gains in ascorbic acid content which seemingly occurred with the iced lettuce may be due to certain physiological processes not inhibited by low temperatures.

Plate II shows lettuce after four days' storage time.

Results with green peppers found in Table 6 show variation in initial content of ascorbic acid to be great; the largest approximately twice that of the smaller with almost as much variation at the end of the experimental week but not for the same samples. The irregularity of ascorbic acid content for peppers stored at room temperature for the various periods could not be explained. In all series there was an apparent gain in ascorbic acid content by the end of the experiment. This did not represent a regular change as in each series there were periods at which losses were noted.

Vitamin losses with the iced peppers occurred irregularly. There was a great range in final ascorbic acid content for peppers stored in ice; the highest being about 100 milligrams per 100 grams greater than the lowest. For four series there were losses in ascorbic acid content by the end of the test period with the one series showing gains which were not consistent with the original content. Final figures showed an average loss of six per cent.

Peppers at room temperature became wilted with general toughening and decline in flavor by the end of four days. Peppers packed in ice were crisp, tender, firm and accept-

EXPLANATION OF PLATE II

Greenhouse grown Grand Rapids Leaf Lettuce

A - Initial sample.

B - Sample after four days' storage at room temperature.

C - Sample after four days' storage in cracked ice.

PLATE II

able for immediate use throughout the experiment.

Data for spring and fall greenhouse grown Waltham and Michigan State tomatoes are shown in Table 7. At no time did ascorbic acid losses exceed two per cent for the Waltham variety stored at room temperature.

With the Waltham tomatoes, it was found that:

1. The spring crop showed higher initial ascorbic acid content than did those from the fall crop.

2. Those gathered in May and in June showed a continued gain in vitamin C content under both conditions of storage; greater gains resulting for those held at room temperature. At room temperature storage, the gains were as great as 35 per cent. For tomatoes stored in ice the gains were as high as 18 per cent.

3. Those gathered in May and June showed higher ascorbic acid content at the end of the experimental week than on the day of harvesting.

4. December gathered tomatoes showed almost no gain in ascorbic acid content whether held at room temperature or in ice storage.

5. The December crop showed distinctly lower ascorbic acid content at the end of the experimental week, as compared with the initial content.

For the Michigan State variety of tomatoes, June harvested, it was found:

1. Increases in ascorbic acid content resulted with

tomatoes held at room temperature. At most, this increase was 21 per cent. A period of cloudy weather prior to ripening of tomato fruit as well as differences in variety may account for some of these differences, as compared with the Waltham variety which was harvested within a short time.

2. For tomatoes stored in ice almost no increase in ascorbic acid content occurred.

Room temperature conditions of storage for tomatoes favored vitamin retention as found in this experiment. However, when tomatoes were kept iced ascorbic acid losses were much lower than for the majority of other products, at no time exceeding five per cent. Iced tomatoes remained firm with less juice leakage when sliced. The natural protective skin of the tomato may be effective in retarding vitamin losses from the iced fruit.

According to Table 8, cantaloup showed irregularities in vitamin C content of initial samples. The highest figure was more than 80 per cent greater than the lowest. Similar differences were found at the end of the test period for the cantaloup stored at room temperature. Gains may be noted for most of the time periods with a loss of approximately seven per cent in the average of all cantaloup at the end of the test week. The maximum gain in ascorbic acid content was found to occur after 48 hours.

For iced cantaloup it may be noted that three series showed losses of ascorbic acid at the end of the test period while the average for five series was an apparent gain amounting to six per cent. Only at the six hour testing was there loss in ascorbic acid content in the average for five series. The apparent gains for cantaloup whether iced or kept at room temperature showed close similarities.

Lack of purity of seed may account for these wide differences in vitamin C values. Ascorbic acid values for cantaloup showed apparent gains rather than losses. This is not in agreement with the findings at the Delaware Experiment Station made by Brasher et al. (1945). The apparent increase may have been due to degree of maturity instead of storage conditions.

Cantaloup ripened readily at room temperature and by the end of five days was past its prime though still edible. Flavor was impaired due to overripe condition. Cantaloup packed in ice ripened less readily and had good retention of flavor with the added advantage of being thoroughly chilled for immediate serving.

Data for strawberries in Table 9 show initial vitamin C content to be higher than for other berries studied. The rate of vitamin C losses from strawberries, whether iced or kept at room temperature, was slower than with other berries. At the time considered inedible, strawberries contained a greater amount of ascorbic acid than did either of the other berries.

When the berries were considered inedible at the end of three days they were dark in color and wilted. Fruit and stems of berries stored in ice remained fresh and bright in color throughout the testing period. Reduced losses of vitamin C in iced fruit were accompanied by a water soaked condition. Different technique in the application of ice needs to be developed for practical use.

In amounts commonly enjoyed, strawberries could contribute generously to the day's supply of vitamin C. Loss of vitamin C from the iced fruit never exceeded 20 per cent for the test period. The berries which were kept at room temperature retained only 75 per cent of ascorbic acid by the end of 24 hours. The retention of ascorbic acid in iced berries was 85 per cent for this same period of time.

Results of two series of blackberries given in Table 9 show similar initial ascorbic acid contents. At room temperature the rate of loss as well as the extent of ascorbic acid losses were great; the rate of loss being most rapid during the first 24 hours. Throughout the experiment results for berries stored at room temperatures were similar for both series.

Berries stored in ice also showed the most rapid loss of ascorbic acid during the first 24 hours. The vitamin content at the end of the test week were similar for the two series.

Blackberries deteriorated rapidly at room temperature with masses of mold developing among the berries which were considered inedible after four days. Iced berries remained firm and free from mold and at no time seemed overripe. Flavor was less pronounced at the end of the test period probably due to water absorption from ice.

Results for dewberries in Table 9 show a high initial content of vitamin C which undergoes rapid and extensive losses, whether stored at room temperature or iced. The losses of vitamin C from this fruit were regular under each storage treatment.

The initial content of vitamin C was slightly less for this fruit than for strawberries but the rate of loss was much more rapid. Mold development made berries inedible after three days storage at room temperature. The condition of the iced fruit remained good throughout the test with change only in flavor thought to be due to water absorption.

Data, Table 6A, show that differences were noted when comparing ascorbic acid values for peppers harvested according to direction of exposure to sunshine. Those from the south portion of the plant which were less shaded were consistently higher in vitamin C than were peppers harvested from the north or more shaded part of the plant. For the plant yielding 15 peppers, the highest vitamin C value for any pepper from the southern exposure was 73 milligrams per 100 grams pepper with 60 milligrams representing the highest value from the shaded side.

From the plant yielding seven peppers the high and the low values for vitamin C content were 63 and 37 milligrams respectively.

From the plant yielding 11 peppers the high and the low values for vitamin C content were 110 and 31 milligrams per 100 grams of pepper.

According to the part of the pepper eaten the difference in ascorbic value for blossom end and stem end portions was negligible.

Peppers having greater maturity with visible pink in fleshy portion tested higher in vitamin C value than those peppers less mature. The amount of seed and core development seemed to have no direct relationship to ascorbic value. Likewise, there seemed to be no relation between vitamin C values and thickness of the flesh of the peppers.

According to data in Table 5A when the entire lettuce plant was used, there was found no appreciable difference in ascorbic acid content.

Great differences were noted, as found in Table 5A as influenced by the size or maturity of the leaf. The large, fully developed leaf with green coloration had lower vitamin value than the small, immature, innermost leaves which were almost entirely lacking in color. The small leaves were more than twice as rich a source of vitamin C than were the outer leaves. This corresponds to findings reported by Munsell and Kennedy (1935) as these inner leaves represent the most actively growing portion of the plant.

Data in Table 10 show the percentage losses in weight for only the un-iced vegetables. In the retail market those vegetables which are sold on the weight basis would undergo much weight shrinkage and spoilage incident to storage.

The rapidity in which weight was lost at room temperature storage was most striking for leaf lettuce and string beans. Losses in weight would probably have been greater for lettuce if methods of sprinkling with water had not been used. Quality also deteriorated rapidly, but at the end of three days, when the vegetables were still fit for human consumption, string beans had lost 25 per cent and leaf lettuce 15 per cent of initial weights.

Peppers lost weight less rapidly than did the lettuce and beans; tomatoes lost almost no weight.

When stored under cracked ice all products showed an apparent gain in weight or remained constant during the six day period.

Vegetables and fruits held at room temperatures show important loss of ascorbic acid during the first 24 hours. The maximum loss in ascorbic acid for any one vegetable under such conditions of storage was 38 per cent. A much greater loss was sustained by fruits. There were apparent gains in ascorbic content for one product, maximum during the 24 hours being slightly more than 15 per cent. After three days at room temperature storage, when most products were still edible, the maximum ascorbic acid loss from any one product was 68 per cent. The final three experimental days brought still further losses.

Retention of ascorbic acid was greater in iced produce in most instances than with the corresponding samples kept at room temperature. Two of the fruits had high losses even though iced; 45 per cent and 36 per cent respectively for the first 24 hours of storage. Losses of ascorbic acid from vegetables were not as high as from fruits during the corresponding time; 25 per cent being the maximum loss. Losses from two of the vetetables were negligible during this time period. For three of the vegetables there were apparent gains with 15 per cent as maximum during the first 24 hours. With the exception of sweet corn, dewberries, and blackberries, all other vegetables and fruits held in ice storage showed a loss no greater than 21 per cent of the total ascorbic acid content after four days. With the exception of asparagus, sweet corn, dewberries and blackberries, the losses were not great even at the end of the six day period.

The conditions of harvesting, transportation, storage, and displaying of fresh produce from the time of harvest until it reaches the ultimate consumer allows chances for much deterioration to occur in quality as well as in nutritive value. Variations in temperature, humidity, exposure to light or air currents may each be counted on having a part in the diminution of palatability and nutritive from fresh fruit and vegetable products.

The destruction of ascorbic acid or vitamin C is generally parallel with injury to other food qualities such as flavor, color and other vitamins which add importance to the problem of maintaining ascorbic values.

Rate and extent of vitamin C losses from fresh products can be greatly reduced by using cracked ice for the entire time from the period of harvest until used; the time at which cracked ice is applied effectively prevents such losses of nutritive value and general palatability than can be retained under ordinary conditions of storage without ice.

Application of cracked ice at the garden areas prevents the initial losses from some vegetables which may be great during the first six or 12 hours. Cracked ice protection during transportation to market insures food maintaining optimum qualities. Also losses due to weight shrinkage are kept to a minimum. During storage at the warehouse or at other points of holding of fresh produce until used, cracked ice is considered beneficial. The conditions of low temperature storage with its accompanying moisture favors retention of nutritive and quality values not possible under dry storage conditions.

While vegetables and fruits are on display waiting selection by the housewife or other ultimate user the protective quality of cracked ice holds to a minimum such losses as nutritive value, spoilage, weight shrinkage and deterioration of general physical condition.

From these experiments it may be inferred that the use of cracked ice with fresh produce is a desirable and recommended practice for retention of ascorbic acid, for reducing losses due to weight shrinkage and spoilage and for enhancing the freshness and general palatability for the entire time from harvesting until being served.

Table 1. Ascorbic acid content mg/100 gm fresh weight of Mary Washington asparagus in 1945.

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Room temperature					
May 9	37.66	34.64	34.14	25.10	23.60	17.54	14.74	9.48	7.12	4.74
May 21	37.14	26.06	27.16	23.28	22.18	18.30	9.02	10.08	4.78	2.56
Average	37.40	30.35	30.65	24.19	22.89	17.92	11.88	9.78	5.95	3.65
Vitamin C loss (per cent)		18.85	18.05	35.32	38.80	52.08	68.24	79.20	84.09	90.24
					Iced					
May 9	37.66	40.18	38.66	41.18	36.66	43.50	43.50	33.20	27.66	24.50
May 21	37.14	37.14	36.02	33.82	30.48	31.60	33.96	29.70	26.52	19.50
Average	37.40	38.66	37.34	37.50	33.57	37.55	38.73	31.45	27.09	22.00
Vitamin C loss (per cent)		+ 3.37	0.16	+0.26	10.24	+0.40	+ 3.56	15.91	27.57	41.18

Table 2. Ascorbic acid content mg/100 gm fresh weight of beans* in 1945.

July 20	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Room temperature					
* (a)	26.42	20.66	17.53	20.42	16.81	12.49	12.01	7.05	6.37	9.78
Vitamin C loss (per cent)		21.80	33.65	22.71	36.37	52.73	54.54	73.32	75.88	62.98
* (b)	31.70	30.74	26.42	24.02	22.58	17.77	16.81	11.37	10.91	10.46
Vitamin C loss (per cent)		2.39	16.66	24.23	28.77	43.94	46.97	64.13	65.58	67.00
* (c)	36.99	31.22	25.46	27.38	22.58	19.94	20.66	15.92	15.46	16.60
Vitamin C loss (per cent)		15.60	31.18	25.98	38.96	46.11	44.16	56.97	58.22	55.18
					Iced					
* (a)	26.42	22.58	23.06	23.06	21.86	22.09	21.62	18.19	17.74	17.28
Vitamin C loss (per cent)		14.53	12.72	12.72	17.26	16.39	18.17	31.15	32.85	34.59
* (b)	31.70	31.70	29.30	31.46	25.94	24.74	25.94	18.19	18.87	18.19
Vitamin C loss (per cent)		0	7.57	0.76	18.17	21.96	18.17	42.62	40.47	42.62
* (c)	36.99	28.34	29.06	33.15	27.38	26.46	24.50	19.56	20.01	20.46
Vitamin C loss (per cent)		23.39	21.44	10.38	25.98	31.18	33.78	47.13	45.70	44.69

* (a) Pencil Pod, (b) Unrivalled Wax, (c) Golden Bountiful Wax.

Table 2. (cont.).*

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Room temperature					
July 20	31.94	28.34	27.86	27.38	25.46	20.66	21.62	12.05	10.46	11.14
Aug. 8	31.79	31.64	31.79	26.06	30.23	22.39	24.34	16.06	15.33	11.61
Aug. 8	29.45	30.67	27.62	24.50	23.71	17.77	18.98	13.39	12.90	10.58
Aug. 8	28.14	25.31	23.14	30.75	27.62	22.63	17.77	15.33	14.36	11.08
Average	30.33	28.99	28.88	27.17	26.76	20.86	20.68	14.21	13.26	11.10
Vitamin C loss (per cent)		4.45	4.78	10.42	11.77	31.22	31.82	53.15	56.28	63.40
					Iced					
July 20	31.94	30.38	30.02	36.03	28.34	31.58	31.58	21.15	22.28	19.33
Aug. 8	31.79	30.67	35.44	33.36	32.05	28.47	27.50	29.69	25.80	24.53
Aug. 8	29.45	28.23	31.27	31.53	31.53	27.50	25.55	27.26	25.31	23.21
Aug. 8	28.14	25.31	28.67	32.05	32.05	28.72	25.07	23.12	25.80	27.17
Average	30.33	28.65	31.35	33.24	30.99	29.07	27.43	25.30	24.80	23.56
Vitamin C loss (per cent)		5.54	+3.36	+9.59	+2.17	4.15	9.56	16.58	18.23	22.32

* Bountiful.

Table 2. (cont.).*

Date	Hours of storage 0	6	12	18	24	48	72	96	120	144
					Room temperature					
July 20	31.14	31.22	29.30	24.02	19.21	18.73	17.29	12.05	12.05	12.05
Aug. 2	21.50	22.72	18.56	16.61	16.61	15.88	13.68	13.68	13.03	11.47
Aug. 2	26.87	25.65	20.03	18.08	18.56	15.39	14.17	14.66	14.08	13.81
Aug. 2	26.87	24.43	20.27	17.10	17.83	14.90	13.68	15.14	13.55	11.99
Aug. 8	26.32	22.88	27.10	24.50	25.02	22.69	16.06	14.60	13.63	10.55
Average	26.54	25.38	23.05	20.05	19.45	17.52	14.98	14.03	13.27	11.97
Vitamin C loss (per cent)		4.37	13.15	24.45	26.71	33.98	43.56	47.14	50.00	54.89
					Iced					
July 20	31.14	30.26	31.22	33.15	29.78	28.82	30.74	21.37	26.83	24.78
Aug. 2	21.50	23.45	21.01	22.47	20.52	21.01	20.27	21.50	22.41	18.50
Aug. 2	26.87	26.38	21.74	22.72	21.98	21.01	21.74	21.01	20.85	17.20
Aug. 2	26.87	28.33	21.50	24.43	21.16	21.98	23.94	22.47	22.93	20.58
Aug. 8	26.32	24.82	27.62	31.27	28.14	23.85	26.28	26.04	25.80	26.38
Average	26.54	26.65	24.62	26.81	25.12	23.33	24.60	22.48	23.76	21.49
Vitamin C loss (per cent)		+0.41	7.23	+1.01	5.35	12.09	7.31	15.30	10.47	19.02

* Stringless Green Pod.

Table 2. (concl.)*

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Room temperature					
July 20	33.63	22.58	22.09	19.94	18.01	17.53	15.37	10.01	11.82	11.14
Aug. 2	26.38	23.94	22.72	19.54	16.12	12.21	12.21	16.12	14.07	13.02
Aug. 2	22.47	22.47	18.32	16.61	16.12	12.70	12.70	15.63	13.55	11.99
Aug. 8	29.97	25.07	25.28	24.76	25.02	18.50	17.77	18.50	12.90	11.87
Aug. 8	27.36	24.82	22.15	23.45	25.02	15.33	15.82	13.14	11.93	11.61
Average	27.96	23.78	21.71	20.86	20.06	15.26	14.77	14.68	12.85	11.93
Vitamin C loss (per cent)		14.95	22.35	25.39	28.25	45.42	47.17	47.49	54.04	57.33
					Iced					
July 20	33.63	24.50	28.82	26.42	24.02	26.42	24.50	19.78	18.19	18.19
Aug. 2	26.38	27.60	26.87	23.45	23.94	20.76	20.52	19.05	19.54	21.63
Aug. 2	22.47	25.16	25.89	22.72	21.98	20.27	22.96	22.96	21.37	23.45
Aug. 8	29.97	29.69	35.96	31.27	35.96	27.72	27.99	28.72	25.80	26.38
Aug. 8	27.36	28.72	26.84	30.23	28.14	26.77	25.55	26.77	23.36	21.89
Average	27.96	27.13	28.88	26.82	26.81	24.59	24.30	23.46	21.65	22.31
Vitamin C loss (per cent)		2.96	+3.29	4.07	4.11	12.05	13.09	16.09	22.56	20.21

* Tender Green.

Table 3. Ascorbic acid content mg/100 gm fresh weight of Chantenay carrots in 1945.

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
	Room temperature									
Sept. 21	7.32	10.07	9.08	7.76	4.10	6.92	5.38	5.32	3.93	8.33
Sept. 21	7.40	7.73	6.43	6.15	5.64	4.99	5.28	4.55	3.87	6.13
Oct. 4	5.89	5.23	4.30	4.64	8.25	3.42	3.76	2.49	3.18	2.46
Average	6.87	7.68	6.61	6.19	6.00	5.11	4.81	4.12	3.66	5.64
Vitamin C loss (per cent)		+11.74	3.86	9.97	12.69	25.67	30.04	40.07	46.74	17.96
	Iced									
Sept. 21	7.32	7.19	7.44	12.10	8.33	7.21	6.69	6.05	9.87	11.83
Sept. 21	7.40	8.08	7.14	9.32	7.93	5.47	5.45	6.17	6.91	6.91
Oct. 4	5.89	5.25	5.13	5.93	5.38	6.47	5.53	9.62	5.06	5.70
Average	6.87	6.84	6.57	9.12	7.21	6.39	5.89	7.28	7.28	8.15
Vitamin C loss (per cent)		0.47	4.42	+32.73	+4.90	7.12	14.29	+5.97	+5.94	+18.52

Table 4. Ascorbic acid content mg/100 gm fresh weight of sweet corn* in 1945.

Aug. 13	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Room temperature					
* (a)	24.31	24.53	20.29	15.77	20.52	17.07	15.70	10.98	6.13	3.49
Vitamin C loss (per cent)		+0.90	16.54	35.13	15.59	29.78	35.42	54.83	74.78	85.64
* (b)	20.42	28.23	13.36	16.66	13.01	11.99	9.77	8.02	3.02	3.19
Vitamin C loss (per cent)		+38.75	34.57	18.41	36.19	41.28	52.15	60.72	85.21	84.38
					Iced					
* (a)	24.31	27.33	19.75	18.52	18.89	14.02	15.09	15.25	12.29	9.80
Vitamin C loss (per cent)		12.42	18.75	23.82	22.29	42.32	37.88	37.26	49.44	59.68
* (b)	20.42	20.25	14.44	15.15	15.59	13.88	11.96	10.80	9.84	7.04
Vitamin C loss (per cent)		8.33	29.28	25.81	23.65	32.03	41.43	47.11	51.81	65.52

* (a) Tender Gold, (b) Trinoka.

Table 5. Ascorbic acid content mg/100 gm fresh weight of Grand Rapids lettuce in 1945.

	Hours of storage									
Date	0	6	12	18	24	48	72	96	120	144
					Room temperature					
Oct. 25	13.38	10.12	10.12	10.26	8.03	5.56	5.40	6.07	4.23	3.33
Oct. 25	12.49	10.36	12.54	7.55	11.71	8.63	5.19	4.53	4.66	2.90
Oct. 25	12.49	11.04	10.56	11.15	8.68	5.91	5.89	6.07	5.81	5.08
Oct. 27	9.56	9.80	9.31	11.72	13.68	7.75	6.84	6.66	4.74	2.32
Oct. 27	10.48	9.62	10.38	10.20	7.42	7.42	5.64	4.84	4.37	3.18
Oct. 27	9.04	11.66	10.70	10.51	7.87	5.91	7.60	6.64	6.03	5.20
Average	11.24	10.43	10.60	10.23	9.56	6.86	6.09	5.81	4.98	3.67
Vitamin C loss (per cent)		7.16	5.65	8.99	14.92	38.94	45.79	48.34	55.73	67.37

Table 5. (cont.).

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Iced					
Oct. 25	13.38	14.96	15.29	10.41	12.41	10.73	10.81	8.84	14.66	12.72
Oct. 25	12.49	12.23	13.90	11.59	15.41	11.72	10.13	9.24	9.94	13.12
Oct. 25	12.49	13.79	12.16	10.38	13.38	12.09	9.86	9.33	10.01	10.49
Oct. 27	9.56	11.81	12.16	12.83	12.16	10.51	12.03	14.78	10.93	8.62
Oct. 27	10.48	14.58	10.95	13.62	11.99	10.88	8.32	13.84	10.65	13.08
Oct. 27	9.04	16.46	12.59	11.98	12.64	10.68	11.22	13.30	12.72	9.53
Average	11.24	13.97	12.84	11.80	12.99	11.10	10.06	11.56	11.49	11.26
Vitamin C loss (per cent)		+24.31	+14.28	+5.01	+15.65	1.22	10.49	+2.82	+2.18	+0.17

Table 5A. Ascorbic acid content mg/100 gm fresh weight of Grand Rapids lettuce.

Product	Leaf size and position of growth			Entire plant
	Small, Inner	Medium, Middle	Large, Outer	
A	12.62	6.95	5.17	7.30
B	13.80	8.35	6.67	5.34
C	13.59	8.12	6.19	5.87
Average	13.34	7.81	6.01	6.17

Table 6. Ascorbic acid content mg/100 gm fresh weight of Ruby King pepper in 1945.

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
	Room temperature									
Sept. 3	79.62	135.94	111.42	58.23	73.70	35.45	57.21	99.63	82.38	84.56
Sept. 3	93.99	103.08	50.47	78.92	82.14	50.59	155.23	86.62	101.74	116.06
Sept. 5	86.39	198.81	89.08	105.84	68.53	166.98	72.61	62.19	51.74	97.31
Sept. 5	148.64	26.13	70.03	75.55	80.56	73.25	68.64	93.62	116.27	156.42
Sept. 5	77.38	133.44	112.13	85.03	97.98	121.03	119.81	109.60	45.33	112.48
Average	97.20	119.48	86.62	80.72	80.58	89.46	94.70	90.33	79.49	113.36
Vitamin C loss (per cent)		+22.28	10.88	16.97	17.09	7.97	2.58	7.08	18.23	+16.62

Table 6. (concl.).

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Iced					
Sept. 3	79.62	66.14	119.94	62.87	74.88	76.71	54.46	78.80	99.72	64.93
Sept. 3	93.99	155.48	53.99	127.52	59.56	41.05	176.36	99.51	153.87	165.46
Sept. 5	86.39	47.15	42.88	124.13	111.21	39.32	72.13	59.26	85.84	76.25
Sept. 5	148.64	100.98	98.30	104.18	80.53	56.15	83.54	72.86	116.38	80.66
Sept. 5	77.38	96.08	89.75	73.68	86.89	135.03	67.14	106.99	142.57	65.68
Average	97.20	93.17	80.97	98.47	83.81	69.65	90.73	83.48	119.68	90.60
Vitamin C loss (per cent)		4.16	16.70	+1.30	13.78	28.35	6.67	14.12	+23.12	6.80

Table 6A. Ascorbic acid content mg/100 gm fresh weight of Ruby King peppers.

Plant yield			Position of growth	
15 peppers	11 peppers	7 peppers	North	South
73.19	110.80	63.65	60.68	73.19
60.68	96.75	55.90	57.47	60.38
60.38	78.73	49.95	57.40	58.37
58.37	75.29	46.01	36.31	57.41
57.47	72.43	39.19	35.27	52.44
57.41	66.93	38.03	31.08	50.31
57.40	59.28	37.27	19.70	29.74
52.44	58.57			
50.31	49.99			
44.31	39.36			
36.31	31.41			
35.27				
31.08				
29.74				
19.70				

Test lot	Edible portion		Total per pepper
	Stem	Blossom	
East	50.812	50.99	50.90
West	48.800	54.82	51.80

Table 7. Ascorbic acid content mg/100 gm fresh weight of tomatoes* in 1945.

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Room temperature					
* (a) May 28	16.81	19.97	16.31	21.69	19.38	24.05	20.63	27.50	25.96	25.69
June 11	17.96	21.38	22.16	23.80	20.30	27.85	26.10	24.36	22.84	16.79
June 20	26.50	25.53	28.63	24.39	25.99	22.70	21.27	17.44	28.31	37.49
Dec. 28	17.07	-	-	13.50	13.63	15.60	13.12	15.79	14.23	8.98
Dec. 28	14.03	-	-	7.17	11.68	14.46	13.57	15.32	11.31	9.25
May & June Vitamin C loss (per cent)		+9.16	+9.55	+14.05	+7.19	+21.79	+11.02	+13.12	+26.69	+33.79
December Vitamin C loss (per cent)		-	-	33.50	18.59	3.34	14.15	+0.60	17.88	41.35
* (b) June 15	17.23	18.88	16.15	13.47	15.32	16.79	17.58	17.18	20.93	18.72
Vitamin C loss (per cent)		+9.58	6.27	20.08	11.09	2.55	+2.03	0.29	+21.47	+8.65

* (a) Waltham, (b) Michigan State.

Table 7. (concl.).*

Date	Hours of storage 0	6	12	18	24	48	72	96	120	144
* (a)					Iced					
May 28	16.81	18.90	20.00	17.52	17.09	20.93	24.01	26.16	21.53	29.88
June 11	17.96	21.35	18.47	19.89	22.22	25.21	20.73	21.12	20.17	20.63
June 20	26.50	29.99	28.70	23.78	22.75	23.80	21.56	24.80	22.97	21.20
Dec. 28	17.01	-	-	19.36	10.77	10.44	11.95	11.85	10.62	11.76
Dec. 28	14.03	-	-	19.72	19.65	11.84	12.56	10.20	12.91	11.54
May & June Vitamin C loss (per cent)		+14.64	9.65	0.10	+0.34	+14.15	+8.23	+17.68	+2.30	+17.04
December Vitamin C loss (per cent)		-	-	+25.66	2.18	28.36	21.16	29.13	24.31	25.08
* (b) June 15	17.23	11.77	15.27	16.92	14.59	15.33	14.96	13.73	18.02	10.53
Vitamin C loss (per cent)		31.69	11.38	1.80	15.32	11.03	13.17	20.31	+4.59	35.23

* (a) Waltham, (b) Michigan State.

Table 8. Ascorbic acid content mg/100 gm fresh weight of Hale's Best cantaloup in 1945.

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
	Room temperature									
Sept. 1	33.09	42.81	32.09	39.87	41.55	41.08	38.45	46.35	37.96	34.30
Sept. 1	39.70	33.84	35.33	34.94	41.65	50.99	25.20	45.05	32.80	42.33
Sept. 4	22.09	39.36	36.43	26.84	28.95	46.05	25.90	43.90	29.69	33.28
Sept. 4	30.73	40.24	43.68	40.67	46.72	34.06	38.94	41.95	34.48	26.47
Sept. 4	40.58	23.82	50.26	39.32	37.52	42.97	21.89	35.63	42.34	23.48
Average	34.24	36.02	39.56	36.33	39.28	43.03	30.88	40.40	35.45	31.97
Vitamin C loss (per cent)		+ 5.19	+15.54	+6.10	+14.72	+ 25.69	9.82	+17.98	+3.55	6.62

Table 8. (concl.).

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
	Iced									
Sept. 1	38.09	40.96	35.51	33.44	32.94	34.78	45.12	39.01	34.87	35.30
Sept. 1	39.70	37.05	44.78	34.81	46.94	41.92	46.07	33.93	42.84	30.84
Sept. 4	22.09	41.67	33.21	31.39	38.03	43.40	36.47	26.03	30.23	35.25
Sept. 4	30.73	25.13	40.43	43.17	29.44	38.07	35.79	35.24	34.90	40.59
Sept. 4	40.58	22.21	32.56	38.71	39.89	37.89	23.33	49.47	30.80	39.35
Average	34.24	33.40	37.29	36.30	37.45	39.21	37.37	36.74	34.73	36.27
Vitamin C loss (per cent)		2.44	+8.94	+6.02	+9.37	+14.52	+9.14	+7.30	+1.43	+5.94

Table 9. Ascorbic acid content mg/100 gm fresh weight of small fruits* in 1945.

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
					Room temperature					
* (a) July 20	37.47	25.46	26.60	24.26	22.58	22.39	22.34	18.42	14.78	11.82
July 20	37.95	24.98	27.38	24.26	22.58	22.58	21.86	17.74	13.87	12.28
Average	37.71	25.22	26.99	24.26	22.58	22.46	22.10	18.08	14.33	12.05
Vitamin C loss (per cent)		33.12	28.42	35.67	40.13	40.45	41.40	52.06	62.01	68.04
* (b) May 30	49.28	47.74	46.72	47.22	36.62	41.86	35.00	29.78	12.02	4.70
Vitamin C loss (per cent)		3.13	5.20	4.18	25.69	15.06	28.98	39.57	75.61	90.46
* (c) July 6	46.81	39.07	30.97	25.69	23.93	22.17	19.71	18.14	14.72	11.29
Vitamin C loss (per cent)		16.54	33.83	45.11	48.87	52.63	57.89	61.25	68.56	75.87

* (a) El Dorado blackberry, (b) Howard strawberry, (c) Boysen dewberry.

Table 9. (concl.)*

Date	Hours of storage									
	0	6	12	18	24	48	72	96	120	144
* (a)					Iced					
July 20	37.47	36.03	25.70	24.98	24.50	22.82	21.38	18.87	16.60	17.96
July 20	37.95	26.90	25.70	24.98	23.78	22.58	21.14	18.19	15.92	18.42
Average	37.71	31.46	25.70	24.98	24.14	22.70	21.26	18.53	16.26	18.19
Vitamin C loss (per cent)		16.56	31.87	33.76	35.99	39.81	43.63	50.85	56.88	51.76
* (b)										
May 30	49.28	39.52	43.64	39.52	41.86	43.96	43.88	42.32	45.98	43.88
Vitamin C loss (per cent)		19.81	11.45	19.81	15.06	10.80	10.96	14.12	6.70	10.96
* (c)										
July 6	46.81	38.01	29.21	28.51	25.34	25.34	24.64	23.27	22.59	21.56
Vitamin C loss (per cent)		17.09	37.60	39.10	45.86	45.86	47.37	50.28	51.75	53.94

* (a) El Dorado blackberry, (b) Howard strawberry, (c) Boysen dewberry.

Table 10. Weight loss on percentage basis.

Product	Hours of storage					
	24	48	72	96	120	144
Lettuce	2.35	10.06	15.46	22.65	38.76	43.48
Beans		17.80	24.30	33.00	37.00	45.00
Tomatoes		1.90	1.90	2.60	3.46	5.80
Peppers		4.63	7.58	13.41	19.60	27.56

SUMMARY AND CONCLUSIONS

Changes occurring in ascorbic acid content, weight, and general quality of locally grown fresh vegetables and fruits during temporary storage were investigated. Products packed in cracked ice from time of harvest were compared with those stored at room temperature for periods up to six days.

Calculations were made to show the milligrams of ascorbic acid per 100 grams for 11 different vegetables and fruits assayed when (a) freshly harvested, (b) stored at room temperature, and (c) packed in cracked ice. This study represented a total of 50 test series.

For most vegetables and fruits, the rate of loss of ascorbic acid was appreciably greater at room temperature than at the temperature of cracked ice.

Of products studied, vegetables lost less ascorbic acid than did the fruits.

An apparent increase in ascorbic acid content was shown by carrots, tomatoes, and cantaloup when stored in cracked ice.

Two products, tomatoes and green peppers, made apparent gains in ascorbic acid content when stored at room temperature.

Spring crop greenhouse grown tomatoes showed a higher initial ascorbic acid content than did those from the fall crop. The spring tomatoes contained more ascorbic acid at the end of the experimental period than on the day of harvesting.

No significant difference was found indicating any superiority of green over yellow varieties of snap beans regarding vitamin retention for either ice or room temperature storage.

Sweet corn, whether iced or kept at room temperature, showed similar vitamin losses during the first three days. Prolonged storage in ice was effective in reducing rate of loss and retention of quality.

Ice packed leaf lettuce showed benefits in vitamin retention and quality during storage.

Asparagus retained its quality during ice storage and at the end of the test period had vitamin content equal to that of room stored asparagus after 24 hours.

All berries showed vitamin retention and quality to be favorably affected by the use of ice. Methods for using ice with small fruits need further testing.

For vegetables and fruits studied, icing was considered an effective means for retarding decline in nutritive value and /or quality, during transportation and storage for periods not to exceed six days in length.

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APPENDIX

TEST DATA

Kind of Fruit or Veg. ______________________ Variety ______________

Growing Location ______________________ Date of Harvest ______________

How Protected from Harvest to Laboratory ______________________

Date and Hour of Starting Tests ______________ Weight of Test Samples ________

Location of Produce during Tests ______________________

Ascorbic Acid Expressed in Int. Units ______, Milligrams ______, Micrograms ______

Un-iced--Normal Room Temp.			Time	Packed in Cracked Ice	
Ascorbic Acid Content - Wgt.	Total Weight	Room Temp.		Ascorbic Acid Content - Wgt.	Total Weight
			Start		
			6 Hours		
			12 "		
			18 "		
			24 "		
			48 "		
			72 "		
			96 "		
			120 "		
			144 "		

Texture	Flavor	Color	Time	Texture	Flavor	Color
			Start			
			6 Hours			
			12 "			
			18 "			
			24 "			
			48 "			
			72 "			
			96 "			
			120 "			
			144 "			

General Observations:--

Test Number ______________, Plotted on Chart Number ______________

Signatures of Analysts ______________ ______________