A STUDY OF THE PREVENTION OF BROWNING IN FROZEN SLICED APPLES FOR USE IN PIE

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This is to certify that the

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A STUDY OF THE PREVENTION OF BROWNING IN FROZEN SLICED APPLES FOR USE IN PIE

By

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A THESIS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The production of apples is an important source of agricultural income in Michigan. The United States Census Bureau (1945) reported a yield of 8,045,236 bushels in 1945 at a value of $15,321,829. There are numerous apple storage buildings in the state, but many varieties do not keep over long periods of time even though they are kept under the proper storage conditions. The Jonathan, a leading variety in Michigan, should not be held in storage after the first of January because it is often attacked by Jonathan spot. The problem of preserving the quality of apples and keeping them as nearly like the fresh product as possible can be solved to a certain extent through the process of freezing. The Jonathan apple has been rated as being one of the best for freezing by Tressler (1946) and Masterson and Lee (1943). Pfund (1939) reported Jonathan among the species most often receiving favorable ratings on "texture, meltiness, juiciness, and firmness". However, she found the flavor and the texture were less agreeable after January. Variety is an important consideration because certain ones do not retain their fresh flavor, odor, and texture during freezing. Johnston (1945) has noted that "selected apples of good quality are such that they will cook fairly soft in pies but the slice will maintain its shape, will hold juice and absorb added water. In addition to this they must maintain their good flavor."

The use of frozen sliced apples in the commercial pie trade increased decidedly during World War II. Tin was not available for canning and another means of preservation had to be used. Lee (1944) and Short (1944) report that the greatest outlet for frozen apples is for pie stock. Cruess and Seagrave-Smith (1946) report that the apple pie is still "king of restaurant desserts, especially a la mode". In a survey made in Manhattan and Brooklyn in 1946, it was found that 40 percent of the men and 50 percent of the women preferred apple pies over peach, blueberry, or apricot pies. Frozen apple slices have qualities which make them desirable for use in pies if care is used in the preparation of the slices before freezing.

The frozen apple pack gives bakers the assurance of an uninterrupted supply of pie apples throughout the year. It also furnishes sliced apples to the baker in a convenient form which assures uniform quality, color, and flavor closely approaching those of the fresh fruit. The prepared fruit saves the labor of peeling, coring, and slicing on the part of the baker. Large inventories of fresh fruit are not necessary for relatively small amounts of frozen fruit can be ordered when needed so that costs may be calculated more accurately.

A prefreezing treatment is necessary to prevent the normal darkening that occurs in apple slices. When certain fruits are cut and exposed to the air, they turn dark and become unattractive in both color and flavor, due to the oxidation of catechol tannins and other easily oxidized substances. In preparing such fruits for freezing, the peeled and sliced fruit must be treated or else the cut surfaces are affected to such an extent that the product is very inferior. Another problem with apple slices concerns the darkening from the inside as well as from the outside. This darkening or browning is objectionable when the product is marketed to the bakery trade. The discoloration occurs not only during the preparation of the fruit but continues slowly during the freezing and zero storage. In order to give the fruit correct prefreezing treatment, it is necessary to understand how each variety responds to the different treatments for the prevention of browning.

DISCUSSION OF LITERATURE

Enzymatic browning

It is a generally accepted fact that the darkening which takes place in the flesh of the apple is due to enzymatic oxidation. Plagge (1938) states that fruits and vegetables are living parts of plants and that the processes common to plant life continue after harvesting. Joslyn (1930) reports that the enzymatic oxidation is due in a great part to the activity of the oxidase enzyme system present in the fruit tissues. This system is not inhibited by storage at temperatures as low as zero degrees Fahrenheit. While fresh fruit is resistant to oxidation, the injury of the tissues on freezing allows mixing of the cell contents with consequent rapid oxidation on exposure to air. Darkening occurs more rapidly when the fruit is exposed to air during thawing than during freezing or storage.

Onslow (1920) reports that the apple contains an oxidase system including an oxygenase, a peroxide, and an aromatic substance with the catechol grouping which produces a brown color. Balls and Hale (1935) believe that the first step in the formation of the brown pigment is the production of hydrogen peroxide by the normal action of an enzyme of direct oxidation. Onslow also states that most of the aromatic compounds of fruit appears to be in the form of catechol tannin. Joslyn (1941) says that flavanols and tannins in fruit turn brown upon oxidation. Balls and Hale (1935) note that besides peroxidase and peroxide, there is present in apple tissue a chromogenic substance capable of rapid oxidation by the peroxidase-peroxide system. This chromogen, considered to be of a tannoid nature, is brown when alkaline and colorless when acid. Natural tannins are powerful reducing agents and exhibit a marked tendency to absorb oxygen, particularly in alkaline solutions.

Overholser and Cruess (1923) found that a solution of sodium chloride lessens or checks browning by inhibiting the activity of the peroxidase and peroxide, but does not destroy either. Cruess, Samisch, and Pancoast (1933) note that the action of sulfur dioxide is on the organic peroxide or oxygenase fraction of the oxidase enzyme system. Peroxidase is not affected by sulfur dioxide.

Quality of pack

Senn and Bisno (1947) report that there is an opportunity for considerable improvement in the quality of frozen fruit for use of bakers. They believe that the sooner emphasis is laid upon definite standards acceptable to users, the faster the volume of such products will increase. Woodroof (1946) states that the biggest problem is not in the development of a workable procedure or technique, but in getting the processors to follow it.

Winter (1945) reports that the quality of any frozen fruit at the time it is used is controlled by a long chain of factors beginning with the selection of variety, culture, harvesting, and subsequent handling. Masterson and Lee (1943), Sparkes (1944), and Tressler, Evers, and Long (1946) agree that apples to be frozen should be firm-ripe and of a variety suited for pie.

The tentative U. S. standards for grades of frozen apples (1945) states that U. S. grade A, or U. S. fancy, must have similar varietal characteristics; practically uniform, bright, typical color; practically uniform in size; practically free from defects; uniform, tender texture; and normal odor and flavor.

Methods for prevention of browning

In 1923 Overholser and Cruess reported the results of their studies on the browning of apple tissue. They found that Yellow Newtown apples immersed for three days in five percent solutions of sodium chloride, hydrochloric acid, sodium sulfite, and sugar were white at the end of the test period. The fruit treated with the sodium chloride solution gave a faint positive reaction for peroxidase and a moderately pronounced test for organic peroxide. Negative tests for organic peroxide were obtained with the fruit from the hydrochloric acid and sodium sulfite solutions.

DuBois and Colvin (1945) mention that a number of materials have been suggested for preventing discoloration, but that none have been universally adopted for one or more reasons. Luther and Cragwall (1946) point out the desirability of using an enzyme inactivating method which does not have the disadvantages of "cooking" the fruit.

Sodium chloride: Joslyn and Mrak (1933) found that the minimum concentration of sodium chloride that would prevent darkening of apples was five percent. The apples were treated for one hour. Lower concentrations of brine and treatment for shorter periods resulted in browning which increased in intensity with decrease in concentration of brine and time of exposure. Sodium chloride will inactivate the oxidase enzyme system at low temperatures but not at room temperatures. The salt will not bleach apples which have darkened.

Sulfur dioxide: Sulfurous acid, sodium bisulfite, and potassium metabisulfite can be used interchangeably for the prevention of browning in fruits. They all yield sulfur dioxide when in solution. A sulfur dioxide content of about 100 parts per million in treated apples inhibits the browning of fresh and frozen apples.

Reports from the Western Regional Research Laboratory (1944-1947) indicate that sulfurous acid can be used as a prefreezing treatment and will penetrate much more rapidly than sodium bisulfite solution, but, due to its obnoxious odor which is strong enough to be very disagreeable to workers, this acid is not generally used. Sodium bisulfite has the advantage of being almost odorless and provides a practical method for treatment. The penetration is stopped by freezing and is not resumed quickly enough on defrosting to prevent browning in areas not penetrated. A delay of at least eight hours should be allowed between dipping the fruit and freezing, regardless of the concentration of sulfur dioxide. Sulfur dioxide not only prevents darkening but will bleach apples which have darkened. Woodroof and Cecil (1944) report that all varieties do not bleach the same amount with sulfur dioxide. Wiegand (1946) reports that a treatment with sodium bisulfite, leaving 50 to 100 parts per million of sulfur dioxide in the fruit, was effective. Sorber (1943) recommends a five minute dip in a solution containing 2000 to 3000 parts per million (0.02 to 0.03 percent). They also report that there is an indication that sugar tends to retard penetration.

Joslyn and Mrak (1933) observed a peculiar browning in apple slices due to incomplete penetration of sulfur dioxide into the apple. These apples were found to have a dark brown crescent-like ring in the flesh at the line of demarcation between the flesh that absorbed sufficient sulfur dioxide and that not penetrated by sulfur dioxide.

In studies made by MacArthur (1945), it was found that potassium metabisulfite not only prevented browning, but that no other discoloration occurred and the slices retained their shape on cooking. No sulfur dioxide flavor was found in any of the cooked samples and they had a better flavor than the samples treated with sodium bisulfite. MacArthur used a one-minute dip in 0.5 percent potassium metabisulfite and held the apples in open containers at least two hours to permit penetration of the solution into the interior of the slices.

Joslyn and Mrak (1933) report that sulfur dioxide will prevent darkening due to its reducing action. It exerts a strong inhibiting action on darkening caused by oxidation of the natural color bases in addition to its bleaching action on anthocyan pigments. Overholser and Cruess (1923) believe this bleaching may in some cases depend upon the union of the color with the sulfur dioxide, because the color returns if the fruit is warmed and the gas expelled. In other cases, the bleaching action apparently depends upon the absorption of oxygen from the coloring matter. Hohl and Swanburg (1946) explain that because of the strong reducing or antioxidant properties of sulfur dioxide, oxygen which would otherwise take part in the browning reaction, is used by the antioxidant.

Lee (1944) reports that a minor objection to sulfur dioxide is found in the persistence of a slight foreign flavor in many cases, even after the product is cooked. A number of people are unable to detect this flavor. Tressler and

DuBois (1944) report that sulfur dioxide and sulfites give an undesirable flavor to the fruit unless used in very small amounts. Cruess and Seagrave-Smith (1946) found that in taste tests, the consumer preferred the sulfited fruit over blanched fruit.

Winter and Hustrulid (1944) estimated that two ounces (11 teaspoons) of sodium bisulfite in five and one-half gallons of water will treat five bushels of apples at a cost of about five cents per bushel. They found that the same solution could be used to dip four to five lots of apples.

Ascorbic acid: Tressler and DuBois in 1938 found that ascorbic acid in solution prevents browning and flavor loss in easily oxidized fruits cut for use in baking or for freezing. The treatment does not affect the flavor and adds to the nutritive value. It was found that l-ascorbic acid is superior to any of its isomers for this purpose. DuBois and Colvin (1945) report that the role that ascorbic acid plays is not thoroughly understood. It has been called an antioxidant although it seems to reduce other substances that produce a brown color in fruit. Observations have been made that recently discolored fruits are returned to the original color when exposed to ascorbic acid. Most fruits that brown readily are low in natural vitamin C and do not discolor until nearly all the ascorbic acid has disappeared.

Bauernfeind *et al*. (1946) report that certain active enzymes, i. e. polyphenolase, in the presence of air, change ascorbic acid to its first oxidation product, dehydroascorbic acid. Dehydroascorbic acid possesses no antioxidant value in retarding the browning action. Before all the ascorbic acid in the package is converted into dehydroascorbic acid, partial browning of the fruit may occur. These researchers also found that the method of defrosting does not significantly affect the vitamin C content of the thawed fruit. A minimum of 150 milligrams of l-ascorbic acid per pound of finished pack (fruit plus sirup) is recommended, but there is greater margin of safety with 200 milligrams. In eight to ten months storage, about 80 percent or more of the added ascorbic acid is retained in the thawed fruit as biologically active vitamin C.

The merits of the ascorbic acid treatment have been summarized by workers at the Hoffman-La Roche laboratories (1947) as follows:

1. Does not introduce foreign substances or unnatural flavors.

2. Is not detectable in the pack by appearance, smell, or taste.

3. Is easily detected by applying recognized chemical and biological tests.

4. Significantly increases the vitamin C value of the pack.

5. Has been proven practical from the cost and quality angle.

The workers at the Merck laboratories (1948) report that the accepted method of calculating the amounts of ascorbic acid in frozen-fruit packs is based on the weight of the total finished pack, including the packing medium.

Ascorbic acid with citric acid: Sorber (1943) notes that a pH below 3.25 has the effect of stabilizing the vitamin C and color in frozen fruits. Luther and Cragwall (1946) report that the simple addition of a suitable acid completely inactivates the enzymes which are so largely responsible for the destruction of natural and added ascorbic acid. They state that it is this rapid destruction that has made the use of ascorbic acid impractical in apples where the enzymes are so active that the added ascorbic acid is quickly destroyed and consequently affords only a limited measure of protection for the treated fruit. They found that the half-life time increases as more citric acid is used. The use of citric acid helps reduce costs since it permits the use of a smaller quantity of ascorbic acid to prevent browning.

Workers at Charles Pfizer (1947) give the following stabilizing effects of citric acid:

1. Retards the activity of the oxidation enzymes naturally present in fruit.

2. Decreases the atmospheric oxidation of the ascorbic acid under the more acid conditions.

3. Forms complexes with traces of iron and copper

and in this manner retards their otherwise destructive effect.

They have found that if citric acid is used at a level of 0.48 percent (based on weight of fruit), the ascorbic acid level can be reduced to 90 milligrams per pound of fruit. Merck laboratories (1948) add that citric acid used in combination with ascorbic acid in vacuum treatments did not seem to prevent the destruction of the ascorbic acid.

Federal Food and Drug Administration regulations

According to Winter and Hustrulid (1944), the Federal Food and Drug Administration permits the use of sodium bisulfite for the purpose of preventing browning in frozen fruits. However, Wiegand (1946) reports that some states frown upon the use of sulfur dioxide. This points to the advisability of seeking other antioxidants. The Administration has questioned the use of sodium chloride for it sometimes affects the palatability of the fruit. The use of l-ascorbic acid to prevent browning in fruits is entirely unquestioned by the Food and Drug Administration.

Vacuum treatment

The problem of combating the discoloration of frozen apple slices is a difficult one since the color changes are not confined to the exposed surface of the fruit. The solution of the problem of internal browning is basically one of penetration, for if the agents used in treating are added in such a way as to penetrate to the center of the slices, no internal browning will result. Bauernfeind and Siemers (1946) show that it is not practical to hold apple slices treated with ascorbic acid at room temperature to increase penetration. The Pfizer laboratories (1947) report that penetration and protection of the center portion can be obtained by the use of a vacuum.

Hoffman-La Roche technicians (1947) report that regular apple slices can be evacuated by using a vacuum of 24 inches or higher for five to fifteen minutes. This removes the air or oxygen-containing gases from the intercellular spaces and allows the liquid to fill these spaces when the vacuum is released. Mazzola (1945) points out that the temperature and chemical characteristics of the liquid must be controlled if this process is to be successful.

Addition of sugar to frozen pack

Sorber *et al.* (1944) state that sugar need not be added to the frozen pack unless desired by the trade. On the other hand, Sparkes (1944) states that there is a general agreement among the authorities that fruits frozen without sugar are inferior. Winter (1942) recommends a four-plus-one pack for apples.

Pies from frozen apple slices

Tressler (1946) suggests that to make pies from frozen apples, the slices should be allowed to thaw just enough so they can be broken apart. The slices are placed on an unbaked pie crust, and then the regular procedure for making pie is carried out.

pH value

Pfund (1939) found that good flavor in cooked apples is associated with relatively high acidity (pH 3.10 to 3.39). The Jonathan rated high in acidity. According to Morris (1946), the average pH of raw apples is 3.35.

Color measurement

Much has been done by Nickerson to standardize color measurement so that a simple and satisfactory conversion of color can be made into current trade terms. It is necessary that such terms be understood in relation to some color standard. The Munsell method of color notation (Nickerson, 1946) has made this standardization possible. This system uses three color dimensions: hue, value, and chroma. Hue is the name of a color, e. g. red, yellow, or blue, and is designated by a number and/or symbol. Value is the lightness or darkness of a color and ranges from one (black) to ten (white). Chroma is the strength or purity of a color. The higher the chroma number, the more color is present. The highest chroma number depends upon the maximum chroma possible for each color. A color notation under the Munsell system is an exact and specific color designation using symbols and numerals written as hue/value/chroma.

Disc colorimetry using the Munsell standards provides a simple, rapid, and direct method for making color measurements. Any color can be matched by the proper choice of four discs, if the color to be matched lies in the geometric space intermediate to the four that are chosen. The colors of the discs are mixed by spinning and matched with the sample through a color comparator eyepiece.

EXPERIMENTAL PROCEDURE

Tests were made on the apples before they were prepared for freezing and after they had been in zero storage for two, five, ten, fifteen, and twenty weeks. Samples were baked as pies for organoleptic scoring, firmness tests, and color measurements. Raw samples were used in analyses for ascorbic acid, sulfur dioxide, and pH values.

Preparation for freezing

Selection of fruit

Jonathan apples grown on the Michigan State College Farms were chosen for use in this study. U. S. No. 1 grade with a minimum diameter of two and one-fourth inches was used. This grade was selected to avoid interference from bruises or off colors when the apples were scored and the color measurements were taken. The apples had been in cold storage approximately two months before they were prepared for freezing. They were firm-ripe and well colored.

Peeling and slicing

The apples were weighed before peeling and the waste was weighed after peeling in order to obtain the percent waste. The fruit was peeled on a Bonanza apple peeler which also removed the cores. The apples were dropped immediately into a one percent sodium chloride solution to prevent browning between peeling and subsequent treatment. The apples were trimmed and then sliced into twelfths. The slices were kept in a one percent salt solution until there was a sufficient amount to be treated. This holding period never exceeded one hour. Stainless steel knives were used for trimming and slicing in order to prevent the development of the blue color which forms when iron comes in contact with the flesh of apples.

The slices were drained in a colander and rinsed 15 seconds under running water before further treatment.

Treatments used to prevent browning

One lot of apples was frozen without additional treatment other than that used in preparing the slices. This lot was used as a control.

Sodium chloride: The sliced apples were placed in a four percent sodium chloride solution and a vacuum drawn on them for 20 minutes. The remainder of the treatment is described under Vacuum method used.

Sodium bisulfite: A 0.1 percent solution of sodium bisulfite was made in an enamel container. The apple slices were placed in a cheesecloth bag and immersed in the solution for two minutes. They were then drained for 15 minutes and left in a covered, enamel container for five hours to allow for penetration before packaging.

Ascorbic acid: The apple slices were placed in a 0.08 percent ascorbic acid solution and held under vacuum for 20 minutes. For the remainder of the treatment, see Vacuum method used.

Potassium metabisulfite: A 0.5 percent potassium metabisulfite solution was made in an enamel container. The prepared fruit was placed in a cheesecloth bag and dipped in the solution for two minutes. Then the fruit was drained for 15 minutes and allowed to stand in a covered, enamel container for three hours to permit penetration before packaging.

Ascorbic acid-citric acid mixture: The apple slices were held under vacuum in a 0.5 percent solution of an ascorbic acid-citric acid mixture for 20 minutes. This mixture was composed of four percent ascorbic acid and 96 percent citric acid. For the remainder of this treatment, also, see Vacuum method used.

Vacuum method used to facilitate penetration of solutions

Three kilograms of apple slices were placed in a large vacuum desiccator, and a weight was placed on top of the slices in order to prevent their floating. They were well covered (two inches above the top of the fruit) with either of the following three solutions: sodium chloride, ascorbic acid, or ascorbic acid-citric acid mixture. The desiccator was covered and the vacuum pump turned on. Time was counted from the time the vacuum became constant (approximately 27 inches). After the desired time had elapsed, the vacuum was broken and the contents allowed to stand for five minutes to permit thorough penetration of the slices. The fruit was removed from the solution and drained for five minutes before being packed with sugar and frozen.

Packaging

After the slices were treated, they were packed in number two tub Nestrite containers. Each tub contained the exact amount of fruit for one pie and was packed with four parts apples and one part sugar. The apples and sugar were added to the tubs alternately in order to secure a complete mixture of the fruit and sugar. The control (no treatment), sodium chloride, sodium bisulfite, and potassium metabisulfite groups were packed with 500 grams of treated fruit and 125 grams of sugar, while the ascorbic acid and the ascorbic acid-citric acid groups were packed with 600 grams of the treated fruit and 150 grams of sugar. The increase in weight was made necessary by the high water content of the vacuum-treated fruit.

Freezing and storage

The apples were frozen at minus 40 degrees Fahrenheit and then held at zero plus or minus two degrees until used in the tests.

Testing

Baking procedure

Pies were baked using fresh apples and apples frozen for two, five, ten, fifteen, and twenty weeks respectively.

Crust: The pastry was made in two batches, each consisting of 650 grams of all-purpose flour, 300 grams of lard, 17 grams of salt, and 160 milliliters of water. The flour and salt were mixed together, using 25 light strokes of a spoon. The fat was added to the flour and mixed at low speed for three minutes with a Hobart Kitchen Aid mixer (Model G). At the end of the mixing time the machine was stopped, and the mixture was scraped down from the sides of the bowl with a rubber spatula. The water was added, and the mixture was mixed at low speed for 40 seconds. The pastry was turned out on a board and folded five times. One-sixth of one batch (enough for one crust) was folded four times and then rolled between cellophane. All the crusts were rolled before the pies were assembled.

Filling: The frozen fruit was defrosted in a household refrigerator (approximately 41 degrees F.) for 14 to 15 hours before making into pies. No additional sugar or spices were added to the apples.

Assembling and baking pies: Nine-inch (top measurement) paper pie plates were lined with pastry, and the apples were arranged on this crust. The outer edge of the crust was moistened with water and the upper crust was placed on top. The crusts were trimmed five-eighths of an inch from the edge; then the edges were turned under and crimped. Three slits (each one and one-fourth inches long) were cut in the top to permit the escape of air and steam. The tops were brushed with milk in order to obtain better browning.

The pies were baked at 400 degrees Fahrenheit for 65 minutes, then cooled about three and one-half hours before tests were made.

Tests on pies

Scoring panel: The panel for scoring the apple pies was composed of six members of the staff in the Foods and Nutrition Department. All but one person had had experience on scoring panels for other products. There were five test periods of five days each and all six treatments previously mentioned were baked each day. The pies were presented to the judges in random order. A sector was removed from each pie and placed on a white plate for the judges to score color, consistency, and odor. Smaller sectors were placed on white trays so that each judge could score flavor, tenderness of fruit, texture of fruit, texture of lower crust, and general conclusion. The judges were requested to record comments concerning any outstanding features. A sample of the score sheet used is shown on page 60 in the appendix.

The scoring was done at 2:30 p.m. in the foods research laboratory. Care was taken that there were no foreign odors in the room at that time. The judges were provided glasses of cold water.

Firmness test: The penetrometer used for the firmness test is described in the A.S.T.M. Standards (1944). To make the test, the upper crust was removed from the cooled pie, and the apple slices were carefully removed and placed in pyrex custard cups. Approximately 150 grams of fruit were used. This amount filled the cups to within one-fourth of an inch from the top.

The grease cone was attached to the penetrometer and pushed up so that the dial read zero. The cup was placed on the stage of the penetrometer, and the stage was adjusted so that the surface of the sample was just in contact with the point of the cone. The needle bar was released for two seconds, the indicator bar was depressed until it reached the top of the needle bar, and the depth of the penetration was then read on the dial. The needle bar plus the grease cone weigh 150 grams.

Color measurement: The color of the baked fruit was measured objectively by the use of Munsell color discs according to the method given by Griswold (1944). In order to match the color of the fruit, four discs were overlapped by means of radial slits and spun by a motor. These discs included two neutrals, one lighter and one darker than the sample, and two hues of strong chroma that lie on either side of the hue to be matched. The neutrals used were N 1/ and N 5/ or N 8/, depending upon the value of the color to be matched. The hues used were 5Y 8/12 and 5 YR 6/12. Samples of these neutrals and hues may be seen on page 25. A diagram of the spinning assembly used is shown on page 26.

The sample of fruit was well mixed and packed in a glass cup. Color of the discs was matched with that of the fruit by looking through a color comparator eyepiece and adjusting the areas of the discs. The percentage of each disc used was measured by means of a scale which circumscribed the discs.

The hue and chroma for each sample were determined from the conversion tables published by Nickerson (1935). The value was calculated from the following formula given by Nickerson (1929):

$$\text{Value} = \sqrt{\frac{(b \times a^2) + (d \times c^2) + (f \times h^2) + (l \times n^2)}{100}}$$

a = value of lower neutral disc
b = area of neutral disc a
c = value of higher neutral disc
d = area of neutral disc c
f = area of lower hue number
h = value of lower hue number
l = area of higher hue number
n = value of higher hue number

Figure 1. Neutrals and hues used in objective color tests

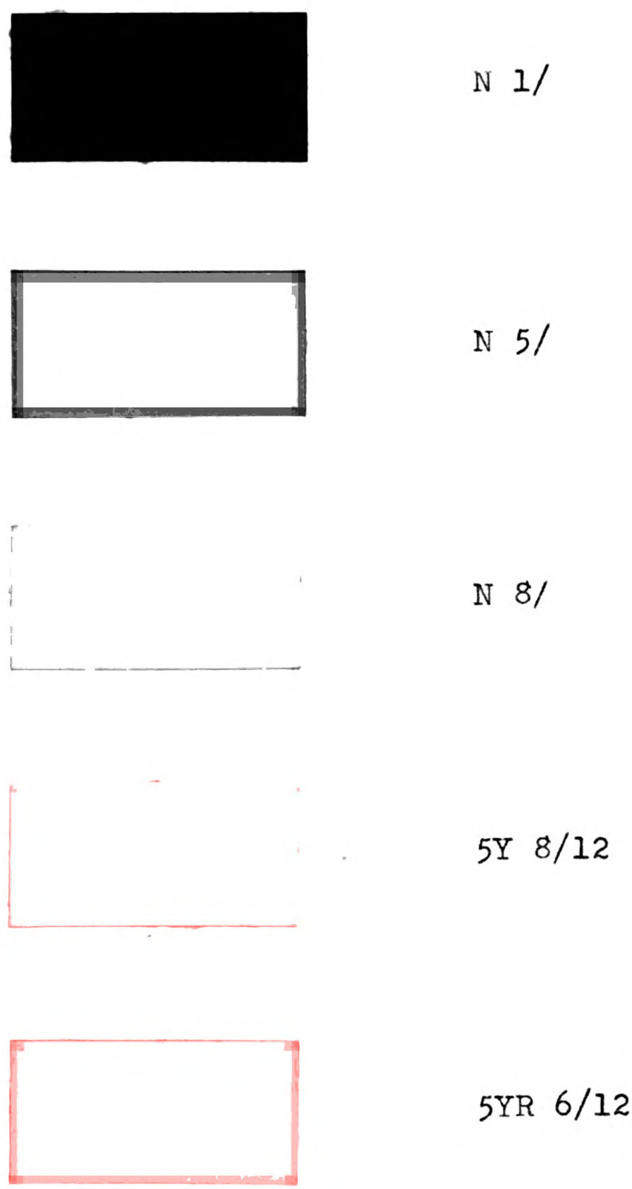
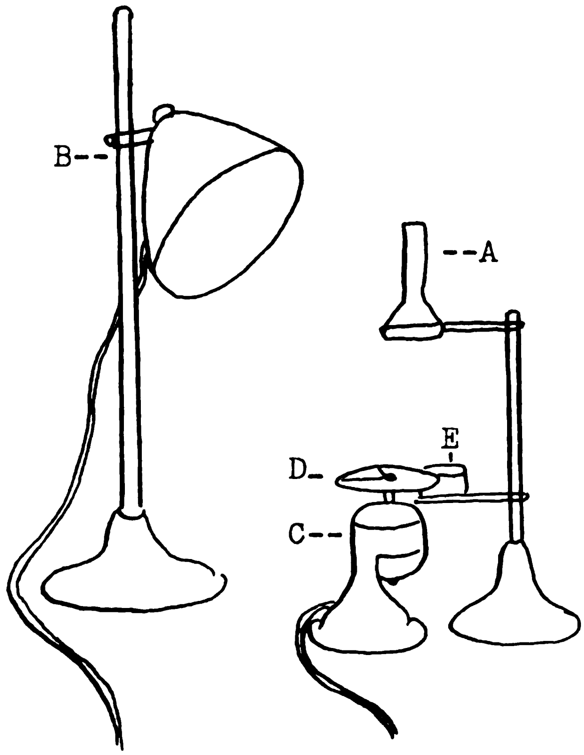


Figure 2. Disc spinning assembly for color measurement



A. Comparator eyepiece

B. Lamp

C. Motor

D. Color discs and calibrated disc

E. Sample cup

The entire assembly is covered with black sateen

Tests on raw fruit

Ascorbic acid determination: Reduced ascorbic acid determinations were made on the frozen fruit by the method described by Loeffler and Ponting (1942). Determinations were made on the samples which had no pretreatment and on those treated with ascorbic acid and ascorbic acid-citric acid mixture.

Sulfur dioxide determinations: Sulfur dioxide content of the frozen fruit was determined according to the method described by Ponting and Johnson (1945). The samples with no treatment and those treated with sodium bisulfite and potassium metabisulfite were analyzed.

pH value: A ten-gram sample of frozen apples was blended with 90 milliliters of distilled water in a Waring Blendor for two minutes. This mixture was filtered and the pH of the filtrate determined by means of a Beckman pH meter.

Statistical methods

Correlation coefficients were calculated, and analysis of variance made, according to methods recommended by Snedecor (1946).

DISCUSSION OF RESULTS

Preparation

Preparation waste

The preparation waste averaged 31.3 percent. The waste included peels, cores, bruises, and any other unusable portions of the fruit. This percent waste is considerably higher than the 12 percent waste which was reported in studies by Masterson and Lee (1943). The differences may lie in the method of removing the peels and cores and in the amount of trimming, since care was taken in the study to remove all peels and discolored areas in the fruit. Also, a mechanical peeler was used in the current study.

Vacuum treatment

Table 8 on page 61 in the appendix shows the volume of the solutions used to treat the fruit and the volume absorbed by the apple slices when vacuum-treated. The slices treated with sodium chloride absorbed the smallest amount of liquid. This constituted seven percent of the original weight of the apple slices. The fruit treated with ascorbic acid gained 40 percent of its original weight, and that treated with ascorbic acid-citric acid gained 46 percent.

Appearance of fruit

The appearance of the raw fruit after defrosting was recorded. The apple slices treated with the sodium chloride solution in a vacuum had a glassy appearance which they maintained throughout the storage period. This was due to the absorption of some of the salt solution. The slices treated with ascorbic acid and ascorbic acid-citric acid solutions under a vacuum had a transparent appearance and looked as though they had been cooked. This transparency was caused by the replacement of the air spaces with the solution. The fruit treated with sodium bisulfite and potassium metabisulfite retained the normal appearance of raw apples.

Kodachrome pictures were made of the defrosted fruit after 15 weeks in zero storage. Since it is difficult to reproduce true colors in this type of picture, the colors in the reproduction of the raw fruit on page 31 are not as true as in the transparency. The picture does show the relative differences in the appearance of the fruit with different treatments. It can be seen that there was some discoloration in the control sample, especially in the core area. None of the other treatments showed discoloration in the raw fruit, even at the end of 20 weeks in zero storage.

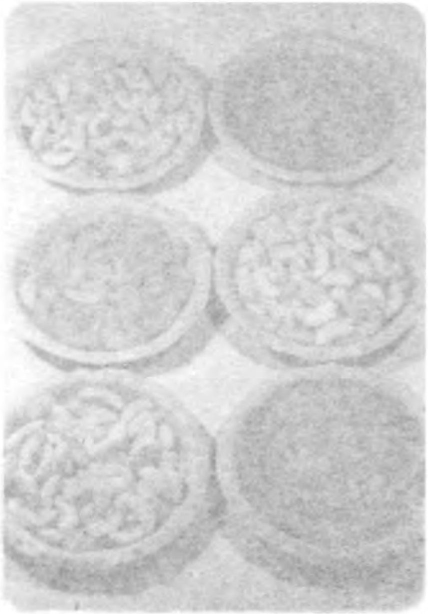
Figure 3. The apple slices before and after baking

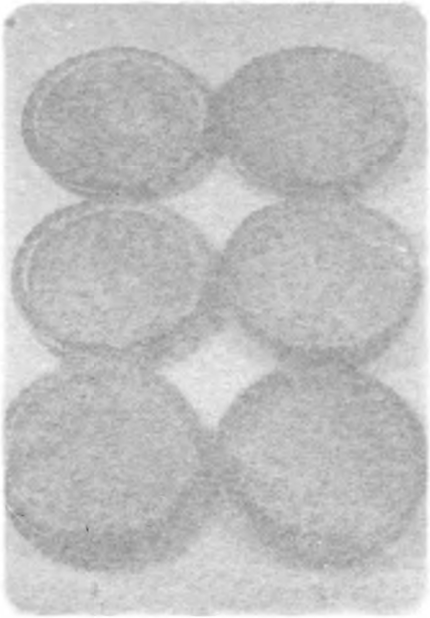
a. Raw, defrosted apple slices

Control	Ascorbic acid
Sodium chloride	Potassium metabisulfite
Sodium bisulfite	Ascorbic acid-citric acid

b. Baked apple slices

Same arrangement as above



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Pies

When pies were baked from the frozen apple slices, the juice from the fruit treated by means of a vacuum had a tendency to boil out onto the top crust. The juice in the sodium chloride-treated fruit boiled out very little, while that in the ascorbic acid- and ascorbic acid-citric acid-treated fruit boiled out enough to almost completely encircle the outer edge of the upper crust. This boiling out was undoubtedly caused by the high liquid content in the fruit. The higher the liquid content in the fruit, the greater the amount of juice that boiled out.

Palatability Scores

The mean scores for the pies in each test period are shown in Table 1 on pages 33 and 34.

Color

The fruit in the control pies was scored lowest for color. The judges described it as being dark and brown. The fruit treated with sodium chloride, ascorbic acid, and ascorbic acid-citric acid received the highest scores. The fruit treated with sodium chloride had a pink cast after baking. The samples treated with sodium bisulfite had a brown tinge, while those treated with potassium metabisulfite had a more yellow, bleached color.

Table 1. Mean scores for each scoring period

Treatment	Time frozen	Color	Consistency	Odor	Flavor	Tenderness of fruit	Texture of fruit	Crust texture (lower)	General conclusion
	weeks								
Fresh	0	5.7	5.6	5.8	5.4	5.7	5.5	4.1	5.3
None	2	3.7	5.1	4.6	4.2	4.8	5.0	4.2	4.4
	5	3.4	5.3	4.7	4.3	4.8	4.9	4.4	4.1
	10	3.8	5.4	4.8	4.7	5.0	5.0	4.9	4.5
	15	3.3	5.5	4.3	4.2	4.7	4.9	4.5	4.3
	20	3.4	5.1	4.8	4.0	4.2	4.7	4.5	3.9
Sodium chloride	2	5.9	5.5	5.1	4.7	5.3	5.3	4.3	4.8
	5	5.4	4.8	5.3	3.9	4.7	4.7	4.5	4.0
	10	5.4	5.8	5.1	3.5	5.1	5.0	4.9	3.9
	15	5.6	5.9	5.4	3.2	4.6	4.7	4.8	3.9
	20	4.7	4.8	4.7	2.6	3.9	4.1	4.2	2.7
Sodium bisulfite	2	5.0	5.5	4.9	4.9	5.3	5.3	4.2	4.9
	5	5.1	5.7	5.4	5.3	5.1	5.3	4.5	5.2
	10	5.1	5.7	5.1	4.7	5.1	5.1	4.6	4.9
	15	5.1	5.8	5.1	5.1	4.9	5.1	4.8	4.9
	20	4.3	5.4	4.5	4.3	4.7	4.7	4.5	4.1

Table 1. (Continued)

Treatment	Time frozen	Color	Consist-ency	Odor	Flavor	Tender-ness of fruit	Texture of fruit	Crust texture (lower)	General con-clusion
	weeks								
Ascorbic acid	2	5.9	3.8	5.2	5.1	5.5	5.2	3.5	4.7
	5	5.7	4.2	5.2	5.5	5.6	5.6	4.0	4.9
	10	5.2	3.8	5.1	5.3	5.5	5.6	3.9	4.8
	15	5.3	3.5	4.8	5.0	5.3	5.5	4.3	4.8
	20	4.8	3.0	5.2	4.9	5.2	5.2	4.2	4.5
Potassium metabisulfite	2	5.8	5.3	5.4	5.1	5.1	5.1	4.3	5.0
	5	5.4	5.4	5.0	5.1	5.1	5.1	4.4	5.0
	10	4.8	5.0	4.9	4.5	4.7	4.6	4.8	4.4
	15	4.9	5.4	4.7	4.8	4.8	4.8	4.4	4.6
	20	4.8	5.5	4.8	4.5	4.5	4.6	4.4	4.2
Ascorbic acid-citric acid	2	5.7	3.6	5.3	4.9	5.2	5.3	3.4	4.7
	5	5.5	4.0	5.5	5.3	5.6	5.8	4.1	5.0
	10	5.3	3.7	4.9	4.5	5.5	5.6	4.3	4.6
	15	5.4	3.9	4.9	4.9	5.5	5.7	4.6	4.9
	20	5.0	2.9	4.8	4.8	5.2	5.5	4.1	4.3

The color scores for the sodium chloride-treated fruit dropped the greatest amount with time in storage. The scores for the fruit treated with ascorbic acid and potassium metabisulfite dropped almost as much as did the scores for the fruit treated with sodium chloride. The scores for the fruit with no treatment dropped the least with storage since these samples had low scores in the beginning.

An illustration of the range of colors obtained in the baked fruit is shown on page 31. This picture was taken of the pies after the fruit was stored for 15 weeks. It shows, also, the variation in the consistency of the apple slices and in the amount of juice, factors which affected the consistency scores discussed in the next section.

Consistency

The fruit treated with ascorbic acid and ascorbic acid-citric acid received the lowest scores for consistency. There was an excessive amount of free juice in these pies which can be accounted for by the high water content of the fruit. This excessive juiciness might be corrected by the use of a thickening agent. The fruit in the control and sodium bisulfite- and potassium metabisulfite-treated pies was mushy and somewhat dry.

The scores for consistency changed very little with storage except in the case of the fruit treated with ascorbic acid-citric acid where the score dropped after the 15-week period.

Odor

The judges made no comments concerning off odors in the baked fruit. At no time were they able to detect the odor of sulfur dioxide. The differences in treatment had no effect on the odor of the fruit, but there was a gradual decline in the scores with length of time in storage.

Flavor

The fruit treated with ascorbic acid received the highest scores for flavor. Although this treatment received the highest average score, one of the judges described the flavor as bland and tasteless. The flavor of the fruit treated with the ascorbic acid-citric acid was occasionally described as tart. These latter samples received the second highest score. Most of the judges commented frequently on the saltiness of the fruit treated with sodium chloride. The flavor of sulfur dioxide was detected only once, by one judge, in any of the samples treated with sulfite solutions. This was in the potassium metabisulfite sample after two weeks in zero storage.

The greatest drop in flavor score, with storage, was in the sodium chloride-treated sample. The time that elapsed between the first and last test periods made very little difference in the flavor of the control and in the samples treated with ascorbic acid and ascorbic acid-citric acid.

Tenderness of fruit

The sodium chloride-treated sample was the least tender of all the treated samples but received the same average score as the control. The judges commented on the lack of tenderness of the sodium chloride-treated fruit more than they did on the control. They described the fruit treated with sodium chloride as being dry, tough, and hard. The ascorbic acid-treated fruit had the highest score for tenderness, and the sample treated with ascorbic acid-citric acid was second. There was a gradual decline in the tenderness scores with the length of time in zero storage.

Texture of fruit

The texture of the fruit treated with ascorbic acid and ascorbic acid-citric acid was most desirable. The texture of the fruit treated with sodium chloride was coarse and disagreeable to the tongue. This coarseness may have been brought about by dehydration of the sample by the salt. All the scores on texture gradually declined with storage.

Texture of lower crust

The pies made from the fruit treated with ascorbic acid and ascorbic acid-citric acid had the soggiest lower crusts. The fact that the scores for texture of the crust and consistency of the fruit followed the same pattern suggests that the amount of liquid present in the fruit has a direct influence on the texture of the lower crust.

General conclusion

The apples treated with sodium bisulfite received the highest average score on general conclusion, and those treated with ascorbic acid were close second. The fruit treated with sodium chloride received the lowest average score. The general conclusion scores appear to be influenced most by the flavor of the fruit, except in the case of the slices treated with ascorbic acid. The color seemed to have some influence, except with the sodium chloride- and ascorbic acid-treated fruit. The salty flavor of the fruit treated with sodium chloride was so evident that it had a great affect on the general conclusion score. There was a steady decline in all of the general conclusion scores with time in zero storage.

Acceptability

The pies made from the fresh apples were acceptable to all the judges but one who was more critical than the others during the entire study. Except for the control and sodium chloride samples, all the pies made from the frozen apples were acceptable to the judges throughout the entire test period. The control sample was not acceptable one day in the five-week test period and one day in the 20-week period. The samples treated with sodium chloride became less desirable with longer time in storage. They were acceptable to the judges after two and five weeks in storage but not acceptable two days in the 10-week test period, one day in the 15-week period, and all five days in the 20-week period.

<u>Analysis of variance of scores</u>

The data were analyzed to separate variation due to replication, treatment, and time in storage. Table 2 on page 40 gives a summary of this analysis. Calculations showed that there was very little difference due to replication. The only places where replication differences did show up were in color and crust texture, the former being significant and the latter being highly significant. The differences in color may be accounted for by irregular lighting in the room where the scoring was done. The total light available in this room is affected by the amount of sunshine coming through the windows. The bamboo blinds at the windows were lowered to subdue the light on bright days and the incandescent lamps were used on dark days. The differences in the crust texture may have been caused by lack of uniformity of the water distribution in the pastry. Wet or dry spots may have made weak places in the crusts and thus may have been responsible for leakage during baking. This leakage was found in one or two pies each day but was no worse in one treatment than in another. This difficulty might be remedied

Table 2. Results of analysis of variance of scores

Factor	Color	Consistency	Odor	Flavor	Tenderness Of fruit	Texture of fruit	Crust texture (lower)	General conclusion
Average scores for each Treatment								
None (control)	3.53	5.28	4.63	4.29	4.71	4.92	4.51	4.24
Sodium chloride	5.40	5.36	5.11	3.61	4.72	4.76	4.55	3.87
Sodium bisulfite	4.91	5.63	4.99	4.87	5.02	5.10	4.51	4.81
Ascorbic acid	5.38	3.65	5.10	5.15	5.42	5.41	3.98	4.74
Potassium metabisulfite	5.16	5.34	4.98	4.82	4.86	4.86	4.47	4.64
Ascorbic acid-citric acid	5.37	3.62	5.09	4.90	5.40	5.58	4.10	4.67
Average scores for each Storage Period								
2 weeks	5.33	4.79	5.07	4.83	5.19	5.22	3.99	4.74
5 weeks	5.09	4.90	5.17	4.90	5.15	5.22	4.32	4.70
10 weeks	4.93	4.91	5.00	4.55	5.17	5.16	4.59	4.51
15 weeks	4.93	5.01	4.87	4.55	4.98	5.12	4.55	4.57
20 weeks	4.51	4.45	4.81	4.20	4.63	4.80	4.32	3.97
F Values								
Treatment	24.63**	7.72**	3.65**	8.86**	8.59**	5.33**	14.07**	17.07**
Storage	122.28**	116.04**	4.75**	30.60**	12.99**	15.69**	12.52**	19.70**
Storage x treatment	3.78**	2.75**	1.43	2.24**	1.06	1.34	1.47	2.46**
Replications	1.99*	0.68	1.22	0.91	1.06	1.33	5.55**	0.70

* Significant
** Highly significant

by allowing the pastry to stand for a time between mixing and rolling.

The differences attributable to treatment and length of frozen storage were highly significant for all scoring factors. These individual factors have been discussed in detail on the pages just preceeding.

The interactions between storage and treatment were also calculated. These were highly significant for color, consistency, flavor, and general conclusion. These figures indicate the lack of similarity in the response of the various treatments to the various storage periods. The data in Table 1 indicate this variation. The scores for the color of the sodium bisulfite-treated fruit were relatively constant up to the last time interval, then dropped. The scores for the potassium metabisulfite-treated fruit dropped through the first three storage periods, then were constant for the remaining time.

The scores for consistency in the control pies continued to increase gradually through the first four time intervals and then dropped back to the same as those of the first period. For the fruit treated with ascorbic acid, the score increased at the second time interval and then declined. The scores for the ascorbic acid-citric acid-treated fruit remained almost constant through the first four test periods and then dropped.

The flavor scores for the fruit treated with sodium chloride made a steady drop throughout the test periods.

The scores for the flavor of the fruit treated with sodium bisulfite increased at the second time interval, decreased at the third, increased at the fourth, and decreased again at the fifth.

The general conclusion scores for the fruit treated with sodium chloride dropped through the first three time intervals, remained constant at the fourth interval, and dropped greatly at the fifth interval. The scores for the fruit treated with potassium metabisulfite were the same for the first two test periods, dropped at the third, increased at the fourth, and decreased again at the fifth.

An example of scores that do not show significant interactions between storage and treatment are the ones for crust texture. These scores tend to go up and then come down, all following very much the same pattern.

Objective Tests on Baked Fruit

Penetrometer

The penetrometer readings on the apple slices from the baked pies are listed on page 43 in Table 3. This method for determining firmness did not work out satisfactorily. It was hoped that this determination would show differences in firmness of the fruit treated in different ways to prevent browning. However, when the apple slices lacked firmness, they cooked up into a sauce which gave very much the same

Table 3. Penetrometer readings on apple slices from baked pies

Treatment		2 weeks	5 weeks	10 weeks	15 weeks	20 weeks
		mm.	mm.	mm.	mm.	mm.
None	average	321	313	304	303	308
	range	309-336	305-321	281-313	292-311	298-317
Sodium chloride	average	288	275	276	283	282
	range	282-297	248-286	260-294	263-300	265-300
Sodium bisulfite	average	317	305	303	300	302
	range	293-325	290-318	278-321	288-310	297-313
Ascorbic acid	average	300	290	290	291	288
	range	279-313	277-320	276-300	282-300	257-317
Potassium metabisulfite	average	320	310	302	302	304
	range	314-324	299-325	297-309	276-330	287-318
Ascorbic acid-citric acid	average	305	295	293	302	310
	range	290-335	278-308	281-320	276-320	287-331

resistance to penetration as did those firm enough to hold their shape.

Correlation coefficients between the penetrometer readings and the scores on consistency, tenderness of fruit, and texture of fruit were calculated. These are given in Table 4. The correlation coefficients between the penetrometer readings and the scores for texture and tenderness are higher for the samples treated with sodium chloride than for any other treatment. However, none of the coefficients were large enough to be statistically significant.

Table 4. Correlation coefficients between penetrometer readings and judges' scores on consistency, tenderness of fruit, and texture of fruit.

Treatment	Correlation coefficients between penetrometer readings and		
	Consistency	Tenderness	Texture
None	-0.028	-0.138	0.090
Sodium chloride	0.014	0.344	0.372
Sodium bisulfite	-0.083	0.046	0.093
Ascorbic acid	0.297	-0.272	-0.367
Potassium metabisulfite	0.014	-0.063	0.049
Ascorbic acid-citric acid	0.025	0.025	-0.188

Color measurement

The results from the objective color tests on the baked fruit are shown in Table 5 on page 46. The fruit treated with sodium bisulfite had about the same hue as the fresh fruit, but the value was lower and not as much of the color was present. The potassium metabisulfite-treated fruit contained the greatest amount of yellow, with the fruit treated with ascorbic acid being second, and that treated with ascorbic acid-citric acid, third. The control contained the smallest amount of yellow.

The figures for value show that the control group was darkest, and that the ascorbic acid-, potassium metabisulfite-, and ascorbic acid-citric acid-treated samples were the lightest, all being nearly the same. The values of the samples treated with sodium chloride and sodium bisulfite were about equal.

There was very little change in hue and value with the length of time in storage, but there was considerable change in chroma. The highest chroma was in the fresh fruit. All of the frozen samples showed a decided decrease in chroma from the first time interval to the last. This shows that there was a loss of color with storage.

The averages of the areas of the color discs required to match the color of the baked fruit in each test period are shown in Table 9 in the appendix. The hue, value, and chroma notations in Table 5 were calculated from these data.

Table 5. Objective color data on apple slices from baked pies, expressed according to the Munsell system

Treatment	Time frozen	Hue*	Value**	Chroma***
	weeks			
Fresh	0	20.58	7.02	9.36
None	2	17.59	4.94	5.58
	5	18.33	4.91	5.33
	10	19.61	5.49	5.21
	15	18.84	5.36	5.23
	20	18.56	5.16	4.32
Sodium chloride	2	20.10	6.64	8.47
	5	18.89	5.88	7.66
	10	18.73	5.86	6.84
	15	19.77	6.03	6.50
	20	19.66	5.61	5.35
Sodium bisulfite	2	20.57	6.63	8.21
	5	20.01	5.88	6.50
	10	19.60	5.85	6.00
	15	20.62	6.15	6.41
	20	20.44	5.86	5.16
Ascorbic acid	2	22.51	6.98	8.33
	5	22.36	6.38	7.20
	10	21.82	6.37	6.58
	15	22.38	6.44	6.58
	20	21.81	6.11	5.74
Potassium metabisulfite	2	23.36	7.12	8.35
	5	22.55	6.44	7.18
	10	22.29	6.44	6.53
	15	22.69	6.44	6.41
	20	22.68	6.26	5.69
Ascorbic acid-citric acid	2	22.35	6.92	7.97
	5	21.01	6.24	7.22
	10	20.97	6.18	6.43
	15	21.83	6.24	6.10
	20	21.54	6.09	5.45

* Hue of yellow-red is 15 and yellow is 25.

** Value runs from one (black) to ten (white).

*** Chroma is the strength of the color. The maximum chroma for yellow-red and yellow is 12.

Objective Tests on Raw Fruit

Ascorbic acid

Ascorbic acid determinations were made on the fruit treated with ascorbic acid and ascorbic acid-citric acid merely as a means of control rather than from the nutritive value standpoint. The fruit receiving no treatment was used as a check. The data obtained are shown in Table 6.

Table 6. Ascorbic acid content of raw, frozen apple slices

Time in storage	Control	Ascorbic acid	Ascorbic acid-citric acid
	mg./100gm.	mg./100gm.	mg./100gm.
3 weeks	0.8	22.7	4.9
11 weeks	0.7	24.8	4.8
16 weeks	0.7	16.0	3.2
21 weeks	0.7	*	5.3

* Sample lost.

The figures indicate that there was very little reduced ascorbic acid in the control samples. This amount remained constant with time in storage. The samples treated with ascorbic acid contained around three and one-half times as much ascorbic acid as those treated with ascorbic acid-citric acid. The ascorbic acid solution with which the fruit was treated contained four times as much ascorbic acid as the ascorbic acid-citric acid solution. The fluctuation in the figures for the treated fruit might be accounted for by variation in the amount of the solution that was absorbed by the fruit.

Sulfur dioxide

The sulfur dioxide content of the fruit treated with sodium bisulfite and potassium metabisulfite was determined to find how well the sulfur dioxide was retained in the fruit with storage. The fruit which received no treatment was used as a check. The data obtained are shown in Table 7.

Table 7. Sulfur dioxide content of raw, frozen apple slices

Time in storage	Control	Sodium bisulfite	Potassium metabisulfite
	p.p.m.	p.p.m.	p.p.m.
6 weeks	0	17	117
11 weeks	0	32	97
16 weeks	0	20	107
21 weeks	0	24	109

The control samples contained no sulfur dioxide. The fruit treated with sodium bisulfite contained an average of 23 parts per million throughout the entire test period as compared to 108 parts per million in the fruit treated with potassium metabisulfite. This can be accounted for in the fact that the fruit was exposed to five times as much sulfur dioxide in the sample treated with potassium metabisulfite as in that treated with sodium bisulfite.

From these figures, it appears that the sulfur dioxide was well retained during zero storage.

pH value

As can be seen in Figure 4 on page 50, all the samples showed a slight increase in pH with time in storage. The pH of both samples treated with sulfur dioxide dropped at the 10-week interval. This drop cannot be explained by changes in the sulfur dioxide content. In only four cases were the pH values of the frozen fruit lower than the pH of the fresh fruit. None of these changes in pH was large and any fluctuations might be accounted for in sampling errors.

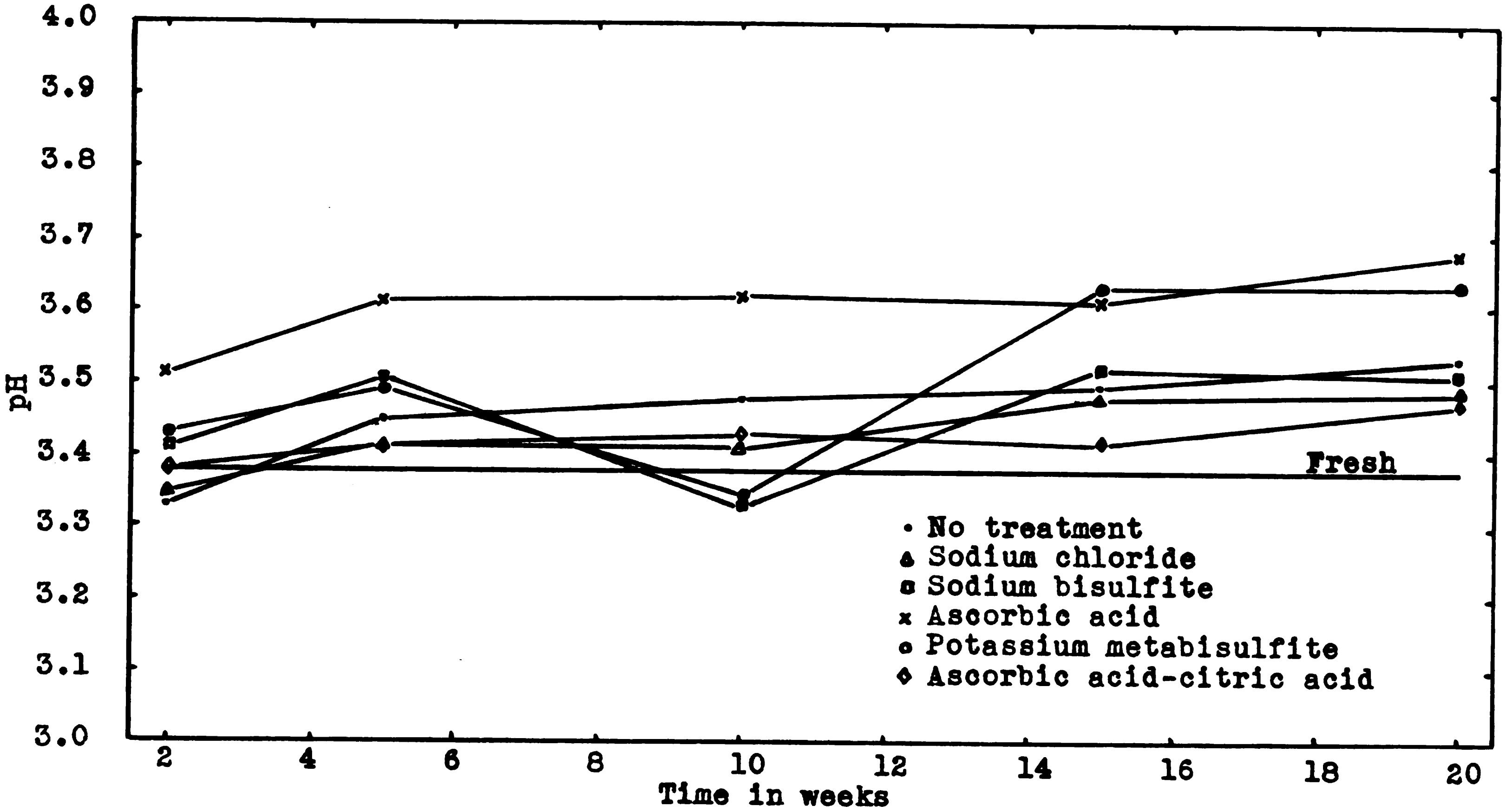

Figure 4. Changes in pH values of frozen apple slices during storage at zero F.

SUMMARY AND CONCLUSIONS

A study was made of five methods of preventing browning in frozen, sliced, Jonathan apples for use in pie. Fruit frozen without additional treatment after peeling and slicing was used as a control. A record was kept on waste in preparation. Pies were made from the fresh fruit, and from frozen apple slices after two, five, ten, fifteen, and twenty weeks in zero storage. There were five replications in each test period. The pies were scored subjectively for color, consistency, odor, flavor, tenderness of fruit, texture of fruit, texture of lower crust, and general conclusion. The firmness of the baked fruit was measured objectively with a penetrometer and color was measured by the Munsell spinning disc colorimeter. The raw fruit from the appropriate treatments was analyzed for the reduced ascorbic acid and for the sulfur dioxide content to determine their retention with storage. The pH of the raw fruit was also measured.

The scores for the various treatments showed sodium chloride best for color, odor, and crust texture; sodium bisulfite best for consistency; ascorbic acid best for flavor and tenderness; and ascorbic acid-citric acid best for texture of fruit. The treatments ranked in the following order for general conclusion score: first, sodium bisulfite; second, ascorbic acid; third, ascorbic acid-citric acid; fourth, potassium metabisulfite; fifth, control; and sixth, sodium chloride.

The scores for color, odor, flavor, tenderness of fruit, texture of fruit, and general conclusion dropped fairly consistently throughout the storage period.

Analysis of variance of the scores showed the differences attributable to treatment and length of zero storage were highly significant for all scoring factors. There was little difference due to replication. The interactions between storage and treatment were highly significant for color, consistency, flavor, and general conclusion and not significant for odor, tenderness of fruit, texture of fruit, and texture of lower crust.

The penetrometer did not prove to be satisfactory for determining firmness in the baked apple slices. There was no correlation between the penetrometer readings and scores on consistency, tenderness of fruit, and texture of fruit.

The Munsell color readings indicated that the fruit treated with potassium metabisulfite contained the greatest amount of yellow. The value in all cases dropped (became darker) with time in storage except in the control which became lighter and then darker. The chroma in all frozen samples declined steadily with storage, indicating loss of color.

Ascorbic acid and sulfur dioxide were well retained in the fruit in zero storage. There was very little change in the pH with storage.

On the basis of these results, it appears that:

1. Sodium bisulfite was the best treatment used for the prevention of browning in frozen, sliced, Jonathan apples; all treatments used except sodium chloride were acceptable; treatment was necessary to prevent browning.

2. The palatability of the fruit declined with storage. However, all samples were satisfactory for all the treatments except sodium chloride and the control for 20 weeks in zero storage.

3. The penetrometer was not satisfactory for determining firmness in baked apple slices.

4. The hue notations varied between treatments but remained fairly constant with storage; the value and chroma notations declined with storage, indicating darkening and loss of color.

5. Ascorbic acid and sulfur dioxide were well retained in the frozen fruit.

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APPENDIX

APPLE PIE SCORE CARD

NAME ____________________ DATE ____________________

Sample Number									
Filling: Color									
Consistency									
Odor									
Flavor									
Tenderness of Fruit									
Texture of Fruit									
Crust: Texture (lower)									
General Conclusion									
Acceptability Yes or No									

KEY	DEFECTS	STANDARD
1. Very poor	Filling:	
2. Poor	Color: Brown, gray	clear, pinkish yellow
3. Fair	Consistency: Excessively juicy, dry pulp too thick juice	juice well retained in pulp
4. Medium		
5. Good	Odor: Lacking, oxidized, foreign	
6. Very good	Flavor: Flat, too sweet, too tart, oxidized, foreign	
7. Excellent		
	Tenderness of fruit: Hard, mushy	Tender but holds shape
	Texture of fruit: Stringy, coarse, rubbery	Velvety, with body
	Crust:	
	Texture (lower): Compact soggy	Flaky, mealy

Table 8. Volume of solutions used in treating apple slices

Treatment	Weight prepared fruit	Volume of solution used	Volume of solution absorbed by slices when evacuated
	kg.	liters	liters
Sodium chloride	18.3	13.0	1.2
Sodium bisulfite	18.0	12.0	--*
Ascorbic acid	17.0	17.0	6.8
Potassium metabisulfite	18.0	12.0	--*
Ascorbic acid-citric acid	15.6	12.0	7.2

* Not vacuum treated.

Table 9. Areas of Munsell color discs - averages for each test period

Treatment	Time frozen weeks	Percent of discs showing YR 6/12	Y 8/12	N 1/	N 5/*	N 8/*
None	2	38	12	43	-	8
	5	32	12	38	18	-
	10	26	18	21	36	-
	15	30	14	21	35	-
	20	26	11	22	40	-
Sodium chloride	2	35	34	7	-	23
	5	43	21	15	22	-
	10	39	18	8	35	-
	15	32	22	3	43	-
	20	27	17	13	43	-
Sodium bisulfite	2	32	37	7	-	24
	5	30	23	16	32	-
	10	30	20	8	42	-
	15	27	26	0	46	-
	20	23	21	7	50	-
Ascorbic acid	2	17	51	7	-	25
	5	19	40	7	33	-
	10	21	34	0	45	-
	15	18	37	0	45	-
	20	18	29	3	49	-
Potassium metabisulfite	2	12	60	7	-	22
	5	18	41	6	35	-
	10	18	37	0	45	-
	15	15	38	0	47	-
	20	15	32	1	53	-
Ascorbic acid-citric acid	2	23	48	7	-	25
	5	27	33	8	32	-
	10	25	28	1	45	-
	15	19	31	0	49	-
	20	18	26	1	56	-

* A darker value had to be used after the two-week storage period in order to match the color discs with the samples.

Table 10. pH values of frozen apple slices

Treatment	2 weeks	5 weeks	10 weeks	15 weeks	20 weeks
None	3.33	3.45	3.48	3.50	3.54
Sodium chloride	3.35	3.42	3.42	3.48	3.48
Sodium bisulfite	3.41	3.51	3.33	3.52	3.52
Ascorbic acid	3.51	3.61	3.62	3.62	3.68
Potassium metabisulfite	3.42	3.49	3.34	3.63	3.63
Ascorbic acid-citric acid	3.38	3.42	3.43	3.42	3.47

Fresh fruit = 3.38