The effect of storage on the qualities and ascorbic acid content of Montana grown McIntosh apples
by Mary Baxter Briggs

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the degree of Master of Science in Home Economics at Montana State College
Montana State University

Abstract:
The average ascorbic acid content of the Montana-grown McIntosh apples used in this study was found to be 2.08 milligrams per 100 grams of raw apple. There was a significant decrease in the ascorbic acid values of the apples during four months of storage at a temperature ranging from 32 to 40 degrees F. and a relative humidity ranging from 6o to 86 per cent. The greatest decrease in the ascorbic acid value of the apples occurred during the first month of storage. This was followed by an increase in ascorbic acid during the second and third months of storage which suggests the possibility of vitamin C synthesis in the apple. A reduction in ascorbic acid value was again noted during the fourth month of storage. Throughout the storage period, data were obtained on the rate of evaporation in the apples and changes in their moisture content due to respiration, and with these data the percentage losses of ascorbic acid were computed on a dry basis. Baring four months of storage the average percentage loss of ascorbic acid in the apples was slightly over 30 per cent while, at the end of one month of storage, the loss amounted to 37.5 per cent. Consistent results were obtained to show that the concentration of ascorbic acid is more than 2 or 3 times greater in the outer area than in the inner area of the McIntosh apple.

Although the individual apples differed somewhat in density and ascorbic acid value, there appeared to be no correlation between the density and the ascorbic acid value of an apple. The total acidity of the apples was found to decrease steadily throughout storage. However, the pH values showed a slight tendency to fluctuate. The pectic acid content was reduced more than 50 per cent during three months of storage.

The scores recorded by a panel of judges indicated that the most-noticeable changes occurring in the apples during storage were decreased firmness and juiciness, accompanied by wrinkling of the skin.

In general, cookery of the apples results in large percentage losses of ascorbic acid.

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ABSTRACT

The average ascorbic acid content of the Montana-grown McIntosh apples used in this study was found to be 2.08 milligrams per 100 grams of raw apple. There was a significant decrease in the ascorbic acid values of the apples during four months of storage at a temperature ranging from 32 to 40 degrees F. and a relative humidity ranging from 60 to 86 per cent. The greatest decrease in the ascorbic acid value of the apples occurred during the first month of storage. This was followed by an increase in ascorbic acid during the second and third months of storage which suggests the possibility of vitamin C synthesis in the apple. A reduction in ascorbic acid value was again noted during the fourth month of storage. Throughout the storage period, data were obtained on the rate of evaporation in the apples and changes in their moisture content due to respiration, and with these data the percentage losses of ascorbic acid were computed on a dry basis. During four months of storage the average percentage loss of ascorbic acid in the apples was slightly over 30 per cent while, at the end of one month of storage, the loss amounted to 37.5 per cent. Consistent results were obtained to show that the concentration of ascorbic acid is more than 2 or 3 times greater in the outer area than in the inner area of the McIntosh apple.

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INTRODUCTION

For many years, the apple has been one of the most widely-used fruits. Several factors have contributed to its popularity in the American diet. In the first place, the apple can be produced with relative ease in almost any part of the country, and then, the crop can be stored for long periods of time under favorable conditions. As a result, the apple is a relatively inexpensive fruit that can be purchased at all seasons of the year. Furthermore, the natural qualities of the apple itself--a pleasing aroma and flavor, a crisp texture, and a versatility for cookery purposes, have made it a general favorite.

Throughout the United States, there are being produced many varieties of apples, each exhibiting characteristic qualities. The popularity of a variety depends on the desirability of these qualities, and may change during a period of years. For example, Gould (18)* has recently stated that in 1928 there were ten leading varieties of apples, each coming within the range of 4.1 to 8.4 per cent of the total commercial production. However, in 1943 the Delicious apple led with 16 per cent of the total production and the McIntosh came next with 10.5 per cent.

In Montana, extensive planting of apple trees began about 1906. Johnson, in his study of the McIntosh apple industry in Western Montana, 1929 (23), reported that nearly all of the plantings after 1920 were of the McIntosh variety. He found that most of the high grade McIntosh apples

* numbers in parentheses refer to literature cited.

were shipped to the New York market and were sold at a premium above other varieties of western apples. A 1935 fruit survey in Montana (5) revealed that of 355,976 apple trees, 71.85 per cent were of the McIntosh variety. Also in a recent communication from an agricultural statistician in Montana (31) the statement is made that about 90 per cent of the apple production in the commercial apple counties of Montana is of the McIntosh variety. This steadily growing preference for the McIntosh apple can doubtless be attributed to the desirability of its qualities. In addition to an attractive bright red skin coloring, it has a crisp, juicy, tender texture, a tart aromatic flavor, and lends itself to a wide variety of uses, whether raw or cooked.

While the appearance and flavor of a food largely influence its market value, it is equally important to give some consideration to its nutritive value. Since the production and use of the McIntosh apple in Montana is gradually increasing, the consumers are justified in asking for some information about the nutrients contributed by this popular fruit. One of the more essential nutrients usually found in fruits is vitamin C or ascorbic acid, so it would seem expedient to obtain some information about the content of this vitamin in the Montana-grown McIntosh apple. In 1934, Fellers in Massachusetts (9) rated varieties of apples in the decreasing order of their vitamin C content and placed the McIntosh apple in group 4 as a poor source of vitamin C. Recently, Fish and co-workers (13) determined the ascorbic acid content of several varieties of West Virginia apples and found that the McIntosh contained 7 to 10 milligrams per 100 grams of tissue, which would class it among

the poorer sources. It might be expected that the McIntosh apple as grown in Montana would be comparable in ascorbic acid content to the McIntosh as grown in other parts of the United States, but Maynard and Beeson (36) have suggested that differences in climatic conditions may make a significant difference in vitamin C values. They state that of climatic factors, light seems to have the preponderating influence on the accumulation of ascorbic acid in plants.

In addition, it is recognized that certain methods of treatment, such as storage or cookery, affect the nutritional value of plant materials. Very little has been reported on the effects of storage on the ascorbic acid content of McIntosh apples, and yet most of the apples have been subjected to a period of storage before being used. Furthermore, no information seems to be available on the losses of ascorbic acid in McIntosh apples during cookery processes and yet many of the apples are cooked before being consumed. It is therefore apparent that there is a need for specific information concerning the retention of ascorbic acid in the McIntosh apples produced in Montana.

As a means of securing such needed nutritional information, this study was planned to determine the qualities and ascorbic acid content of Montana-grown McIntosh apples, when placed in storage and at monthly intervals during four months of storage, the apples to be tested both raw and cooked.

HISTORICAL BACKGROUND

Interest was shown in the nutritive value of apples as early as 1916 when Rubner (43) presented analytical data giving the composition of apples and other winter fruits and vegetables. However, an indication of the presence of vitamin C in apples seems to have appeared for the first time in the reports of Givens, McClugage, and Van Horne in 1921 and 1922 (15,16). They found that a per diem dose of 10 grams of raw apple would protect a guinea pig against scurvy for three months, while protection was not secured by an equivalent amount of apple cooked at 100 degrees C for fifteen minutes. A few years later, Kohman, Eddy, and Carlsson (29) conducted similar studies and found that 15 grams of raw apple fed every other day proved insufficient to protect from scurvy. Of the apples held in cold storage from October to March, about twice the feeding dose was required to produce the same effect as with fresh apples. Another early report on the vitamin C content of apples appeared in 1929 in which Hessler and Craig (21) stated that when 20 grams of raw Jonathan apples were fed daily to guinea pigs during the period from September to December, they did not quite give protection against scurvy. From December to February, 30 to 40 grams of raw apple were required to afford the same degree of protection. At about the same time a group of English workers (5) reported the vitamin C content of English varieties of apples. They found that the vitamin C in the peel of the apple was three or four times as concentrated as that in the outer cortex and six times as concentrated as that in the inner cortex. Givens, McClugage, and Van Horne (16), Fellers (11), Manville, McMinis, and Chuinard (34), Todhunter (48),

Batchelder and Overholzer (4), Kolesnik (30), Eheart (8), Keys (26,27), and Gross (19) all gave evidence to substantiate the belief that the peel is a much richer source of vitamin C than the inner portion of the apple. Zilva, Kidd, West, and Perry (54), English workers, went further to state that in addition to being more concentrated near the skin, vitamin C was more concentrated in the red peel of Bramley apples than in the green peel. A similar conclusion was made by Kessler (25) working with German apple varieties, that fruit which had ripened unevenly because of shading had 30 to 50 per cent more ascorbic acid on the red side. He attributed this increase in vitamin C to light intensity. Maynard and Beeson (36) also concluded that light affected vitamin C content, showing, for instance, that the quantity of ascorbic acid in fruit growing on different parts of one tree may be proportional to the amount of light received during ripening. Todhunter (36) concluded that fruit on the outer exposed branches had consistently higher ascorbic acid content than fruit from the inner branches.

There has been considerable evidence, in addition to that shown in early work (21,29) to indicate that storage, also, has a marked influence on the ascorbic acid content of apples. Fellers, Cleveland, and Clague (10) reported a 20 per cent loss of ascorbic acid in four to six months of storage while Batchelder (3) reported a loss of 17 per cent after three months storage and 25 per cent loss after six months. A decrease of 12.4 to 52.5 per cent of the initial value on storage was shown by Kolesnik (30). Studies by Marsh (35) and by Manville et al (34) both revealed reduction of vitamin C content during storage of apples.

Fish (12) found that, in general, there was considerable loss of ascorbic acid during the first two months of storage but during the second two months there was only a small additional loss. He further indicated that ascorbic acid was lost from the skin more rapidly than from the flesh during storage. On the other hand, Keys (26) reported that New Zealand-grown Sturmer apples were relatively rich in vitamin C and maintained high values after many months of storage.

Losses of ascorbic acid appear to vary with storage temperature. Kessler (25) noted that the storage of apples at a temperature below 5 degrees C. for five months resulted in very little loss of vitamin C. Bracewell et al (5) stated that the vitamin C content of Bramley Seedling apples grown in England was unchanged after storage in air at 3 degrees C. for five months, but Todhunter (49) thought that a storage temperature above 32 degrees F. (0 degrees C.) did not favor vitamin C retention. Eheart (8) concluded that losses of vitamin C were greatly reduced if the apples were stored below 40 degrees F. (4.5 degrees C.) and Batchelder (4) believed there was more loss at 40 than at 32 degrees F. West and Zilva (52) have recently reported a different effect of storage, a tendency toward a noticeable increase in the total vitamin C content of apples, especially with early picked fruit, thus suggesting the possibility of synthesis of vitamin C in stored apples. It was not specified whether the compound synthesized was ascorbic acid or dehydro-ascorbic acid.

In addition to the preservation of ascorbic acid content, storage conditions may also affect the keeping quality of apples. For example, Riviere and Pichard (42) concluded from a storage study that fruits stored

in darkness kept longer than those stored in light. Potter (39) and Rassmussen (41) found that storage at 30 degrees F. lengthened the keeping life of the McIntosh variety, although the ultimate quality was not equal to that resulting from storage at 32 degrees F. Neller, St. John, and Rowell (37), Haller (20), and Kertesz (24) reported changes in the quality and quantity of pectic constituents during storage. Haller stated further that the rate of conversion at different temperatures was proportional to the rate of softening of apples in storage. Batchelder (3) concluded that the variety of apple and the temperature and composition of the storage atmosphere were also important factors.

The effect of cookery on the ascorbic acid content of apples has been the subject of a number of studies, the earliest being that of Givens, McClugage, and Van Horne (15), previously cited. Hessler and Williams (22) reported that sauce made from apples, of which 20 grams of the uncooked apple protected guinea pigs from scurvy, was of practically no value. Todhunter (48) noted a 50 per cent loss of vitamin C in preparing sauce from Winesap apples, while Curran and co-workers (6), making chemical analyses for ascorbic acid, noted losses when apples were baked or used for sauce or pie. Keys (26) was also aware that oxidation of vitamin C was rapid when apples were heated.

The question of relationship between fertilizer in the soil and the initial vitamin C content of apples has been a controversial one. Batchelder (2) reported that apples from trees receiving complete fertilizer treatment seemed richer in vitamin C. Maynard and Beeson (36) though, pointed out that it was not stated in the study by Batchelder

whether consideration was given to the position of the fruit on the tree. Nor was an actual soil deficiency established. Bracewell and co-workers (5) and Todhunter (50) have stated that no evidence was obtained to indicate a relationship between nitrogen and vitamin C. Kessler (25), on the other hand, believed that over-fertilizing of trees with nitrogen depressed the ascorbic acid content of the fruit. Regarding quality, Smock and Boynton (46) pointed out that a disadvantage of increasing amounts of nitrogen fertilizer was an apparent decrease in firmness of fruit at harvest time. However the rates of softening during storage were not increased.

Nutrition workers have considered many other factors as having a possible influence on the ascorbic acid content of apples. Todhunter (49) presented a summary of these studies showing that season, age of tree, immaturity of fruit when picked before normal harvesting time, chromosome number of the apples, total acidity, sugar or ash content appeared to have no relation to the ascorbic acid content of apples but concluded that variety seemed to be the chief factor affecting vitamin C content. Whether data were obtained from biological assay or from chemical analyses of apples, there appears to be a wide range in ascorbic acid content of the different varieties. Hessler and Craig (21) stated that 20 grams of raw Jonathan did not quite give protection from scurvy to guinea pigs, while Manville, McMinis, and Chuinard (34) reported that 10 grams of Gravenstein gave protection. Dove and Murphy (7) have shown that the Vitamin C content of Northern Spy apples is five to six times that of the McIntosh variety. Fish, Dustman, and Marsh (13) have analyzed

the ascorbic acid values of several varieties of apples and have classified them according to vitamin C content. For example, Duchess and Red Duchess contain 15 to 20 milligrams of ascorbic acid per 100 grams of tissue; Golden Delicious, Jonathan, Stayman Winesap, and Grimes Golden, 10 to 15 milligrams; and McIntosh, Maiden Blush, Wagener, Wealthy, York Imperial, Melba, and Rome Beauty, 7 to 10 milligrams.

Maynard and Beeson (36) summarized the question of causes of variation in the vitamin C content of plants by noting that it seemed justifiable 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 environmental conditions.

EXPERIMENTAL PROCEDURE

The McIntosh apples used in this study were obtained through the cooperation of the Horticulture department from the Moen Orchard at Bigfork, Montana, and were extra fancy grade with an average color consistently over 66 per cent and average size with 130 to 150 apples to a box. The apples, produced by young trees approximately twelve years old, were all picked early in October and placed in common storage at about 40 degrees F. As soon as possible, several boxes of unwrapped apples were transported to the laboratory for test material and were at once placed in a permanent storage.

Storage conditions: Permission was secured to store the apples in a "walk-in refrigerator" in the Student Union Building on the campus, where fresh foods, including fruits, vegetables and meats, were stored at all times. The refrigerator, equipped with an air cooling unit, maintained a temperature ranging from 32 to 40 degrees F. (0 to 4.5 degrees C.) according to readings taken each week. The relative humidity was also observed weekly and was found to range from 60 to 86 per cent, as determined by a Taylor hygrometer. The boxes of apples were placed on shelves in the refrigerator early in November and were stored there through March. At monthly intervals they were sorted and the few bruised or spoiled apples were discarded.

Loss of weight of apples during storage: To observe the loss of weight by evaporation during storage, four apples were selected at random from each of three boxes and put into cheesecloth bags, which were buried in the center of the respective boxes. The weight of each bag of apples was taken at the beginning of the storage period and at monthly intervals thereafter.

Any loss of weight was assumed to be an indication of the loss that occurred in the apples throughout the box.

Moisture content: The moisture content of the apples was determined at the beginning of the permanent storage period and at monthly intervals thereafter so that the ascorbic acid values could be computed on both moist and dry bases. For this test, a modification of the A.O.A.C.* method (1) was used. A 5-gram radial section of apple, consisting of both peel and flesh, was pulped with mortar and pestle and spread as evenly as possible over the bottom of a weighed metal dish provided with a tightly fitted cover. The sample and dish were weighed and dried in a vacuum oven at a pressure of about 25 mm. of mercury and at 70 degrees C. for eight hours. At the end of the drying period, the dish was covered, placed in a desiccator to cool and then weighed. From these data it was possible to compute moisture loss. This test was repeated with samples from five different apples at each of the monthly testing periods.

pH value: It seemed desirable to measure periodically the pH value of several apples to find whether a relationship existed between this factor and the ascorbic acid content. A 10-gram radial section of apple, both peel and flesh, was dropped into 100 ml. of distilled water and blended for four minutes in a Waring Blendor. After filtering the mixture, the pH value of the filtrate was determined using a glass electrode and a Cameron pH meter. The pH values for five apples were obtained at each testing period.

Total acidity: Total acidity was also determined at monthly intervals to

* Association of Official Agricultural Chemists

ascertain changes occurring in the apples during storage and to note any relationship between total acidity and ascorbic acid content. The solution used in determining total acidity was prepared according to the A.O.A.C. method (1) by adding a 75-gram sample of raw apple to 200 ml. of distilled water and blending for four minutes in a Waring Blendor. The solution was boiled for one hour, during which time water was added at intervals to replace water lost by evaporation, and then the solution was transferred to a 500 ml. volumetric flask, cooled, made up to volume, and filtered. Total acidity was determined by titrating 25 ml. of this solution with 0.1 N NaOH, using phenolphthalein indicator. At each testingperiod, this determination was made on each of five apples.

Pectic acid: Since pectic constituents of apples have been reported as changing during storage, tests were made to determine the extent of the change during three months of storage. The pectic acid content was determined using the A.O.A.C. method (1). A solution of apple was prepared as for total acidity determination and 200 ml. were transferred to a beaker together with two lumps of cube sugar. Addition of 200 ml. of 95 per cent alcohol caused the formation of a precipitate which was filtered off and washed with the alcohol. The precipitate was then transferred to the original beaker with hot water, evaporated to about 40 ml. and cooled to 25 degrees C. To this were added 5 ml. of a solution of NaOH (10 per cent) and water to make a total volume of 50 ml. The solution was allowed to stand 15 minutes before 40 ml. of water and 10 ml. of dilute HCl were added. After boiling for 5 minutes, a precipitate of pectic acid was formed which was filtered off and washed with hot

water. The precipitate was washed back into the original beaker, the volume was again adjusted to 40 ml. and the solution was cooled to 25 degrees C. The saponification with dilute NaOH, precipitation with dilute HCl, and boiling were repeated. The precipitate of pectic acid was washed thoroughly with hot water, transferred to a porcelain crucible and dried in an electric oven for 24 hours at 65 degrees C. The dried sample was weighed, ignited and weighed again. The loss in weight represented the amount of pectic acid in the apple sample.

Starch: A qualitative test for starch was made by dropping iodine solution on apple slices. A blue coloration would indicate the presence of starch.

Density: It seemed desirable to measure the density of the McIntosh apples used in this study so that any possible relationship which might exist between their densities and their ascorbic acid content could be noted. The density of the apples was determined from a weight-volume relationship obtained by weighing each of ten apples in air and also submerged in water.

Ascorbic acid determination: Analyses were made to determine the ascorbic acid values of the Montana-grown McIntosh apples when placed in storage and at monthly intervals throughout storage. The Loeffler and Ponting method (32) for determining ascorbic acid was used on each of the ten apples whose densities had been previously determined. The method is based on the principle that under suitable experimental conditions, ascorbic acid seems to quantitatively reduce certain colored reagents (28). In this case, the blue dye, 2, 6-dichlorobenzenoneindophenol,

was the colored compound and the color changes were recorded on the galvanometer of an Evelyn photoelectric colorimeter.

a. Standardization of the dye

The instrument was adjusted to read "100" with distilled water in the colorimeter tube. Then the dye solution was made by adding approximately 13 mg. of 2,6-dichlorobenzenoneindophenol to 1 liter of distilled water. With a rapid delivery pipette 9 ml. of dye solution were added to 1 ml. of metaphosphoric acid solution (1 per cent) in a dry, polished colorimeter tube. The tube was shaken slightly, placed in the colorimeter and a galvanometer reading was taken ten seconds after the start of the dye addition. This reading was called G_1 and from this was derived a value called L_1 using the calibration chart. The L value which is given in the calibration table is obtained from the equation: $L = (2 - \log G)$. The average of L_1 values for three acid samples was used in calculation. The L_1 value was established each day or each time it was necessary to change acid or dye solution during the day.

b. Sampling and blending

For the ascorbic acid test a 50-gram sample was taken from a cored, unpeeled apple by cutting opposing radial sections not exceeding $\frac{1}{4}$ inch in width at the skin edge. The sample was immediately dropped into 350 ml. of metaphosphoric acid solution (1 per cent) and blended in a Waring Blendor for 4 minutes. The resulting mixture was filtered through coarse filter paper.

c. Testing for ascorbic acid

Into each of three clean, dry colorimeter tubes was pipetted a 1-ml. portion of the filtrate. To the first tube were added 9 ml. of

distilled water and with this tube inserted in the colorimeter, the galvanometer was adjusted to read "100", using Filter 520 and a 10 cc. aperture. To the second tube were added 9 ml. of dye solution from a rapid delivery pipette. The tube was slightly agitated and a reading taken 10 seconds after the start of the dye addition. The procedure for the second tube was repeated on the third tube and the average of the two readings was called G_2 from which a corresponding value called L_2 was obtained from the calibration table accompanying the Evelyn photoelectric colorimeter.

d. Calculation

The amount of ascorbic acid in the sample solution was calculated by use of the following equation: mg. of ascorbic acid per 100 grams of apple

$$= K (L_1 - L_2) \times \frac{\text{ml.(gm.) acid extractant} + (\text{pct. liquid in sample}) \quad (\text{gm. sample})}{\text{gm. sample}}$$

The value for the K factor is established for each colorimeter and in 1944 was found to be 10.8 for the instrument in this laboratory.

Ascorbic acid in areas of the apple: In determining the ascorbic acid content of various areas of an apple, slight modifications of the method previously described were used. A 25-gram sample of the outer area was taken by removing peel and flesh to a depth not exceeding $\frac{1}{4}$ inch. The sample was blended with 175 ml. of metaphosphoric acid solution (1 per cent) and filtered. The ascorbic acid determination was made in accordance with the above method. A 25-gram sample of the inner flesh area (remaining after the peel and outer $\frac{1}{4}$ inch of flesh were removed) was also blended with 175 ml. of metaphosphoric acid solution (1 per cent) and the ascorbic acid content determined. In cases where the ascorbic acid content of the peel alone was

determined, 25 grams of peel were removed from the apples by the use of a paring blade on an apple corer and the sample was blended with 175 ml. of metaphosphoric acid solution (1 per cent) and tested for ascorbic acid.

Judging: At each test period, a panel of five judges scored five apples, selected at random from the boxes. They used a scorecard especially prepared by the investigator, which provided for judging qualities of appearance, flavor, texture and juiciness. (See page 21 for copy of scorecard). It seemed of interest to know how the qualities of the Montana-grown McIntosh apple would rate during storage.

Cookery processes: Apples were subjected to three different methods of cookery so that the effect of cookery on ascorbic acid content could be noted.

a. Baked apples

Unpeeled, cored apples, each with 6 grams of sugar added, were cooked in covered glass baking dishes for 25 to 30 minutes at 350 degrees F. Weights were taken before and after cooking. Samples weighing 50 grams were removed from the cooled apples by using a corer to cut through the skin from one side of the apple to the opposite side. The samples were tested for ascorbic acid by the method previously described and percentage losses due to cookery were determined.

b. Apple pie

Pie crust was prepared according to standard method and was pressed into a pyrex pie pan. Approximately 650 grams of 3/8 inch slices from cored, peeled apples were combined with sugar, cinnamon, flour and salt of known weight. A top crust was pressed into place and the pie was baked

Scorecard for Judging Apples

Possible score	Quality	Apple No. 1	2	3	4	5
6	**Color of skin**					
5	dark red					
4	a/					
6	rosy red with dark streaks					
4						
3	red with yellow spots					
2	light red					
1	green					
5	**Shape**					
5	uniformly curved					
4						
3	flattened sides					
2	rough dips or bulges					
1	misshapen					
5	**Condition of skin**					
5	smooth					
4						
3	slightly wrinkled					
2						
1	wrinkled					

Possible score	Quality	Apple No. 1	2	3	4	5
5	**Freedom from decay and injury**					
5	unblemished					
4	bruised					
3						
2	open bruises					
1	decayed					
5	**Firmness**					
3	hard					
4						
5	firm					
4						
2	mealy					
1	mushy					
5	**Juiciness**					
3	very juicy					
4						
5	juicy					
2	slightly dry					
1	dry					

Possible score	Quality	Apple No. 1	2	3	4	5
5	**Color of pulp**					
5	white					
4						
3	creamy					
2						
1	brown					
5	**Texture of pulp**					
5	close, even grain					
4						
3	moderately close grain					
2						
1	coarse grain					
6	**Flavor**					
2	sour					
6	moderately sweet and aromatic					
5						
4	sweet and moderately aromatic					
3	bland					
1	bitter					
47	**Total Score**					

Instructions to judges: For each characteristic, check the one word or set of words which best describe the apple being judged.

a/ Scores with no accompanying description provided means for making intermediate judgments.

at 425 degrees F. for 50 minutes. Weights were taken before and after baking. When cool, a 50-gram sample was removed in a wedge-shaped slice extending from the outer edge to the center of the pie. Ascorbic acid determination was made according to the previously described method and percentage losses due to cooking were computed.

c. Apple sauce

Apple sauce was prepared by three different methods and ascorbic acid determinations were made on 50-gram samples from each lot by the method previously described.

The methods of preparing apple sauce were:

1. Peel and core 225 grams of apple. Cut in eighths and add directly to 50 grams of boiling water. Cook for 7 minutes in a covered utensil. Put apples through a Foley food mill and add 20 grams of sugar.
2. Core but do not peel 225 grams of apple and proceed as in method 1.
3. Peel and core 225 grams of apple. Cut in eighths and add directly to 50 grams of boiling water. Cook for 7 minutes in a covered utensil and then add 20 grams of sugar, omitting the use of a food mill.

Ascorbic acid analyses were made to determine not only percentage losses due to cookery, but also to judge which method of preparation resulted in the highest retention of ascorbic acid.

RESULTS

In presenting the results of this study it will be noted in table I, that the average ascorbic acid content of the Montana-grown McIntosh apple when placed in storage was 2.08 milligrams per 100 grams of raw apple. A comparison of this value with those of other commonly-used fruits indicates that this apple is apparently a rather poor source of ascorbic acid. For example, the approximate ascorbic acid content of 100 grams of strawberries is about 65 milligrams; of a banana about 10 milligrams; of one-half of a medium-sized grapefruit, about 40 milligrams; and of a small orange, about 60 milligrams.

It may also be seen in table I that the average ascorbic acid values of the apples used in this study apparently declined during storage. The most pronounced decrease in ascorbic acid seemed to take place in the first month of storage, after which the values appeared to increase for a time, only to diminish again during the fourth month of storage. It is of interest to note that the average ascorbic acid value at the end of four months of storage was apparently not as low as that at the end of one month of storage.

As a means of determining the significance of these apparent changes in ascorbic acid values shown in table I, the data were subjected to statistical treatment, using analysis of variance following the method outlined by Snedecor (47). This analysis takes into consideration the variation in ascorbic acid value of the individual apples used in each monthly test and the differences in the average ascorbic acid values determined from month to month during storage. By means of this method, it is possible to determine whether the variation between months is more significant than the

Table I. Ascorbic acid values of raw McIntosh apples determined at monthly intervals during storage.

Apple No.	Ascorbic acid values of McIntosh apples				
	When placed in storage	Stored one month	Stored two months	Stored three months	Stored four months
	mg./100gm.	mg./100gm.	mg./100gm.	mg./100gm.	mg./100gm.
1	2.37 a/	1.33	1.27	1.36	1.69
2	2.80	1.92	1.02	2.20	1.69
3	2.37	1.33	1.70	1.36	1.35
4	2.03	1.33	2.63	1.70	1.35
5	1.69	1.55	1.95	1.70	1.35
6	1.95	1.33	1.69	1.95	1.61
7	1.95	1.11	1.95	2.20	1.69
8	2.03	1.85	1.95	1.87	1.95
9	1.78	0.52	1.69	1.36	1.44
10	1.78	1.03	1.95	2.20	1.35
Av.	2.08	1.33	1.78	1.79	1.55
S.d.	0.343	0.403	0.434	0.351	0.209

a/ In analyzing data all values were transformed to angular degrees following the recommendation of Fisher and Yates (14).

variation within the months. First, the individual and group data for all the monthly testing periods were used and the analysis is shown in table II where the ratio between the two mean squares indicates that the monthly group averages differ significantly among themselves.

Since in table I there were apparent variations in the average ascorbic acid values determined monthly during storage, the lowest being recorded at the end of the first and four months of storage, it seemed desirable to compare further each monthly group of ascorbic acid values with those obtained at the first testing period. From tables III and VI it is evident that the variance of the ascorbic acid values when placed in storage and their values after one and four months of storage is highly significant. Less significance is shown in the variance between the ascorbic acid values of the apples when placed in storage and their values after two or three months of storage (tables IV and V).

Table II. Analysis of variance of ascorbic acid values of McIntosh apples determined at monthly intervals during storage.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between months	4	10.67	2.67 a/
Within months	45	30.49	0.678
Total	49	41.16	

a/ Significant variation at a 5% level

Table III. Analysis of variance of ascorbic acid values of McIntosh apples determined when placed in storage and after one month of storage.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between months	1	14.03	14.03 a/
Within months	18	14.80	0.82
Total	19	28.83	

a/ Highly significant variation

Table IV. Analysis of variance of ascorbic acid values of McIntosh apples determined when placed in storage and after two months of storage.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between months	1	5.15	5.15 a/
Within months	18	12.31	0.68
Total	19	17.46	

a/ Significant variation at a 5% level

Table V. Analysis of variance of ascorbic acid values of McIntosh apples determined when placed in storage and after three months of storage.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between months	1	6.69	6.69 a/
Within months	18	9.14	0.51
Total	19	15.83	

a/ Significant variation

Table VI. Analysis of variance of ascorbic acid values of McIntosh apples determined when placed in storage and after four months of storage.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between months	1	11.59	11.59 a/
Within months	18	6.12	0.34
Total	19	17.71	

a/ Highly significant variation

In addition to recording the ascorbic acid values of the apples as determined at monthly intervals during storage, the values were compared to determime the percentage losses of ascorbic acid from month to month. Before making such a comparison it was necessary to put the values on a comparative basis. One factor which affected the values of the stored apples was their change in weight due to loss of moisture by evaporation. An indication of these moisture losses was obtained from the weight loss of the bags of apples which had been buried in the boxes of apples at the beginning of the storage period. By use of these data it was possible to correct the ascorbic acid values for evaporation and thus to have comparable values, all based on the initial gross weight of the bags of apples, from which to determine percentage losses of ascorbic acid during storage. These losses may be noted in table VII where the greatest percentage decrease of ascorbic acid seems to have occurred during the first month of storage while there appears to have been an increase of ascorbic acid during the second and third months. It may be observed, also, that the percentage loss of ascorbic acid after four months was slightly more than 30 per cent, which is less than the percentage loss at the end of the first month.

Percentage losses computed on the basis of dry matter are presented in table VIII. It may be noted that the average percentage of dry matter appeared to decrease during the third month of storage even though evaporation during this month was reported in the previous table. Such a decrease in dry matter may have been due to respiratory processes occurring in the apples during storage, in which carbohydrates are converted to water and carbon dioxide. (17).

Table VII. Average percentage losses of ascorbic acid in Montana-grown McIntosh apples determined at monthly intervals during four months of storage and corrected for moisture losses due to evaporation.

Storage period	Percentage of moisture lost by evaporation	Av. ascorbic acid content of raw apple	Av. ascorbic acid content corrected for evaporation	Average percentage loss of ascorbic acid
	Pct.	mg./100 gm.	mg./100 gm.	pct.
When placed in storage		2.08	2.08	
Stored one month	2.5	1.33	1.30	37.5
Stored two months	3.3	1.77	1.72	17.3
Stored three months	4.5	1.79	1.71	17.8
Stored four months	6.2	1.55	1.45	30.3
Av.	4.1	1.70	1.65	

Table VIII. Average percentage losses of ascorbic acid in Montana-grown McIntosh apples determined at monthly intervals during four months of storage and calculated on a dry basis.

Storage period	Average percentage of dry matter	Av. ascorbic acid content of raw apple	Av. ascorbic acid content Calculated on a dry basis	Average percentage loss of ascorbic acid
	pct.	mg./100 gm.	mg./100 gm.	pct.
When placed in storage	15.4	2.08	13.47	
Stored one month	15.4	1.33	8.42	37.5
Stored two months	15.8	1.78	10.89	19.2
Stored three months	15.3	1.79	11.15	17.2
Stored four months	16.1	1.55	9.01	33.1
Av.	15.6	1.70	10.59	

An interesting fact is reported in table IX where it is shown that the concentration of ascorbic acid was greater in the outer area of the apple than in the inner area. This general relation persisted throughout storage. The ratio of the values of the outer and inner areas gradually declined during the first two months of storage, indicating that the losses of ascorbic acid were greater from the outer area than from the inner. During the third month, however, there seems to have been a rather inexplainable increase in the ascorbic acid value of the outer area.

In considering the ascorbic acid values of the apples, the question arises whether certain qualities such as density, pH, and total acidity might affect these values. Since ascorbic acid is readily oxidized, it seems possible that compact or loose structure in the apple might influence the amount of oxygen held within its tissues. An indication of structure can be obtained by measuring the densities of the apples and comparing them with their ascorbic acid values. These data are presented in table X. It will be noted that the individual apples vaired only slightly in density. Some computations of correlation between the densities and the corresponding ascorbic acid values were made using the formula recommended by Snedecor (47). The results of the computations revealed that no significant relation seemed to exist between the densities and the ascorbic acid values of the apples.

In table XI are shown the pH values of the apples determined at monthly intervals during four months of storage. In general, the pH values increased as storage progressed, indicating that the degree of acidity was decreasing. It is interesting to note that during the third

Table IX. The ascorbic acid values of the inner and outer areas of Montana-grown McIntosh apples determined at monthly intervals during three months of storage.

Apple No. and area	Ascorbic acid values			
	When placed in storage	Stored one month	Stored two months	Stored three months
	mg./100 gm.	mg./100 gm.	mg./100 gm.	mg./100 gm.
1- Inner	0.51	1.27	1.19	0.59
Outer	2.29	2.46	1.86	1.95
2- Inner	1.02	0.93	0.93	0.84
Outer	3.30	2.12	2.12	1.94
3- Inner	0.25	0.34	0.68	0.85
Outer	2.03	1.86	1.44	1.95
4- Inner	0.76	1.27	0.68	1.10
Outer	2.29	2.71	1.61	2.79
5- Inner	1.27	0.93	0.68	0.76
Outer	3.73	2.46	1.86	3.13
Av. for Inner	0.76	0.95	0.83	0.83
Av. for Outer	2.73	2.32	1.78	2.35
Ratio	3.59	2.44	2.14	2.83

Table X. The densities and ascorbic acid values of raw Montana-grown McIntosh apples determined at monthly intervals during four months of storage.

Apple No.	Densities and ascorbic acid values of McIntosh apples									
	When placed in storage		Stored one month		Stored two months		Stored three months		Stored four months	
	Density	Ascorbic acid	Density	Ascorbic acid	Density	Ascorbic acid	Density	Ascorbic acid	Density	Ascorbic acid
	gm./ml.	mg./100 gm.	gm./ml.	mg./100 gm.	gm./ml.	mg./100 gm.	gm./ml.	mg./100 gm.	gm./ml.	mg./100 gm.
1	.805	2.37	.792	1.33	.799	1.27	.804	1.36	.777	1.69
2	.793	2.80	.765	1.92	.801	1.02	.805	2.20	.797	1.69
3	.785	2.37	.770	1.33	.796	1.70	.791	1.36	.760	1.35
4	.768	2.03	.825	1.33	.791	2.63	.779	1.70	.782	1.35
5	.808	1.69	.784	1.55	.787	1.95	.781	1.70	.775	1.35
6	.788	1.95	.813	1.33	.765	1.69	.784	1.95	.808	1.61
7	.778	1.95	.815	1.11	.768	1.95	.789	2.20	.803	1.69
8	.799	2.03	.761	1.85	.796	1.95	.793	1.87	.810	1.95
9	.759	1.78	.794	0.52	.784	1.69	.789	1.36	.796	1.44
10	.780	1.78	.795	1.03	.779	1.95	.793	2.20	.787	1.35
Av.	.786	2.08	.791	1.33	.787	1.78	.791	1.79	.790	1.55

Table XI. The pH values of raw Montana-grown McIntosh apples determined at monthly intervals during four months of storage.

Apple No.	P pH values of raw McIntosh apples				
	When placed in storage	Stored one month	Stored two months	Stored three months	Stored four months
1	3.74	3.80	4.30	3.93	3.95
2	3.75	3.83	4.31	4.01	3.90
3	3.68	3.81	3.92	3.83	3.90
4	3.68	3.85	4.18	3.81	4.50
5	3.67	3.82	3.96	4.12	4.26
Av.	3.70	3.82	4.13	3.94	4.10

month of storage there was an indication of a slight increase in acidity.

From an examination of table XII, it is evident that the total acidity of the apples used in this study also declined during storage. In comparison, the acidity of the apples at the beginning of storage was nearly three times as great as at the end of four months of storage.

A constituent of apples that has interested workers for some time is the group of pectic substances that seem to undergo changes during ripening and storage. In order to observe any such changes in the McIntosh apples, the pectic acid content was determined at the beginning and end of three months of storage and the results are reported in table XIII. Although the firmness of the apples did not change very much during three months of storage (table XIV), the pectic acid content was reduced more than 50 per cent.

A summary of the scores given to the qualities of the apples judged at monthly intervals during four months of storage appears in table XIV. A definite reduction in firmness and juiciness, with a decided wrinkling of the skin, was evident after four months of storage. It may be seen, that in the opinion of the judges, the apples decreased somewhat in total quality after one month of storage and seemed to maintain that quality during the second and third months of storage. The most decided decline in total quality, though, did not occur until during the fourth month of storage.

The ascorbic acid content of apples cooked by various methods is shown in table XV. The data are expressed in milligrams per 100 grams of the cooked product. It may be seen that in general, apple sauce made by

Table XII. The total titratable acidity of Montana-grown McIntosh apples as measured at monthly intervals during four months of storage and expressed as milliliters of normal sodium hydroxide solution.

Apple No.	Average ml. of N NaOH required to neutralize the acid in 100 gms. of apple				
	When placed in storage	Stored one month	Stored two months	Stored three months	Stored four months
1	7.93	6.96	4.05	4.29	3.20
2	9.38	5.63	5.81	5.33	3.16
3	9.15	5.55	4.66	4.03	4.24
4	8.88	6.66	4.16	5.36	3.73
5	11.00	5.98	5.25	3.97	3.63
Av.	9.27	6.14	4.79	4.60	3.54

Table XIII. The pectic acid content of Montana-grown McIntosh apples determined at the beginning and end of three months of storage.

Apple No.	Percent of pectic acid in apples		Average Percentage loss
	When placed in Storage	Stored three months	
1	0.443	0.156	
2	0.434	0.124	
3	0.440	0.312	
Av.	0.439	0.197	55.13

Table XIV. Average scores for qualities of McIntosh apples judged monthly during four months of storage by a panel of five judges. (See scorecard, page 21).

Quality	Average scores				
	When placed in storage	Stored one month	Stored two months	Stored three months	Stored four months
Color of skin	4.16	4.08	4.35	4.84	4.36
Shape	4.16	3.56	4.00	3.40	3.60
Condition of Skin	5.00	5.00	5.00	3.92	3.00
Freedom from decay and injury	4.36	4.00	3.85	4.36	3.92
Firmness	4.84	3.84	4.25	4.08	3.60
Juiciness	4.64	4.64	4.25	4.28	3.68
Color of pulp	4.32	4.56	4.30	4.20	3.92
Texture of Pulp	4.04	4.04	4.20	3.68	4.52
Flavor	4.76	4.88	4.05	4.32	4.16
Average total score a/	40.28	38.60	38.25	37.08	34.76

a/ Perfect total score 47

Table XV. Ascorbic acid content of Montana-grown McIntosh apples cooked by different methods, with tests repeated at monthly intervals during three months of storage.

Method of cookery	Ascorbic acid content of cooked McIntosh apples			
	When placed in storage	Stored one month	Stored two months	Stored three months
	mg./100 gm.	mg./100 gm.	mg./100 gm.	mg./100 gm.
Sauce- Method 1	0.25	0.34	0.17	0.25
Sauce- Method 2	0.84	0.67	0.50	0.25
Sauce- Method 3	1.01	0.51	0.42	0.50
Baked	0.35	0.34	0.42	0.25
Baked in pie	0.25	0.34	0.25	0.25

Table XVI. Percentage losses of ascorbic acid content of Montana-grown McIntosh apples caused by cookery and determined at monthly intervals during three months of storage.

Method of cookery	Percentage losses of ascorbic acid from cooked apples			
	When placed in storage	Stored one month	Stored two months	Stored three months
	pct.	pct.	pct.	pct.
Sauce- Method 1	85.9	70.3	88.9	83.7
Sauce- Method 2	52.6	42.5	66.7	83.0
Sauce- Method 3	44.2	54.5	72.6	66.4
Baked	82.8	73.0	75.9	85.7
Baked in pie	84.2	67.1	85.7	81.6

method 2, where the peel was left on the apples, and method 3, where the peeled, cooked apples were not sieved, supplied more ascorbic acid than apples prepared by the three other methods. As the apples were cooked at monthly intervals during storage and tested, their ascorbic acid content showed a slight tendency to decrease during storage although inexplainable fluctuations in values seem to have occurred. Similar irregularities appear in table XVI where the percentage losses of ascorbic acid due to cookery are recorded.

DISCUSSION OF RESULTS

From the foregoing results it is evident that the ascorbic acid value of Montana-grown McIntosh apples of good quality is 2.08 milligrams per 100 grams of tissue, which means that the McIntosh is a rather poor source of this nutritive factor. According to the literature, only a few workers have reported ascorbic acid values for McIntosh apples and results obtained in Montana agree closely with those reported in 1934 by Smith and Fellers (45) in Massachusetts. By means of biological assay they found that it required from 20 to 25 grams of the McIntosh apple daily for a protective dose for guinea pigs. On the basis that 0.5 milligrams of ascorbic acid are required daily to protect guinea pigs from scurvy this would mean that their McIntosh apple contained from 2.0 to 2.5 milligrams of ascorbic acid per 100 grams of tissue. However, in a recent study on apples grown in West Virginia, Fish and co-workers (13) report the McIntosh apple as containing from 7 to 10 milligrams of ascorbic acid per 100 grams of tissue and yet their method differed somewhat from that commonly used.

This study of the effect of storage on the ascorbic acid values of

apples apparently differs from any other studies reported, in that it has followed from month to month the changes in ascorbic acid values as well as the rate of evaporation of the apples and changes in moisture content due to respiration. Fish (12), Batchelder (3), and Fellers and co-workers (10) have reported percentage losses of ascorbic acid in from three to six months and from eight to ten months of storage with no indication that they considered evaporation or any changes in moisture content.

It is of special interest to note that the stored apples showed the lowest ascorbic acid values at the end of the first month of storage, with an increase in the second and third months and a dropping off of value during the fourth month. The only other workers who have noted anything of similar nature are West and Zilva (52) in England, who recently reported that vitamin C was synthesized when apples were stored at 3 degrees C. and the capacity for synthesis was high in young but almost non-existent in mature fruit. There were no indications of immaturity in the Montana fruit and yet there were significant signs of increases in vitamin C values, or possible synthesis, during the second and third months of storage at 0 to 4.5 degrees C.

The finding that the ascorbic acid value of the outer area of the McIntosh apple is more than two or three times as great as the value of the inner area agrees very well with similar reports by Keys (26), Gross (19), Todhunter (48), Eheart (8) and other workers who reported greater concentration of ascorbic acid in the outer area of the apple than in the inner area.

Other qualities of the apples that seem to have been affected by storage are total acidity and pH value or degree of acidity. Unlike ascorbic acid values, total acidity values showed a steady decline throughout the entire storage period. However the pH values showed some of the same tendency to fluctuate that the ascorbic acid values showed during storage. The total acidity decreased considerably during storage, but in contrast, even though there were also changes in the pH values, there was still a fairly high degree of acidity at the end of the four months of storage. Thus it seems possible that pH might have the greater influence on ascorbic acid retention.

In general, apples undergo great losses of ascorbic acid during cooking. Curran and Tressler (6), in an extensive study of the effects of cookery on ascorbic values of apples, reported approximate losses of 80 per cent due to baking apples, whole or in pie. Though cooked apples have appetite appeal and are in common use, they have little recognized nutritive value, being especially low in vitamin C content.

SUMMARY

In this study it was found that the average ascorbic acid content of the Montana-grown McIntosh apple as previously described, is 2.08 milligrams per 100 grams of raw apple. When the apples were placed in storage for four months at a temperature ranging from 32 to 40 degrees F. and a relative humidity ranging from 60 to 86 per cent, there was a significant decrease in the ascorbic acid values. The greatest decrease in the ascorbic acid value of the apples occurred during the first month of storage. This was followed by an increase in ascorbic acid value during the second and third months of storage which suggests the possibility of vitamin C synthesis in the apple. A reduction in ascorbic acid value was again noted during the fourth month of storage. Throughout the storage period, data were obtained on the rate of evaporation in the apples and changes in their moisture content due to respiration. With these data available, the percentage losses of ascorbic acid were computed on a dry basis. During four months of storage, the average percentage loss of ascorbic acid in the apples was slightly over 30 per cent while, at the end of one month of storage, the loss amounted to 37.5 per cent. Consistent results were obtained to show that the concentration of ascorbic acid is considerably greater in the outer area than in the inner area of the McIntosh apple.

Although the individual apples differed somewhat in density and ascorbic acid value, there appeared to be no correlation between the density and the ascorbic acid value of an apple. The total acidity of the apples was found to decrease steadily throughout storage. However, the pH values, or the degree of acidity, showed a slight tendency to fluctuate. The

pectic acid content was reduced more than 50 per cent during three months of storage.

The scores recorded by a panel of judges indicated that the most noticeable changes occurring in the apples during storage were decreased firmness and juiciness, accompanied by wrinkling of the skin.

In general, cookery of the apples results in large percentage losses of ascorbic acid.

CONCLUSIONS

The average ascorbic acid content of the Montana-grown McIntosh apples used in this study is 2.08 milligrams per 100 grams of raw apple.

The storage of McIntosh apples for four months at a temperature ranging from 32 to 40 degrees F. and a relative humidity ranging from 60 to 86 per cent results in a significant reduction in ascorbic acid value amounting to about 30 per cent, computed on a dry basis.

During this same storage period and under the same conditions of storage, the McIntosh apple sustained some changes in quality, indicated by a wrinkling of the skin and a decrease in firmness.

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