THE EFFECT OF REFRIGERATOR STORAGE ON THE PALATABILITY AND ASCORBIC ACID CONTENT OF MARKET FRESH BROCCOLI

by

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INTRODUCTION

In recent years there have been a number of improvements in the methods of producing, handling, packing, and transporting of fresh produce. These, together with improved storage facilities in the local markets, have made a great variety of good quality fresh fruits and vegetables available to the homemaker during every month of the year. In addition, improvements in home refrigerators have made it both convenient and practical for the housewife to buy groceries only once or twice a week. Many fresh fruits and vegetables have been found to retain their quality very well with refrigeration for several days.

Broccoli is one of the fresh vegetables now available throughout almost every month. However, it is generally considered to deteriorate quite rapidly.

The purposes of the present study were to determine the quality of fresh broccoli as it was purchased from the market, and to determine the losses of quality when this broccoli was stored for periods of three and five days under conditions similar to those available to the homemaker. The quality was measured by palatability and ascorbic acid tests. A third purpose of the study was to discover if there were a relationship between the palatability and ascorbic acid content of the fresh and stored broccoli.

REVIEW OF LITERATURE

The United States Department of Agriculture (1948) declared that good quality broccoli should be fresh, clean, and not overmature; darkish green or purplish green in color; with tender, firm stalks and compact clusters of buds. It also stated that overmature broccoli is usually woody, tough or stringy. This overmaturity is indicated by the opening or blooming of the bud clusters, although an occasional open blossom does not necessarily mean that the broccoli is overmature.

While fresh broccoli is not one of the most commonly consumed vegetables in the United States, it is available during almost every month of the year, and a considerable amount of it is purchased each year. In a study of consumer purchases of fresh vegetables, Rasmussen (1948) found that broccoli was available in certain retail food stores in New York during 11 of the 12 months in 1938-39, in 10 of the 12 months in 1941-42, and during every month in 1945-46. He also found in percentage of total vegetables sold in these stores that broccoli ranked fourteenth during 1938-39, fifteenth in 1941-42, and twenty-second in 1945-46.

Rasmussen (1948) found that the average price per pound in these New York stores was 7.3 cents in 1938-39, and 8.7 cents in 1941-42. However, in a study conducted in four stores in Columbus, Ohio, during an 11-week period from January to April in 1948, Sherman, Lenox, and Gould (1949) found that the price of broccoli varied from 18 to 35 cents per pound, with an average of 25.8 cents.

There seemed to be some disagreement among studies reported on the palatability of fresh vegetables. Van Duyne, Owen, Wolfe, and Charles (1951) stated that the nature and quality of the vegetable and at least some of the details of the cooking procedure affected palatability. They suggested that differences in these details may be responsible for some of the conflicting results of different laboratories. In their study on methods of cooking fresh vegetables, they found that broccoli cooked in a pressure saucepan was preferred to that cooked in a tightly covered aluminum saucepan. However, Brinkman, Halliday, Hinman, and Hamner (1942) found that, although broccoli was acceptable when cooked in a pressure saucepan, it was definitely inferior to that cooked by the open-kettle method. Trefethen, Causey, and Fenton (1951) reported no significant differences in scores for color, texture or flavor of broccoli cooked in boiling water or in a pressure saucepan. Individual preferences for methods of cooking and degree of "doneness" differ. It was suggested by Greenwood and Salerno (1949) that these differences be taken into consideration in the planning of an experiment.

When determining the quality of vegetables, the ascorbic acid content is considered a good objective measurement. Vitamin C is the most easily destroyed of the vitamins, and is affected by almost every treatment which a vegetable receives prior to actual consumption. Fenton (1940) stated that as vitamin C is lost, the general quality, including aroma, color, flavor, texture, and nutrients, also deteriorates. For this reason, in fresh vegetable studies the ascorbic acid content has been used as a method of measuring the acceptability of the product.

The ascorbic acid content of fresh broccoli is quite high in comparison with that of many other vegetables. Lampitt, Baker, and Parkinson (1945b), in analyzing 12 samples of fresh broccoli, reported values of from 1.32 to 1.86 mg per g with an average ascorbic acid content of 1.59 mg per g. In another study, Zeppelin and Elvehjem (1944) found 147 mg per 100 g, while Wheeler and Tressler (1939) reported 1.16 to 1.99 mg per g. Harris and Oliver (1942) found an average of 69 mg per 100 g and Van Duyne, et al. (1951) found averages of 1.04 and 0.84 mg per g in tests during two different years.

The ascorbic acid content of fresh vegetables is known to vary with the season of the year. Brown and Fenton (1942) found considerable differences in the ascorbic acid content of fall and spring parsnips. Therefore, they emphasized the importance of reporting the time of the year in which a study on fresh vegetables is done. In a study on 92 samples of cabbages over a period of a year, Lampitt, Baker, and Parkinson (1943) found considerably more ascorbic acid present in the late spring than during the rest of the year.

Wheeler and Tressler (1939) reported the ascorbic acid content of broccoli to be higher in the summer months than in the fall. The average of four varieties was 1.84 mg per g during the summer and 1.26 mg per g in the fall. On the other hand, Tucker (1948) found that the ascorbic acid content of broccoli harvested in the fall was higher than that harvested in early July. In 1945, July broccoli contained 104.9 mg per 100 g, while fall broccoli had 112.1 mg per 100 g. In 1946, the values were 88.5 mg per 100 g in July and 93.1 mg per 100 g in the fall.

Hanson (1945) made a study of the variation in the vitamin and mineral content of five green vegetables, including broccoli. The vegetables were planted in July and August and harvested at monthly intervals for a period of nine months. The ascorbic acid content of the broccoli was highest in September with an average of 181.8 mg per 100 g. It decreased gradually during the fall and winter months and was lowest in January and February with 119.8 and 116.5 mg per 100 g, respectively. In March it was 161.2 mg per 100 g and it continued to be high throughout the spring months. However, Hansen stated that these seasonal variations were not necessarily consistent. He concluded that the ascorbic acid content of fresh vegetables was influenced more directly by hereditary factors than by climatic changes.

There are few definite reports on the influence of variety on the ascorbic acid content of broccoli. Wheeler and Tressler (1939), in their work with four varieties, found that while there was variation between varieties, these differences were not as important as the differences in summer and fall samples of each variety. During the summer, they found that Italian Early Calabrese broccoli contained an average of 1.71 mg per g, Italian

Green Sprouting, 1.99 mg per g, Propagane, 1.80 mg per g, and Emerald Isle, 1.85 mg per g. In the fall these same varieties gave values of 1.27, 1.16, 1.45, and 1.14 mg per g, respectively. The differences between varieties were not consistent.

A study of ten vegetables, including broccoli, was made by Lampitt, Baker, and Parkinson (1945d). They found significant differences in the ascorbic acid content of different varieties of broccoli and of all but two of the other vegetables.

One of the difficulties encountered in determining the ascorbic acid content of a fresh vegetable, such as broccoli, is that of obtaining a uniform or representative sample for analysis. Patton and Miller (1948) found that the vitamin C content varied from 83 to 174 mg per 100 g among different heads of the same sampling of broccoli. These same workers also analyzed a single stalk of broccoli and found 180 mg per 100 g in the leaves, 142 mg per 100 g in the flowers, and 98 mg per 100 g in the stalk. Zepplin and Elvehjem (1944) reported 50 to 80 mg of ascorbic acid per 100 g in broccoli stems and 75 to 143 mg per 100 g in the flowers. Wheeler and Tressler (1939) also found more ascorbic acid in the blossoms than in the whole plant. According to Lampitt, Baker, and Parkinson (1943) the range for any one vegetable may vary as much as 50 per cent for vegetables purchased from the local market. They stressed the importance of using a large sampling with thorough mixing.

A number of studies have been done on the retention of ascorbic acid in vegetables stored under different conditions.

Zepplin and Elvehjem (1944) stated that the largest loss occurs immediately after harvesting, during the first two days, with an even greater loss if the vegetable has been damaged in any way. Much of this loss could be prevented by immediate storage in crushed ice. They found that fresh broccoli lost only eight per cent of its ascorbic acid when packed in crushed ice for three days, while it lost 21 per cent when it was put immediately into the hydrator of a mechanical refrigerator.

Almost all of the workers agreed that ascorbic acid is lost very quickly when broccoli is stored at room temperature. Patton and Miller (1948) reported 70 per cent retention with storage at room temperature (80° F.) for one day and only 56 per cent retention with room temperature storage for two days. However, broccoli from the same sampling retained 92 per cent of its ascorbic acid after refrigerator storage (42° F.) for two days. Zepplin and Elvehjem (1944) found that moistening and storing at room temperature is of no value in preserving the ascorbic acid content. Wheeler and Tressler (1939) studied the effect of room temperature and refrigerator storage on the retention of ascorbic acid in broccoli blossoms. The fresh blossoms contained 1.84 mg per g. After storage at refrigerator temperature for two weeks, they still contained 1.64 mg per g, while after four days at room temperature, this value had decreased to 1.09 mg per g. Later work by these same authors on the whole broccoli plant showed an actual increase in the ascorbic acid content with refrigerator storage. After two weeks at temperatures of 1 to 3° C., broccoli which had originally contained 1.26 mg per g contained 1.27 mg per g.

Lampitt, Baker, and Parkinson (1945a) also reported a slight increase in the ascorbic acid content of broccoli stored at 3° C. (refrigerator temperature). However, they found a slow rather than a rapid decrease in that stored at room temperature (20° C.).

The loss of vitamin C in storage varies a great deal with different vegetables. It also varies in different parts of a single vegetable. Zepplin and Elvehjem (1944) found that broccoli stems, while containing less ascorbic acid than the blossoms, (50 to 80 mg per 100 g), lost very little when stored at room temperature for 48 hours, and only 40 per cent after storage for 96 hours. The flowers, which contained 75 to 143 mg per 100 g lost 43 per cent after 24 hours at room temperature and 65 per cent after 48 hours. Fenton (1940) stated that surface area is an important factor in determining ascorbic acid retention. Therefore, it is better to store vegetables in the uncut or untrimmed state.

In addition to the loss of ascorbic acid, there are certain physical changes which occur when fresh vegetables are stored at room temperature. The vegetable appears more wilted and the texture becomes tougher. Patton and Miller (1948) considered broccoli which had been stored at room temperature for two days to be unmarketable. However, Zepplin and Elvehjem (1944) found that these physical changes are very slow in refrigerated broccoli.

Zepplin and Elvehjem (1944) also found that different refrigerators may give various results because of differences in humidity and circulation of air. They stated that the best conditions for preserving ascorbic acid are low temperature, high humidity, and decreased exposure to air movement.

In a study on the effect of reduced evaporation on the vitamin content of vegetables in refrigerator storage, Harris, Wissman, and Greenlie (1940) used two types of refrigerators, which they referred to as the A and H types. The A type had a relative humidity of 63 per cent, while that of the H type was 93. They found the destruction of vitamin C was 64 per cent more rapid in the A type than in the H type. High humidity and low air movement were not only more effective in preserving ascorbic acid, but also reduced wilting.

Ascorbic acid in vegetables is also lost during the cooking process. The extent of its destruction in cooking is dependent upon a number of factors, among which are the method of cooking, the temperature of the water at the time the vegetable is added, the length of time required for the water to begin to boil after the vegetable is added, the proportion of water to vegetable, the cut surface of the vegetable, and the length of time the vegetable is held after cooking before serving.

The loss of ascorbic acid is caused by the action of ascorbic acid oxidase. Lampitt, Clayson, and Barnes (1944) stated that this enzyme is destroyed at temperatures of 65° C. and above. The method of cooking is important in the destruction of this enzyme. The total destruction of ascorbic acid is greater in steaming than in boiling, according to Fenton (1940), because the enzyme is not destroyed as rapidly. However, more of the retained ascorbic acid is leeched into the cooking water during boiling. Wellington and Tressler (1938) found more ascorbic acid in steamed cabbage than in drained, boiled cabbage. Lampitt, Baker, and Parkinson (1943) cited two reasons for less total retention of ascorbic acid in steaming than in boiling: first, there is more oxygen in contact with the vegetable when it is steamed; second, in steaming, the vegetable condenses water vapor more rapidly than it can be replaced, so that air is drawn in at a stage when the cells are ruptured and the oxidase is still active.

Van Duyne, et al. (1951) reported that the ascorbic acid content of broccoli was higher when it was cooked in a tightly covered saucepan than when it was cooked in a pressure saucepan. However, in palatability tests, the broccoli cooked in the pressure saucepan was preferred over that cooked in a tightly covered saucepan.

Brown and Fenton (1942) boiled, steamed, and pressure-cooked parsnips whole, in pieces, or in shreds. They found that the ascorbic acid loss was least when the vegetables were boiled whole, or cut in pieces and cooked in a pressure saucepan. In these two methods, at least 90 per cent of the ascorbic acid was retained.

In regard to the temperature of the water at the time the vegetable is added, Lampitt, Baker, and Parkinson (1943) suggested that the ascorbic acid oxidase may be more active during the period just after the vegetable is added, before the water comes back to a boil, and that the vegetable should be added slowly so as not to stop the boiling. However, in actual experiments in which the vegetable was added slowly, they found no significant effect except in the case of cabbage, in which the oxidase is more active than in most vegetables. With the other vegetables, including broccoli, the percentage retention was about the same as when boiling was stopped for a short time by the addition of the entire amount of vegetable at once.

Fenton (1940) also stated that since the enzyme responsible for the destruction of ascorbic acid is destroyed by boiling a short time, the greatest loss occurs during the first part of the cooking period. Therefore, it is important that the water be boiling before the vegetable is added.

The proportion of water to vegetable in cooking seems not to be as important as some of the other factors. Lampitt, Baker, and Parkinson (1943) reported no significant effect from varying the ratio of water to vegetable from 1:1 to 32:1 in cooking cabbage. The ascorbic acid retention varied from 32 to 52 per cent. In a later experiment, these same authors (1945c) found that the volume of water to vegetable was much more important when the vegetable was shredded than when it was cooked in larger pieces. With shredded cabbage, the retention was 49 per cent with a 2:1 ratio of water to vegetable, but only 22 per cent with a 6:1 ratio. However, with quartered cabbage, the retention varied only slightly with different water to vegetable ratios.

The amount of cut surface exposed is also important in ascorbic acid retention. Wellington and Tressler (1938) found less total destruction when cabbage was cooked in fine shreds than when it was cooked in strips or quarters. This was attributed to the fact that with the shredded vegetable, heat could penetrate more quickly to inactivate the enzyme. However, much more of the ascorbic acid retained was dissolved in the cooking water. Lampitt, Baker, and Parkinson (1945c) found that when a shredded vegetable was cooked with a 2:1 ratio of water to vegetable, the ascorbic acid diffused more readily from the tissues and the concentration in the vegetable and in the liquid was about equal. This was not true of vegetables cut in larger pieces because of the smaller surface area.

From these effects it can be seen that the way in which the vegetable is prepared for cooking, as well as the method which is used in cooking, is dependent to a great extent on whether or not the cooking liquid will be used. Tucker (1948) stated that since the water used in the preparation of most vegetables is not ordinarily served, the retention of ascorbic acid in the vegetable itself is more important than the total retention.

A final factor affecting the retention of ascorbic acid in cooked vegetables is the length of time that the vegetable is kept hot after being cooked. Lampitt, Baker, and Parkinson (1943) found that cooked Brussels sprouts lost 20 per cent of their retained ascorbic acid after holding 15 minutes, 40 per cent after half an hour, and 50 per cent after an hour.

When vegetables are cooked under controlled conditions to obtain the greatest ascorbic acid retention, the values for the retained ascorbic acid may actually be slightly higher than those for the raw vegetable. There have been a number of theories proposed to explain this phenomenon such as the bound acid theory of McHenry and Graham (1935). Harris and Olliver (1942) disproved this and other previous theories. They stated three probable reasons for an increase in ascorbic acid content with cooking: first, incomplete extraction of the raw vegetable, especially in the case of hard fibrous vegetables, giving too low a value for the raw sample; second, variations in sampling, and not enough samples to obtain a true value; and third, the decreased action of the oxidase in the cooked sample because of inactivation by heat.

PROCEDURE

Broccoli was purchased at a local market, on the first day of each of eight periods between February 15 and May 19, 1952. During each of these periods, the broccoli was tested for palatability and ascorbic acid content on the day of purchase and on the third and fifth days after storage in the refrigerator.

Equipment

The equipment used for testing included: volumetric flasks, Erlenmeyer flasks, wash bottles, funnels, beakers, volumetric and graduated pipettes, graduated cylinders, an acid pitcher, a stirring rod, Kodak timers, a strainer, filter paper, sharp stainless steel knives, enameled bowls and dishpans, plates, forks, glasses, serving dishes, a water pitcher, a Waring blendor, an electric hot plate, an Ainsworth analytical balance, watch glasses, a Harvard trip balance, weights and shot, a Klett-Summerson photoelectric colorimeter, Klett test tubes, a Magic Chef gas range, a walk-in refrigerator, a cutting box, one-pint heavy aluminum saucepans with lids, aluminum foil racks, and pliofilm bags.

The cutting box was constructed so that the stalks of broccoli could be cut in three-inch lengths. This length was chosen so that the broccoli could be cooked standing upright in the one-pint saucepans.

The saucepans had tight-fitting lids with valves to allow steam to escape during the cooking process.

The racks which supported the broccoli in the pan were made of three tightly folded strips of heavy aluminum foil. These strips were eight inches long and 1/4-inch wide. They were bound together in the center by another strip of folded foil. The ends of the strips were bent down one inch from the outer edge at a 90° angle, thus forming a rack with six compartments which stood one inch tall in the saucepan.

The pliofilm bags used for storing the broccoli were approximately 8 x 4 x 18 inches. They had 1/4-inch holes punched six inches from the lower edge and one inch from the side through all thicknesses of the folded bag so that each bag had eight holes in all.

Reagents Used

Reagents used were crystalline ascorbic acid (Cebione Merck), sodium 2,6-dichlorobenzenoneindophenol dye, metaphosphoric acid pellets, distilled water, and butyl stearate.

Purchasing of the Broccoli

At each test period, from 10 to 12 pounds of broccoli were selected from that available at the store. The broccoli was sold in bunches which varied in weight so that the number of bunches purchased each day was different. Because the quality of the broccoli within each bunch varied, it was hard to make any real selection. There were both good and poor heads in each bunch. This variation in quality within the bunches made the preparation of representative samples for testing more difficult.

Preparation of the Broccoli for Storage

The weight of the broccoli purchased was recorded in grams, together with the number of bunches, the cost, and a description. Because of the large size of the bunches, each bunch was weighed individually. It was separated and put into dishpans for random sampling.

The amount of broccoli needed for the first day's testing was set aside. The remaining broccoli was put into three large pliofilm bags. The weight of each of these bags of broccoli was recorded. They were then placed in the refrigerator until time to be tested.

Procedure for the First Day's Testing

The total weight of the broccoli set aside for the first day's testing was recorded. It was then cut into three-inch stalks by means of the cutting box. In the cutting, very large leaves were removed, then any badly bruised spots were cut off. The broccoli was not washed at this time, but was reweighed and this weight recorded as the weight after preparation. This total amount was divided into three parts, one for the palatability test, one for the raw ascorbic acid, and the other for the cooked ascorbic acid tests. The broccoli not to be used immediately was put in smaller pliofilm bags in the refrigerator until ready for use.

Procedure for the Third and Fifth Days' Testing

When the broccoli had been stored for three days, it was taken from the refrigerator and weighed in the pliofilm bags. This weight was recorded together with a short description of the appearance. The amount needed for that day's testing was removed and prepared for testing in the same manner as the broccoli on the first day. The remainder was weighed again in the pliofilm bags and put back in the refrigerator until the fifth day.

On the fifth day, the procedure was the same as on the third day, except that no broccoli was put back into storage.

Palatability Tests

The broccoli to be used for palatability tests was washed quickly, shaken gently to remove excess moisture, and weighed into duplicate 100 g portions. If the lower end of the stem measured more than 3/4 inch in diameter, the stalk was split into two parts. If not, it was left whole. In each case the lower end of the stem was scored 1/2 inch deep.

These 100 g samples were cooked in 200 g of water and 0.5 g salt in small aluminum pans fitted with aluminum foil racks. After the water was brought to a boil, the broccoli was placed upright in the pan and cooked at a rapid boil for 10 minutes, with the lid closed tightly. In this way, the stems of the broccoli, which were in the boiling water, were cooked thoroughly without overcooking the flower portion. At the end of the cooking period, the stalks were lifted from the pan with a fork, placed in the serving dishes and served immediately. They were scored by a panel of six judges using Form 1 as a scorecard. The scores were recorded and tabulated.

Preparation of the Broccoli for the Ascorbic Acid Tests

Raw. The broccoli for the raw ascorbic acid tests was washed quickly, shaken gently to remove excess moisture, and weighed into duplicate 100 g samples. Because of the tough, fibrous nature of the raw broccoli, the samples were prepared for the blender by slicing quickly into pieces approximately 1/2-inch square.

Cooked. The broccoli to be cooked was washed and weighed into duplicate 100 g samples in the same manner as the raw. The cooking of these samples was the same as for the palatability tests except that the salt was omitted. At the end of the cooking period, the broccoli was drained for two minutes, reweighed, and this weight recorded. One hundred grams of the cooked broccoli was put in the blendor as the initial step in the ascorbic acid determinations. All calculations were made on the basis of 100 g of raw broccoli.

Ascorbic Acid Tests

The duplicate samples of raw and cooked broccoli were analyzed for ascorbic acid content by a modification of the Loeffler-Ponting method. The solutions needed for this analysis included:

1. A one per cent solution of metaphosphoric acid. This was prepared by adding 100 ml of a 10 per cent stock solution to 900 ml of distilled water. The stock solution was made each day by dissolving 100 g metaphosphoric acid pellets in enough distilled water to make one liter of solution.

2. A solution of sodium 2,6-dichlorobenzenoneindophenol dye. This was prepared by dissolving and filtering ± 20 mg of the dye with hot distilled water into a 1000 ml volumetric flask. This solution was cooled, made up to volume, and stored in the refrigerator until needed.

3. A stock solution of ascorbic acid. This was used in the

standardization of the dye solution. It was prepared by weighing exactly 25 mg of crystalline ascorbic acid (Cebione Merck), and dissolving these crystals with enough freshly prepared one per cent metaphosphoric acid to bring the volume of the solution to 250 ml.

All of these solutions were warmed to room temperature before being used.

- Standardization of the Dye Solution. The ascorbic acid dilutions used in the standardization were prepared by pipetting 3 ml, 4 ml, and 5 ml of the stock solution into each of three 100 ml volumetric flasks and making these up to volume with freshly prepared 1 per cent metaphosphoric acid. The concentration of ascorbic acid in these solutions was 3 micrograms per ml, 4 micrograms per ml, and 5 micrograms per ml, respectively.

Five ml of dye solution were pipetted into each of eight Klett tubes. The colorimeter was calibrated to zero with a Klett tube containing 5.0 ml of distilled water. To one of the tubes of dye, 5.0 ml of the 1 per cent metaphosphoric acid was added, using a 5 ml volumetric pipette. The tube was inverted quickly three times and inserted in the colorimeter. The reading was taken 15 seconds after the beginning of the addition of the acid. This reading of dye plus acid is referred to as the blank reading. A check was run on each test.

The same procedure was followed for each of the ascorbic acid dilutions. Five ml of the three dilutions were pipetted into the tubes containing dye. The reading was made after 15 seconds and a check was run on each dilution.

The ascorbic acid factor was calculated as follows:

$$\text{ascorbic acid factor} = \frac{\text{concentration of ascorbic acid}}{\text{blank reading} - \text{ascorbic acid reading}}$$

The average of the values for the three concentrations of ascorbic acid was used as the ascorbic acid factor in calculating the ascorbic acid content of the broccoli samples.

Method of Extraction. Each 100 g sample of raw and cooked broccoli was put into the Waring blendor containing approximately 500 ml of one per cent metaphosphoric acid and several drops of butyl stearate (to prevent excessive foaming). After blending for five minutes, the mixture was transferred quantitatively into a 1000 ml volumetric flask and made up to volume with one per cent metaphosphoric acid. The flask was inverted 10 times to mix thoroughly and a portion of the mixture filtered through fluted filter paper.

The cooking liquid was made up to a volume of 200 ml with one per cent metaphosphoric acid and filtered. These filtrates were then analyzed for ascorbic acid content.

Analysis of the Filtrate. In order to obtain an accurate analysis for ascorbic acid in the colorimeter, it is necessary that the solution analyzed contain approximately the same concentration as the dilutions used in standardizing the dye. In other words, the readings for the samples should fall within the range used in the dye standardization. To obtain the correct concentration, the filtrates had to be diluted. A two to fifty or three to fifty dilution was satisfactory for the broccoli samples. These dilutions were made by pipetting either two or three ml of the filtrate into a 50 ml volumetric flask, then making up to volume with one per cent metaphosphoric acid.

The method of analysis was similar to that used in the standardization of the dye. Three tubes were used for each determination. Five ml of distilled water were pipetted into one tube and five ml of dye into each of the other tubes.

To correct for turbidity and the normal color of the solution, five ml of the unknown solution were added to the tube containing the distilled water. The tube was inverted quickly three times, inserted in the colorimeter, and the machine calibrated to zero.

Five ml of the unknown were added to one of the tubes containing dye and the reading taken 15 seconds after the beginning of the addition. Duplicate readings were made for each of the dilutions. These readings were referred to as the unknown readings.

The concentration of ascorbic acid was calculated as mg per 100 g of sample by the following formula:

dye blank - unknown reading = corrected unknown

$$\frac{\text{ascorbic acid factor} \times \text{corrected unknown} \times \text{dilution}}{\text{aliquot portion}} = \text{mg ascorbic acid per 100 g of sample}$$

RESULTS AND DISCUSSION

A description of the broccoli on the day it was purchased is found in Table 1. In general, if the broccoli was of good quality when purchased, it tended to retain most of that quality, although it did become somewhat drier and often developed a few yellow buds during storage. If however, the broccoli was of poor quality at the time of purchase, especially if overmature, it became wilted and dry very quickly and the buds lost much of their green color. These tendencies were also noted in the palatability and ascorbic acid tests.

Price

The prices of the broccoli purchased for this study are recorded in Table 2. The average price per pound was 21 cents. It varied during the eight periods from 14 to 35 cents per pound. These prices were similar to those found by Sherman, Lenox, and Gould (1949) in Columbus, Ohio, during the spring of 1948. During the first two months of the present study, the price was lower than during the last two months, the average price being 17 cents during February and March, as compared with an average of 25 cents during April and May.

There appeared to be little or no relation between the price of the broccoli and either the ascorbic acid values or the palatability scores. The quality of the broccoli did not necessarily increase with the price. In fact, the broccoli with the lowest

Table 1. Description of the broccoli on the day of purchase.

Period	Date of purchase	Color	Stems	Buds	Leaves	Freshness	Average quality rating
1	Feb.15	green	medium size some slightly bruised	medium size, not overmature	many very large	good	good
2	Feb.29	green to purplish buds	medium to slender	medium to small	none large	good	good
3	Mar. 7	many yellow and brown buds	very slender to thick	one head with blooms visible inside buds, others close to blooming	many large	wilted and not fresh appearing	fair to poor
4	Mar.28	many yellow buds	very slender	large, some beginning to bloom	none large	wilted	fair to poor
5	Apr. 4	all dark green	fairly thick	compact	few small	quite crisp and fresh	very good
6	Apr.18	mostly green, some yellow buds	mostly medium some very slender, some very thick	most buds fairly compact, some almost blooming	none large	wilted	fair to poor
7	May 2	green	large and thick	fairly compact, none too mature	none large	fresh and crisp	fair
8	May 14	green	medium to very large some very long	fairly compact, some bruised	none large	wilted and slightly dry	fair

Table 2. Number of bunches, total weights, and prices of broccoli purchased during the eight periods.

Period	Number of bunches	Total weight in lbs.	Price per bunch	Total price	Price per lb.
1	5	10 1/2	$ 0.29	$ 1.45	$ 0.14
2	6	11 3/4	0.29	1.74	0.15
3	6	11 1/4	0.33	1.98	0.17
4	7	10 3/4	0.35	2.45	0.23
5	6	11 1/2	0.35	2.10	0.18
6	8	11 1/4	*	3.97	0.35
7	8	12 1/4	0.33	2.64	0.22
8	8	12 1/4	0.39	3.12	0.26
Average					0.21

* Although sold in bunches, broccoli for this period was priced by the pound rather than by the bunch. It was purchased at a different local market because of a truck strike which made it unavailable at the original market.

original ascorbic acid values was purchased at a time when the price was highest. This can be explained partly by the fact that in this locality, more broccoli is available during the winter and early spring months than later in the spring. Therefore, the price is lower at the earlier period and there is greater opportunity for selection.

Palatability

The results of the palatability tests are summarized in Table 3.

In cooking the broccoli for palatability testing, an effort was made to have the individual stalks in each 100 g sample as nearly alike as possible, so that all the judges would be scoring broccoli of similar quality. This was difficult to accomplish, however, because of the quality variations among stalks in each bunch as it was purchased. This meant that often one judge would score his portion of a given sample very low while other judges would score portions of the same sample much higher. For example, in scoring the broccoli of the third period, after three days' storage, one judge considered a sample unacceptable and gave it an average total score of -3. Another considered it acceptable and gave it an average total score of +2. These differences in the scores of the judges are similar to the wide variations in the ascorbic acid values for the broccoli. When these scores were averaged, definite trends could be observed. It was interesting to see that these trends were similar to those found with the ascorbic acid tests.

The broccoli on the first day of each period was considered acceptable and given an average score of slightly superior. After storage for three days, the average score was standard, and it was still acceptable at all but the fourth period, at

Table 3. Average palatability scores for fresh and stored broccoli for the eight periods.

Period	Days of storage	Number of judges	Average scores for duplicate samples*					
			Aroma	Appearance	Flavor	Texture	Acceptability	Total
1	0	6	0.5	1.3	0.8	0.8	+	0.8
	3	6	-0.2	0.8	0.0	1.5	+	0.5
	5	6	-0.2	1.0	0.6	1.0	+	0.6
2	0	6	-0.2	0.8	0.6	1.0	+	0.6
	3	5	-0.2	1.1	0.6	1.7	+	0.8
	5	5	-1.1	-1.1	-0.9	0.7	+	-0.6
3	0	6	0.0	0.5	0.2	0.9	+	0.4
	3	6	-0.5	-0.7	-0.7	1.0	+	-0.2
	5	5	-1.4	-1.8	-1.7	0.6	?	-1.1
4	0	5	-0.4	-0.1	-0.2	0.4	+	-0.1
	3	6	-1.0	-2.3	-1.3	0.5	?	-1.0
	5	5	-2.2	-4.0	-3.7	-0.6	-	-2.6
5	0	5	-0.5	0.5	0.6	1.6	+	0.6
	3	6	-0.1	1.0	0.5	1.6	+	0.8
	5	5	-0.6	1.8	1.2	1.4	+	1.0
6	0	6	-0.3	-0.4	0.4	0.9	+	0.2
	3	6	-1.2	-1.7	-1.0	0.9	+	-0.8
	5	6	-1.6	-3.4	-2.4	0.0	?	-1.8
7	0	5	0.3	1.2	1.2	1.8	+	1.1
	3	6	-1.0	-0.4	0.5	1.7	+	0.2
	5	6	-1.2	-3.2	-1.0	1.2	?	-1.0
8	0	5	0.0	0.2	0.5	0.9	+	0.4
	3	5	-0.5	-0.3	-0.2	0.7	+	-0.1
	5	6	-1.0	-1.5	-1.0	-0.7	?	-1.0

* Possible range of scores: -5.0 to + 5.0.

which time the acceptability was considered questionable. After the fifth day, the average score had decreased to moderately inferior and was marked acceptable during three periods, questionable during four, and unacceptable during one. These scores were averages of the total scores of all judges at each time of testing.

Broccoli of good original quality tended to remain high in palatability throughout storage. The range of the average total scores was less during periods 1, 5, and 2. The highest average total scores throughout storage were also found during these periods. As seen from Table 1, the broccoli during these three periods was of good quality when purchased. The ascorbic acid retentions were also high.

The broccoli of period 4 had an average total score of -0.1 on the first day, -1.0 on the third day, and -2.6 on the fifth day. This broccoli was considered of poor quality when purchased and had low ascorbic acid retentions after both storage periods.

The samples were scored for aroma, appearance, flavor, and texture. Of these four characteristics, the aroma scores were generally lower than any of the others. In most cases, the average aroma scores were below standard on all three days of each period. The judges described the aroma as being strong, hay-like or sulfury. However, it did not seem to affect the acceptability of the sample, if the other scores were high.

Texture was usually highest of the four characteristics scored. All of the judges preferred the crisper texture of the broccoli cooked for only 10 minutes, to the softer texture of that cooked for a longer period during part of the preliminary work.

Flavor and appearance scores varied the most with differences in the quality of the broccoli. The judges definitely objected to the yellow color, more open buds, and bitter flavor of the overmature broccoli. In many cases, the appearance was considered more objectionable than the flavor. Several of the judges commented at different times that they would eat broccoli of that quality, but would not serve it.

Ascorbic Acid

Raw. The ascorbic acid content of the fresh raw broccoli on the day it was purchased varied from 82.22 to 127.40 mg per 100 g, with an average value of 109.35 (Table 4). This was slightly lower than many of the reports in the literature. It was higher, however, than that found by Harris and Olliver (1942), who reported 57 to 91 mg per 100 g. In comparing the values found in the present study with those of other reports, it must be remembered that this broccoli was purchased from a local market, where there was no way of determining its previous history. The majority of the studies reported in the literature were done on broccoli grown under controlled conditions and tested soon after being harvested.

The ascorbic acid content of the fresh raw broccoli for the first period (February 15) was 111.63 mg per 100 g. During the

Table 4. Ascorbic acid content of raw broccoli and the percentage retained after storage.

Period	Date of purchase	Values on day of purchase	Values on third day	Values on fifth day	Ascorbic acid retained after third day	Ascorbic acid retained after fifth day	Ascorbic acid retained on fifth day as compared with third day
		mg/100g	mg/100g	mg/100g	pct	pct	pct
1	Feb. 15	111.63	108.00	85.73	96.75	76.80	79.38
2	Feb. 29	126.69	110.11	87.36	86.91	68.96	79.34
3	Mar. 7	127.40	98.28	117.62	77.14	92.32	119.68
4	Mar. 28	123.62	105.17	80.98	86.06	65.51	77.00
5	Apr. 4	111.59	125.42	109.62	112.39	98.23	87.40
6	Apr. 18	103.02	79.83	80.13	77.46	77.78	100.41
7	May 2	88.65	93.11	74.86	105.03	84.44	80.40
8	May 14	82.22	79.38	76.86	96.55	93.48	96.83
Average		109.35	99.91	89.15	92.26	82.19	90.06

next two periods, it increased to 126.69 on February 29 and to 127.40 on March 7. For the rest of the spring, it fell gradually until on May 14, the last period, it was 82.22. This would seem to be a seasonal variation. However, this study was not complete enough, or carried on over a long enough period to be able to make any definite statement concerning seasonal variation. Hansen (1945), after determining the ascorbic acid content of several vegetables, including broccoli, over a period of nine months, stated that a trend such as this was not necessarily consistent. He believed that variations in ascorbic acid content were probably more directly related to variety than to seasonal trends. No information was available regarding the variety or varieties of broccoli used in this study.

The losses in the weight of the broccoli after each storage period varied somewhat, but were less than one per cent at all times. The loss of ascorbic acid during storage was considerably greater. In considering the average of the eight periods, the broccoli lost 7.74 per cent of its original ascorbic acid content after storage for three days, and 17.81 per cent after five days. This is in agreement with the 8 per cent loss found by Patton and Miller (1948) after two days of refrigerator storage, but is somewhat more than the 11 per cent reported by Wheeler and Tressler (1939) for broccoli stored for two weeks in the refrigerator. The actual change during the first three days of storage varied from a gain of 12.39 per cent to a loss of 22.86 per cent. A gain in the ascorbic acid content was found during only two of the periods. After five days of storage, the losses varied from 1.77 to 34.49 per cent of the original ascorbic acid content. Between the third and fifth days of storage, there was again a gain in the ascorbic acid values during two periods. This was 19.68 per cent in the third period, but only 0.41 per cent in the sixth. During the other periods the loss from the third to the fifth days varied from 3.17 to 23.00 per cent, with an average loss for all eight periods of 9.94 per cent.

There was considerable variation between the values obtained for duplicate samples of the same sampling of broccoli (Tables A, B, and C, Appendix). These differences, as well as the variations and actual gain in several cases after storage may be explained in part by the differences between the individual heads of broccoli. Patton and Miller (1948) found that the ascorbic acid content of different heads of the same sampling of broccoli varied from 83 to 174 mg per 100 g.

The conformation of the broccoli stalk also affects its ascorbic acid content. For this study, the broccoli was cut into uniform three-inch lengths. However, the size of the flower portion of the stalk and the thickness of the stem varied so much from one period to another, as well as during a single period, that it was impossible to control the proportion of blossoms to stem. This could account for much of the variation between the raw samples. Zepplin and Elvehjem (1944) have shown that the ascorbic acid content of the flowers and of the stems may be quite different. In analyzing the flowers and stems separately, they found 75 to 143 mg per 100 g in the flowers, but only 50 to 80 in the stems.

In spite of these variations due to factors beyond control, there were certain trends in the loss of ascorbic acid during storage which were interesting to note. In the first place, the appearance of the broccoli just after purchase did not seem to be directly related either to the original ascorbic acid content or to the retention of ascorbic acid with storage (Tables 1 and 4). For instance, the broccoli of the fifth period which appeared most desirable just after purchase was only fifth high in original ascorbic acid content, yet it was first in percentage retention after both three and five days of storage. In the second period, in which the broccoli was also considered good in quality rating, it ranked second in original ascorbic acid content, but was fifth and seventh in percentage retention after storage for three and five days respectively.

Another observation which can be made is that there seemed to be little or no relationship between the original ascorbic acid content and the percentage retention after storage. The broccoli of the fifth period, which ranked fifth in original ascorbic acid content, was first in percentage retention after both three and five days of storage. During the eighth period, the original ascorbic acid content was lowest, yet it ranked fourth in percentage retention after three days and second after five days. On the other hand, the broccoli of the second period, which was second in original ascorbic acid content, ranked fifth after

Table 5. Ascorbic acid in raw and cooked broccoli after zero, three, and five days' storage.

Days of storage	Period	Raw	Cooked	Ascorbic acid retained
		mg/100g	mg/100g	pct
0	1	111.63	115.85	103.78
	2	126.69	110.76	87.43
	3	127.40	131.91	103.54
	4	123.62	131.35	106.25
	5	111.59	128.76	115.39
	6	103.02	82.48	80.06
	7	88.65	77.66	87.60
	8	82.22	78.32	95.26
3	1	108.00	107.01	99.08
	2	110.11	102.72	93.29
	3	98.28	101.23	103.00
	4	105.17	119.93	113.37
	5	125.42	119.50	95.28
	6	79.80	84.42	105.79
	7	93.11	72.76	78.14
	8	79.38	72.14	90.88
5	1	85.73	85.55	99.79
	2	87.36	91.63	104.89
	3	117.62	96.06	81.67
	4	80.98	80.74	99.70
	5	109.62	118.55	108.15
	6	80.13	59.24	73.93
	7	74.86	63.31	84.57
	8	76.86	70.42	91.62

three days and seventh after five days.

Cooked. The ascorbic acid content of the cooked broccoli was determined both in the cooked vegetable and in the cooking liquid. However, because the cooking liquid is not ordinarily eaten with the vegetable, the retention of ascorbic acid in the vegetable itself was considered the more important. The average content of the cooked broccoli on the day of purchase was 107.14 mg per 100 g, as compared with an average of 109.35 mg per 100 g in the raw vegetable. The percentage retention on the day of purchase varied during the eight periods from 80.06 to 115.39 per cent with an average retention of 97.98 per cent (Tables 5 and 6). This was slightly higher than that reported by Van Duyne, et al. (1951) who cooked broccoli by a method similar to that used in this study.

Considering the averages, the amount of ascorbic acid present in the cooked broccoli decreased with storage, as did the amount in the raw broccoli (Table 6). However, the average percentage retention with cooking decreased only slightly after each of the storage periods. The stored broccoli did not necessarily lose more ascorbic acid in cooking than the fresh. The average retention was 97.98 per cent on the day of purchase, 97.55 per cent on the third day, and 93.31 per cent on the fifth day. The overall average retention for all three periods was 96.28 per cent.

Table 6. Average ascorbic acid in raw and cooked broccoli after zero, three, and five days' storage.

Days of storage	Raw	Cooked	Ascorbic acid retained
	mg/100g	mg/100g	pct
0	109.35	107.14	97.98
3	99.91	97.46	98.55
5	89.15	83.19	93.31

The variations in ascorbic acid retention were at least as great in the cooked samples as in the raw (Table 5). In several cases, there was an increase in the ascorbic acid values of the cooked broccoli over the raw values. When the values for the cooking liquid were added to those for the solids, the total ascorbic acid content of the cooked was from 2.04 to 30.78 per cent higher than the raw in 19 of the 24 cases (Table 7). Van Duyne, et al. (1951) also found higher values for ascorbic acid in cooked broccoli and other vegetables than they did in the raw when the figures for the cooked vegetables and the cooking liquid were added together. These differences may be explained on the basis of variation in sampling and in the conformation of the broccoli stalk, as in the case of the raw broccoli.

High values for the cooked broccoli may also be attributed to the increased efficiency of the method of extracting the ascorbic acid from the cooked broccoli over the method used for the raw. The inefficiency of the method for the raw may be due to certain properties of the ascorbic acid oxidase which is one cause for the destruction of ascorbic acid in vegetables. This enzyme is known to be destroyed by heat; its activity is increased by crushing, grinding, and bruising of the raw vegetable; and the extent of its action is related to the amount of exposed surface area. Because of these properties, it was easier to control the action of the enzyme in the cooked broccoli than in the raw. The broccoli to be cooked was left in whole pieces with a stem diameter of 3/4 inch or less, while the raw sample was cut

Table 7. Ascorbic acid content in raw and cooked broccoli and cooking liquid after zero, three, and five days' storage.

Days of storage	Period	Raw	Cooked	Cooking liquid	Total cooked	Ascorbic acid retained
		mg/100g	mg/100g	mg/100g	mg/100g	pct
0	1	111.65	115.85	20.51	136.36	122.15
	2	126.69	110.76	21.53	132.29	104.42
	3	127.40	131.91	12.25	144.16	113.16
	4	123.62	131.35	16.05	147.40	119.24
	5	111.59	128.76	17.18	145.94	130.78
	6	103.02	82.48	14.54	97.02	94.18
	7	88.65	77.66	12.80	90.46	102.04
	8	82.22	78.32	10.33	88.65	107.82
3	1	108.00	107.01	16.34	122.35	114.20
	2	110.11	102.72	15.11	117.83	107.01
	3	98.28	101.23	14.75	115.98	118.01
	4	105.17	119.93	13.78	133.71	127.14
	5	125.42	119.50	22.52	142.02	113.24
	6	79.80	84.42	9.70	94.12	117.94
	7	93.11	72.76	9.98	82.74	88.86
	8	79.38	72.14	10.96	83.10	104.69
5	1	85.73	85.55	12.95	98.50	114.90
	2	87.36	91.63	12.86	104.49	119.61
	3	117.62	96.06	15.29	111.35	94.67
	4	80.98	80.74	14.09	94.83	117.10
	5	109.62	118.55	19.36	137.91	125.81
	6	80.13	59.24	11.58	70.82	88.38
	7	74.86	63.21	8.18	71.49	95.50
	8	76.86	70.42	10.40	80.82	105.15

into pieces approximately 1/2 inch square. This was deemed necessary in order to facilitate blending, because of the fibrous nature of the raw broccoli. However, it did expose more cut surface area in the raw sample. The sample for cooking was plunged immediately into boiling water. The ratio of water to vegetable was such that the boiling was stopped only a few seconds by the addition of the vegetable. This heat treatment helped to inactivate the oxidase before the sample was put into the blendor. On the other hand, no such action was taken to inactivate the enzyme in the raw sample, and the grinding action of the blendor probably increased its activity. After cooking, the broccoli was more tender so that it produced a very smooth mixture with blending. The raw sample did not produce a completely homogeneous mixture with blending even though it had been cut in small pieces.

For these reasons, it seems logical that the values for cooked broccoli were higher than those for the raw in many cases. This is in agreement with a similar conclusion of Harris and Olliver (1942).

The high retentions of ascorbic acid found in the cooked broccoli would indicate that both fresh and stored broccoli are excellent sources of vitamin C. Even after five days of storage, the average amount furnished by 100 g of cooked broccoli was 83.19 mg, which is higher than the daily allowance recommended by the National Research Council (1948).

There did not seem to be a direct relationship between palatability and ascorbic acid content. However, the relationship of both of these to the original quality of the broccoli is both interesting and important since it points out certain conclusions concerning the practicality of storing broccoli in the refrigerator for several days before using it. Broccoli of good original quality was found to remain high in both ascorbic acid content and palatability scores after storage. On the other hand, broccoli of poorer original quality became less palatable quickly, even though it still contained a high amount of ascorbic acid. A high ascorbic acid content is of little value if the product is undesirable in palatability. Therefore, it is believed that only broccoli of good original quality should be stored.

SUMMARY

The purposes of this study were to determine the quality of market fresh broccoli and to ascertain the effects of refrigerator storage on it. Quality was measured by palatability and ascorbic acid tests. A third purpose was to discover if there were a relationship between palatability and ascorbic acid content of the fresh and stored broccoli.

The broccoli was purchased from a local market at eight times during the spring. Tests were made on the day of purchase and after three and five days of storage at temperatures similar to those of a home refrigerator.

The price of the broccoli varied considerably from one period to the next, but, in general, it was lower during the first two months of the study. There appeared to be little or no relation between price and the quality of the broccoli as purchased.

When palatability scores for the eight periods were averaged, it was found that fresh broccoli on the day of purchase was considered slightly superior. After three days of storage, it was considered standard; after five days, moderately inferior. If the original quality of the broccoli was good, the palatability scores tended to remain high. But for poorer quality broccoli, the scores decreased fairly rapidly after each storage period.

The broccoli was scored for aroma, appearance, flavor, and texture. Of these, aroma scores were generally lower than standard, while texture scores were usually higher. Because the scores for flavor and appearance varied the most with differences in the quality of the broccoli, these two characteristics had the most influence on over-all palatability scores.

The average ascorbic acid content of the fresh raw broccoli on the days of purchase was 109.35 mg per 100 g. After storage for three days, this average was 99.91 mg per 100 g, and after five days it was 89.15 mg per 100 g. In considering the average of the eight periods, the broccoli lost 7.74 per cent of its original ascorbic acid content after three days of storage, and 17.81 per cent after five days. As in studies reported by Lampitt, Baker, and Parkinson (1945b), Zepplin and Elvehjem (1944) and others, there was considerable variation in the losses found after storage.

The average percentage retention of ascorbic acid in the cooked broccoli was 97.98 on the day of purchase, 97.55 on the third day of storage, and 93.31 on the fifth day. The decrease in percentage retention after each storage period was only slight, and the ascorbic acid content of cooked broccoli was still high even after storage for five days. Thus, it would appear that fresh or stored broccoli may be considered a good source of vitamin C.

The percentage retentions during each period varied considerably. In several cases there were increases. When the values obtained for the cooking liquid were added to those for the solids, the total ascorbic acid content of the cooked broccoli was higher than the raw value in 19 of the 24 cases. This may be due in part to differences between individual stalks of broccoli and in the proportion of blossoms to stem in each stalk. It may also be the result of the increased efficiency of the method of extracting the ascorbic acid from the cooked broccoli over the method used for the raw. In the cooked samples, less surface area was exposed, boiling water was used, and a more homogeneous mixture was produced with blending. This helped to control more closely the action of the ascorbic acid oxidase which is responsible in part for the destruction of ascorbic acid in fruits and vegetables.

As a result of this work, the investigator believes that broccoli can be stored in the refrigerator for several days before using it. However, the advisability of this storage would depend on the original quality of the broccoli. Broccoli of good quality was found to remain high in both ascorbic acid and palatability after storage. On the other hand, while broccoli of poorer quality retained a high amount of ascorbic acid after storage, it became less palatable quickly. A high ascorbic acid content is of little value if the product is undesirable in palatability.

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APPENDIX

Form 1

SCORE CARD

Fruits and Vegetables

Date ____________________

Sample No. ______________

Name ____________________

1. Aroma	Use the following numbers as a guide for scoring:					
2. Appearance Color Shape Shriveled	Very superior +5 Superior +4 Moderately sup. +3 Slightly sup. +2 Very sl. sup. +1					
3. Flavor	Standard 0 Very sl. inferior -1 Sl. inferior -2 Moderately inf. -3 Inferior -4					
4. Texture	Very inferior -5					
Would you consider this as an acceptable product to serve at a meal?						
Comments:						

Table A. Ascorbic acid content of duplicate samples of raw and cooked broccoli and cooking liquid after zero days' storage.

Period	Raw: Duplicate samples	Raw: Average	Cooked: Duplicate samples	Cooked: Average	Cooking liquid: Duplicate samples	Cooking liquid: Average
	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g
1	112.53 110.72	111.63	112.93 118.77	115.85	20.691 20.328	20.510
2	127.64 125.73	126.69	109.79 111.73	110.76	21.336 21.717	21.527
3	127.40 127.40	127.40	134.53 129.29	131.91	12.376 12.132	12.254
4	125.46 121.77	123.62	135.16 127.53	131.35	16.236 15.867	16.052
5	122.45 100.73	111.59	131.90 125.61	128.76	16.195 18.170	17.183
6	94.95 111.10	103.02	80.60 84.36	82.48	14.814 14.274	14.544
7	96.53 80.77	88.65	80.85 74.47	77.66	13.396 12.204	12.800
8	75.60 88.83	82.22	79.72 76.92	78.32	10.584 10.080	10.332
Average		109.35		107.14		15.593

Table 3. Ascorbic acid content of duplicate samples of raw and cooked broccoli and cooking liquid after three days' storage.

Period	Raw		Cooked		Cooking liquid	
	Duplicate samples	Average	Duplicate samples	Average	Duplicate samples	Average
	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g
1	107.09 108.90	108.00	106.92 107.09	107.01	17.424 15.246	16.335
2	107.38 112.84	110.11	106.11 99.32	102.72	14.924 15.288	15.106
3	103.75 92.82	98.28	103.74 98.72	101.23	13.104 16.501	14.753
4	116.24 94.10	105.17	110.59 129.26	119.93	14.514 13.038	13.776
5	132.33 118.50	125.42	126.01 112.98	119.50	25.280 19.750	22.515
6	88.89 70.70	79.83	91.03 77.81	84.42	9.965 9.427	9.696
7	116.23 69.98	93.11	78.70 66.82	72.76	10.769 9.193	9.981
8	78.12 80.64	79.38	70.12 74.16	72.14	10.962 10.962	10.962
Average		99.91		97.46		14.141

Table C. Ascorbic acid content of duplicate samples of raw and cooked broccoli and cooking liquid after five days' storage.

Period	Raw: Duplicate samples	Raw: Average	Cooked: Duplicate samples	Cooked: Average	Cooking liquid: Duplicate samples	Cooking liquid: Average
	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g
1	85.73 85.73	85.73	85.18 85.92	85.55	12.700 13.208	12.954
2	91.00 83.72	87.36	97.84 85.42	91.63	13.104 12.618	12.861
3	116.94 118.30	117.62	94.77 97.35	96.06	14.560 16.016	15.288
4	75.05 86.90	80.98	82.56 78.92	80.74	13.430 14.746	14.088
5	98.75 120.48	109.62	120.58 116.51	118.55	20.540 18.170	19.360
6	76.76 83.49	80.13	59.65 58.82	59.24	12.120 11.042	11.581
7	77.49 72.23	74.86	66.92 59.70	63.31	9.062 7.288	8.175
8	84.42 69.30	76.86	68.04 72.80	70.42	10.206 10.584	10.395
Average		89.15		83.19		13.088

Table D. Losses in weight and in liquid during cooking of the broccoli.

Period	Weight of broccoli cooked	Volume of water used in cooking	Zero days storage		Three days storage		Five days storage	
			Broccoli after cooking	Liquid after cooking	Broccoli after cooking	Liquid after cooking	Broccoli after cooking	Liquid after cooking
	g	ml	g	ml	g	ml	g	ml
1	110	200	119	98	119	92	120	92
2	100	200	114	103	108	74	111	94
3	100	200	112	84	114	91	112	106
4	100	200	110	94	112	91	112	94
5	100	200	106	83	107	95	112	82
6	100	200	106	98	106	94	104	121
7	100	200	106	99	106	97	106	111
8	100	200	111	105	107	112	108	97
Average	101	200	110	96	110	93	111	98

THE EFFECT OF REFRIGERATOR STORAGE ON THE PALATABILITY
AND ASCORBIC ACID CONTENT OF MARKET
FRESH BROCCOLI

by

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INTRODUCTION

Information concerning the advisability of storing fresh vegetables for several days before using them would be valuable to the homemaker. Therefore, this study was made to determine the quality of market fresh broccoli and to ascertain the effects of refrigerator storage on it. Quality was measured by palatability scores and ascorbic acid tests. The relationship between these two types of tests was also studied.

PROCEDURE

Broccoli was purchased from a local market at eight times during the spring. It was tested for palatability and ascorbic acid content on the day of purchase and after three and five days of refrigerator storage. The ascorbic acid tests were made on both the raw and the cooked broccoli by a modification of the Loeffler-Ponting method. The broccoli to be stored was put in large pliofilm bags and kept in the refrigerator until time to be tested.

DISCUSSION OF RESULTS

There appeared to be little or no relation between price and the quality of the broccoli as purchased.

The average palatability scores for the eight periods decreased gradually after each of the storage periods. When the quality as purchased was good, the palatability scores tended to remain high, or even increase after storage. But the scores for poorer quality broccoli decreased fairly rapidly with storage.

Of the four characteristics scored, aroma scores were generally lower than standard, while texture scores were usually higher. Scores for flavor and appearance varied the most with differences in the quality of the broccoli, and had the most influence on over-all palatability scores.

The average ascorbic acid content of the fresh raw broccoli on the days of purchase was 109.35 mg per 100 g. In considering the average of the eight periods, the broccoli lost 7.74 per cent of its original ascorbic acid content after three days of storage, and 17.81 per cent after five days.

The average percentage retention of ascorbic acid in the cooked broccoli was 97.98 on the day of purchase, 97.55 on the third day of storage, and 93.31 on the fifth day. The decrease in percentage retention after each storage period was only slight, and the ascorbic acid content of the cooked broccoli was high even after storage for five days. Thus, it would appear that fresh or stored broccoli may be considered a good source of vitamin C.

The percentage retentions during each period varied considerably. In several cases there were increases. When the values obtained for the cooking liquid were added to those for the solids, the total ascorbic acid content of the cooked broccoli was higher than the raw in 19 of the 24 cases. This may in part be due to differences between individual stalks of broccoli and in the proportion of blossoms to stem in each stalk. It may also be the result of the increased efficiency of the method of extracting the ascorbic acid from the cooked broccoli over the method used for the raw. In the cooked samples, less surface area was exposed, boiling water was used, and a more homogeneous mixture was produced with blending. This helped to control more closely the action of the ascorbic acid oxidase which is responsible in part for the destruction of the ascorbic acid in fruits and vegetables.

As a result of this work, the investigator believes that broccoli can be stored in the refrigerator for several days before using it. However, the advisability of this storage would depend on the original quality of the broccoli. Broccoli of good quality was found to remain high in both ascorbic acid and palatability after storage. On the other hand, while broccoli of poor quality retained a high amount of ascorbic acid after storage, it became less palatable quickly. A high ascorbic acid content is of little value if the product is undesirable in palatability.