

EFFECTS OF CERTAIN PRE-FREEZING TREATMENTS
AND FREEZING TEMPERATURES ON YELLOW TRANS-
PARENT APPLES PRESERVED FOR USE IN PIES

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EFFECT OF CERTAIN PRE-FREEZING TREATMENTS
AND FREEZING TEMPERATURES ON YELLOW TRANSPARENT
APPLES PRESERVED FOR USE IN PIES

Many varieties of fruits, particularly apples, are grown in Oklahoma. Apples are unique in that summer and winter varieties make this fruit available throughout the year. Oklahoma apple growers are experiencing losses due to codling moth injury. Fall and winter apple varieties are particularly affected by this pest. Apples maturing in early or mid-summer sustain smaller loss due to codling moth infestation. Because of this fact, there is an increasing trend in Oklahoma favoring planting of summer maturing apples.

The tart flavor and juiciness of the summer apples are palatability qualities highly desired for fruits used in making pies. The tendency of summer apples to disintegrate when cooked cause them to be less acceptable for use in baked products than the majority of fall and winter varieties. Their poor keeping qualities limit the time over which they are available. In view of these situations, there is need for a greater variety of methods of utilizing this crop if it is to gain in financial importance to the farmers.

Preservation by freezing results in less alteration of the apple flavor and texture than many other processing methods. Few results have been reported on the pre-freezing treatments of summer apples. Limited work has been conducted on the use of various calcium salts as firming agents for frozen apple slices, but practically all of these studies have dealt with fall and winter varieties of apples.

The purpose of this study was to determine: (1) acceptable methods for firming Yellow Transparent apple slices with calcium chloride;

(2) acceptable methods and materials for preventing discoloration of apple slices (a) during pre-freezing treatments, (b) during time period held in freezer storage, and (c) when thawed for utilization in pie; and (3) the effect on texture, juice drainage, and baking qualities of calcium firmed apple slices of the temperature at which fruit was frozen.

If successful pre-freezing treatments for the summer and early fall variety of apples grown in Oklahoma can be developed, a new cash crop could be established for the farmers of the state.

REVIEW OF LITERATURE

Apples

Since the summer variety of apples have many characteristics desirable for pies, better methods of preservation are needed. Freezing is one of these methods which may be used. Frozen sliced apples are used principally for pies. W. C. Gaunt (1947) recently said in regard to the large fruit production in this state, "Oklahoma might well be called the state with the greatest possibilities for the development of quick freezing."

Freezing apples presents some problems not encountered with fruits having colored flesh, as strawberries and other small fruits. Tressler and DuBois (1940), Wiegand (1946), and Luther and Craggall (1946) state that certain conditions must be controlled in order to have a good frozen apple product. When apples are not properly treated before freezing, they may deteriorate in flavor, color, and texture. Darkening, change in flavor, and softening of texture are particularly objectionable for fruits which are used in pies. Discoloration may occur during preparation of fruit for freezing and continue slowly during and/or following thawing.

It has long been known that the discoloration of apples occur after injury to the cell structure induced by cutting, bruising, or freezing. Overholser and Gruess (1920), Bales and Hale (1935), and further substantiated by Joslyn (1941) are in agreement concerning the fact that oxidative discoloration of apples is an action catalyzed by peroxidase, an enzyme system present in the fruit tissue. This reaction occurs when the enzyme oxygenase catalyzes the oxidation of catechol compounds causing formation of an organic peroxide. This latter substance when

acted upon by peroxidase causes darkening of the apple tissues. The rate at which browning develops bears relationship to the tannin content of the fruit, i. e., fruit containing the larger amounts of tannin discolor more rapidly than fruits containing smaller amounts.

It is important that the peroxidase be inhibited in order to delay the discoloration of cut fruit. Bauernfeind and Siemers (1945) classify peroxidase inhibitors as (a) substances that affect enzymes directly and (b) substances that accelerate its inactivation by peroxide. The former class, which includes the sulfhydryl compounds, is more important in the inhibition of fruit darkening. In 1946 Bauernfeind and Siemers stated that the sulfhydryl derivative occurring in pineapple juice would prevent discoloration of sliced apples.

The acidic content of fruits varies both with the variety and the stage of maturity. This is especially true with apples. Nightingale (1930) found that developing fruits increased in acidity until the soft ripe stage when the per cent of acid suddenly decreased.

Woodroof (1940) reported that L-malic and citric acids occurring in fruit are important factors in controlling enzymatic reactions, permeability, and turgidity of cells. These reactions do not occur as rapidly at a decreased pH.

Enzyme inactivation by heating may be accomplished by the use of steam or water scalding methods. Water scalding with subsequent cooling in water caused greater losses due to leaching of nutrients than did steam scalding or cooling in air as reported by Western Regional Research Laboratory (1944), Melnick and co-workers (1944), Hohl (1945), and Cruess and Smith (1946). Although steam scalding is used principally by commercial packers, this method is less frequently used in the home because of the lack of adequate equipment.

The effectiveness of ascorbic acid and its isomers has been given consideration by Yourga, et al (1944), Bauernfeind and Siemers (1946), and Luther and Cragwall (1946). Results with fruits have not been consistent. Although ascorbic acid is effective in preventing discoloration with peaches, it has not been too satisfactory as an anti-oxidant for apples because of its slow penetration into the fruit. Whether using the ascorbic acid in a dipping solution, in a sugar-syrup solution, or as a dry salt complete penetration into the slice is important. These workers are in agreement with Melnick, et al (1944), Tressler and DuBois (1944), Wiegand (1946), Luther and Cragwall (1946), and Powers and Esselen (1946). In general the slow penetration of the ascorbic acid into the apple slices has indicated that this treatment has greater value when used with a deaeration procedure as described by Bauernfeind and Siemers (1946).

If penetration is incomplete, the slices will be light colored and attractive on the outside but will have dark centers. These various workers also recognize that the treated fruit must be held at room temperature six to eight hours before freezing to allow for penetration of the ascorbic acid into the fruit tissue. Such a holding period or delay before freezing is not practical when large quantities of fruit must be processed and is not in general use.

The following authorities, Joslyn (1930), Atkinson and Strachan (1941-42), and Wiegand (1946) are in agreement that sugar solutions are useful in protecting fruits from oxidation. The glaze or film of sugar or syrup fills space around the fruit, thus excluding air. These workers also found that sugar added to fruit retards development of yeasts and molds, reduces the danger of fermentation and preserves color, flavor, and aroma. The use of sugar causes a withdrawal of water from

the fruit. The sugar dissolves in this juice and forms a concentrated syrup which gradually drains to the bottom of the container. Although the sugar pack is preferred for most fruits, Sorber, et al (1944) state that sugar has not been found necessary for retention of quality of apples during freezing storage.

The treatment of apples before freezing is an important factor in the frozen storage life of this fruit. Atkinson and Strachan (1941-42) and Woodroof and Cecil (1945) were successful in preventing discoloration by using a sulphur dioxide treatment. These workers, as well as Tressler and Evers (1947), indicate that sulfited fruit should be held in cool storage several hours before freezing to insure penetration of the salt into the apple slices since freezing stops penetration of the sulphur dioxide. Either sulphurous acid, the sulfite, or bisulfite salts of sodium may be used as the source of sulphur dioxide. Sorber, et al (1944) reported that when sulphurous acid is used, a delay before freezing is not necessary as the rate of penetration is rapid. Because of the fumes given off by the sulphurous acid and the special equipment that must be used, this acid is not practical as an anti-oxidant for home use.

Ice crystal formation as affected by the rate and temperature at which the foods are frozen is discussed by Tressler and Evers (1947), Woolrich and Bartlett (1942), MacArthur (1945), and Lee, Gortner, and Whitcombe (1946). Slow freezing destroys the colloidal complex of the cells and reduces turgidity. Rapid freezing at a low temperature produces small ice crystals. The smaller the ice crystals which are formed the less tendency there is to rupture the cells. Woodroof (1938), Plagge (1938), Tressler and DuBois (1940), MacArthur (1945), and Tressler and Evers (1947) all recommend 0°F. or below (-10°, -15°, -

-20°F.) for freezing foods. According to Nicholas (1945), the fact that sugar or sugar syrup lowers the freezing temperature of a liquid necessitates a lower temperature for the freezing of sweetened products. This holds true for fruits packed in sugar or syrup.

Discoloration of the peeled fruit may be prevented by the use of a holding solution if delay is necessary prior to pre-freezing treatments. Workers at the Western Regional Research Laboratory (1944) recommend that apples should be held in a weak salt brine (not over 1 per cent salt, by weight) to prevent browning. Sorber, et al (1944) recommend the use of a salt and vinegar solution (2 tablespoons vinegar and 2 tablespoons salt per gallon water).

Whether scalding, syrup pack, sodium bisulphite dips, or ascorbic acid treatments are used to prevent darkening, complete penetration of the apple slices is the important factor, according to Powers and Esselen (1946). Workers are in general agreement that fruit treated with l-ascorbic acid or dipped in sodium bisulphite must be held long enough for the chemical to penetrate to the center of the slice before they are frozen. Most of them agree that scalding fruit in steam or in water is effective in preventing discoloration if the heat is penetrating enough to inactivate the enzymes contained in the fruit.

Much interest has been shown in the use of various calcium salts for improving the texture and firmness of apple slices for use in pies and other products. There is a paucity of literature concerning the use of calcium chloride as a firming agent for apples. Bullis and Wiegand (1931) reported successful firming of cherries by the use of calcium carbonate. Kertesz (1939) in his work with vegetables identified calcium pectate as the tissue firming compound formed when calcium chloride was used as the firming agent.

Woodroof and Cecil (1945) obtained good results with calcium chloride as the firming agent for fruits. Powers and Esselen (1946) have developed several procedures for firming the McIntosh apple slices. Their use of calcium chloride as a firming agent was quite effective in preventing canned, fresh, and frozen apple slices from becoming excessively soft or mushy when baked in pies.

The mechanics of the calcium firming of apple slices is discussed in detail by Baker (1947). He concluded that the amount of calcium salts necessary to accomplish the firming will depend on the type and quantity of natural salts present in the fruit tissue, the degree of ripeness of the fruit, and the action of acids and enzymes either added or naturally present. Esselen, Hart, and Fellers (1946, 1947) noted that calcium chloride also aided in the retention of color. According to Esselen, Hart, and Fellers (1946, 1947) and Hills, Nevin, and Heller (1947) calcium salts may be added to apples through the use of dipping or syrup solutions. The optimum amount of calcium chloride recommended by Hills, Nevin, and Heller (1947) to firm ripe Yellow Transparent apples is 0.1 to 0.2 per cent. They also found that slices cooked soon after being treated with calcium chloride usually show case-hardening; that is, the slices are toughened on the surfaces but are still soft in the interior. The firmness of the apple slices becomes more equalized after a few weeks of storage prior to cooking. According to Hills, Nevin, and Heller (1947) the ideal method for obtaining uniformly firmed slices would be to apply the calcium chloride solution by the evacuation and impregnation procedure. From the standpoint of the homemaker this has the disadvantage in that it is a batch process and requires special equipment.

The problem of packaging fruits which are to be frozen is one which involves the minimization of enzymatic and chemical changes by preventing

access of outside air. Tressler (1940), Pennington (1941), Woodroof and Dupree (1942), Raback (1947), and Tressler and Evers (1947) discuss the advantages and disadvantages of the various types of containers and conclude that the desirable qualities of a material for this use are that it be odorless, tasteless, non-toxic, moisture-vapor proof, inexpensive, and easily and/or readily obtainable. Types of containers for frozen fruits and vegetables include wooden boxes and barrels, glass and tin containers, and paperboard cartons with moisture-vapor-proof bags.

The paperboard carton, having a moisture-vapor-proof cellophane heat-sealed liner or overwrap, is commonly used for holding small or household quantities of fruits and vegetables. The package must be carefully sealed if complete protection is secured for the food. Western Research Laboratory reported in Frozen Food Industry (1946) and Food Ind. 12 (1947) state that an imperfect seal ruins the efficiency of the best water-vapor resistant material.

Recent work reported by these workers recommend dipping the packaged frozen foods in a molten thermoplastic mixture which upon cooling solidifies and forms a protective film. This method of packaging is not commonly used because it is expensive and is not readily obtainable.

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Pastry

Since sliced frozen apples are used principally in pies, the quality of the pastry is of importance in making an acceptable product. The desirable characteristics for pie crust are that it be crisp, tender, and flaky, well-browned around the edges and more delicately browned in the center. It should be tender enough to be cut easily with a fork, and the flavor should be pleasing and delicate.

Plain pastry used in making fruit filled pies contains fat, flour, salt, and liquid. Authorities differ as to the kind and amount of these ingredients which should be used in making pastry, the ratio of fat to flour showing the greatest variation.

The following ratios of fat to flour have been recommended: Fisher (1933): two parts fat to five parts flour; White (1942): three parts fat to eight parts flour; other workers (Food Ind., 17 (1945): three parts fat to ten parts flour. Nicholas, Ruth, and Swanson (1947) recommend the use of a one to three ratio of fat to flour for frozen pastries. This ratio is also the amount recommended in the majority of cookbooks. According to Platt and Fleming (1923) shortening has an important influence on the taste, the digestion, the nutritive value, and the keeping quality of pastry. The amount of fat used depends upon how rich a pastry is desired.

The kind as well as the amount of fat used influences the type of pastry made. The definition of a fat or shortening given by Davis (1921) has never been replaced by another. It is as follows:

"A shortening is any fat or fixed oil used as an ingredient in a baked product. That material has the greatest shortening power, which, when baked in a dough under standard conditions gives to the product a minimum breaking strength and a minimum crushing strength."

The shortometer devised by Davis (1921) for the measurement of breaking

strength of pastries was later improved by Bailey (1934). The objective testing of pastry tenderness is done with the Bailey shortometer.

According to Robinson and Black (1945) fats are formulated from (a) hydrogenated meat fats or vegetable oils, (b) blends of meat fats and vegetable oils, and (c) blends of hydrogenated fats with unhardened fats or oils, either from vegetable or meat sources. The Handbook of Food Preparation, submitted by the terminology committee of the Food and Nutrition Division, American Home Economics Association (1947), also gives these same classifications. Lowe (1946) found that pastry made with oils had the least breaking strength and hence was the tenderest pastry. Fisher (1933), Cawood (1934), and Lowe (1938) found lard pastry to have the least breaking strength of the plastic fats tested. Jordon (1944) found that the hydrogenation of lard increases its firmness but decreases its shortening power in pastry. Mattil, Higgins, and Robinson (1946) found lard to be more digestible than vegetable oils because a major portion is not hydrogenated and there is no appreciable destruction of the naturally occurring essential, unsaturated fatty acids. Lowe (1946) states that butter gives a browner crust, one that is flaky, but which in most instances is less tender than a plain pastry made with lard or hydrogenated fats.

Noble, et al (1936), Harvey, (1937), Lowe (1946), and Lowe, Nelson, and Buchanan (1938) discuss how the iodine number and congealing point of fats affect the shortening power. These workers found that fats with the highest iodine values and lowest congealing points produce the tenderest pastry; those fats which are the most unsaturated produce the tenderest but not the flakiest pastry.

Soft wheat flours produce a mealy pastry. Most workers are in agreement with Lowe (1946) that all-purpose flour is preferable for use

in making pastry.

The technique of mixing and handling the dough affects the quality of the finished product. Two general methods for mixing pastry are the cold water and the hot water methods. According to Lowe (1946) the type of pastry obtained depends to a large extent upon the technique of adding the water and rolling, although the method of mixing flour and fat is important. Prolonged mixing of pastry after water has been added produces a pastry having a higher breaking strength, hence a tough pastry.

Baking temperatures recommended for pastry vary from 365° to 473°F. (185-245°C.). Lowe (1946) states that pastries baked at the higher temperatures were judged more palatable.

Various experiments in frozen pastry and frozen whole pies have been made. Some of the more recent are those reported by Clark and Okerson (1945), Quick Frozen Foods (June, 1946), Nicholas, Ruth, and Swanson (1947), Trossler and Evers (1947), and Fenton (1947). They found the development of rancidity in the pastry, because of the fat content is the major factor which must be controlled. The long time required to thaw pastry makes it impractical to freeze it in large quantities. (Sunderlin, Collins, and Acheson (1940). A satisfactory method for freezing pastry shells and filled pies has not yet been perfected.

In this Review of Literature consideration has been given to several phases of this study. The pre-freezing treatments, freezing temperature, and method of packaging apple slices for frozen storage and also general proportions of ingredients, methods of mixing and baking pastry for pies has been reviewed.

PROCEDURE

Materials

Supplies of Yellow Transparent apples for this study were grown near Stillwater, Oklahoma, and were secured from the Department of Horticulture orchards maintained by the College. Arrangements were made with the fruit growers to supply fruit of uniform quality and maturity. Bushel and half-bushel lots of apples were brought to the laboratory as needed. To delay ripening of fruit, the apples were kept in cold storage at approximately 40°F.

Other materials used in this study are discussed in each section.

Equipment

The equipment used was similar to that found in any well-equipped laboratory. Bowls, paring knives, measuring spoons and other cooking utensils were of standard size.

A table model, hand operated rotary peeler with iron wire prongs was tried as a peeling device for the apples. This peeler was found unsatisfactory due to the discoloration of the apple tissue caused by the prongs.

In order to determine the pH of the fruit, 25 grams apple slices and 50 cc. of water were placed in the Waring blender and reduced to a pulp. The Beckman electric pH meter served as a means for taking pH readings on the (a) raw and (b) baked apple slices and (c) juice drained from the thawed fruit.

The Bailey shortometer was used for testing the breaking strength of the pastry wafers. The pastry wafers were cut into strips, 3 1/2" X 2" X 3/32", and pricked with a pricking block before baking.

Gas ovens with thermostatic controls were used for baking.

The temperature of the ovens was checked with Taylor Kohrenheit oven thermometers. A centigrade chemical thermometer was used where other temperature readings were involved. A Lux-clock or timer and a stop watch was used for the timing intervals.

Weights of materials were taken by the use of a chain-o-matic balance and gram trip scales. A needle-type precision penetrometer was used to measure the firmness of the calcium chloride treated apple slices.

The apple slices used in preliminary tests were wrapped in vegetable parchment paper and those stored for use in pies were packaged in quart-sized cartons with heat-sealed-moisture-vapor-proof cellophane liners. A commercial home freezer and the locker storage units maintained by the Horticulture Department was used for freezing and storing the fruit for varied lengths of time.

Preliminary Tests

Preliminary work showed that the iron wire prongs of the peeler caused the apples to discolor where the prongs entered the fruit. Due to the irregular shape of the fruit, the mechanical peeler left much of the apple to be peeled by hand. Because of these disadvantages, it was decided that the apples would be peeled by using a paring knife instead of a mechanical peeler. It was also found that if the apples were cut into twelfths they would be of desired thickness in most instances.

Holding Solution

The pared apples were kept in a holding solution prior to slicing and scalding. The most effective agents for preventing discoloration of the peeled fruit as determined by the preliminary tests were 2 tablespoons salt and 2 tablespoons vinegar per gallon of water.

In the preliminary tests, six acids, two salts, and seven acid-salts combinations were used to determine which was most effective as an anti-oxidant to prevent discoloration of the peeled fruit. The concentration used, the contact time and results were recorded. The methods used are given in Table 1. The results of these tests will be given under Results and Discussion of this paper.

The parts of the apple, according to Bigelow, Gore and Howard (1905) are given in Figure 1. The various regions of the apple slices will be referred to by name when discussing the results of anti-oxidant treatments. The most sensitive portion of the apple slices to oxidation is the core line. Although the torus flesh of the apple slices might remain unoxidized, if the core line darkens, the slices are rendered unsatisfactory for use in making pies.

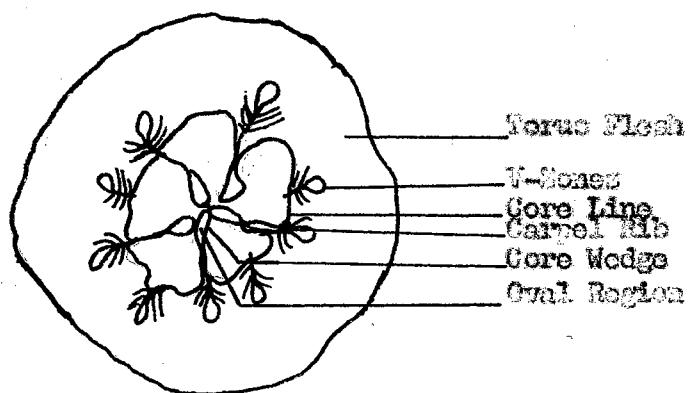


Figure 1

Diagrammatic Cross Section of Apple

Showing Location of Various Regions and Structures

Table 1

Anti-oxidant Materials Tested for Effectiveness of Preventing Discoloration of Peeled Apples Held in Solution Prior to Pre-freezing Treatments

Anti-oxidant	Concentration Used Per Cent	Min. and Max. Time Fruit in Contact with Solution*
Citric Acid	0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6	20 - 60 min.
Ascorbic Acid	225 mg., 450 mg., per gal. water	20 - 60 min.
Lemon Juice	1, 1.5, 2, 2.5, 3, 3.5, 4 %	20 - 60 min.
Cider Vinegar	2 T. per gal. water	20 - 60 min.
Distilled Vinegar	2 T. per gal. water	20 - 60 min.
Ascorbic- Citric Acid	2, 4 t. per gal. water	20 - 60 min.
Non-Iodized Salt	1, 1.5, 2, 2.5, 3, 3.5, 4 %	20 - 150 min.
Iodized Salt	1, 1.5, 2, 2.5, 3, 3.5, 4 %	20 - 150 min.
Citric Acid	4 - 2 - 1 t. per gal. water	20 - 150 min.
Iodized Salt	4 - 4 - 6 t. per gal. water	
Ascorbic Acid	225 mg. - 225 mg. per gal. water	20 - 60 min.
Iodized Salt	4 t. - 6 t. per gal. water	
Lemon Juice**	4 t. - 6 t. per gal. water	20 - 60 min.
Iodized Salt	4 t. - 6 t. per gal. water	
Distilled Vinegar**	2 T. per gal. water	20 - 150 min.
Iodized Salt	2 T. per gal. water	
Distilled Vinegar**	2 T. per gal. water	20 - 150 min.
Non-Iodized Salt	2 T. per gal. water	
Cider Vinegar	2 T. per gal. water	20 - 150 min.
Iodized Salt**	2 T. per gal. water	
Cider Vinegar	2 T. per gal. water	20 - 150 min.
Non-Iodized Salt**	2 T. per gal. water	

* Fruit observed at 5 minute intervals.

** The supply of fruit available limited the extent of testing with these materials.

In the preliminary experiments, because of the relatively small amount of fruit used in each test, the apples were sliced as soon as peeled and then placed in quart-sized glass bowls containing the different anti-oxidant solutions. These were kept in solution for the

time periods given in Table 1. Approximately 36 apple slices were placed in each bowl. At the end of each time testing period a few apple slices were removed and the effectiveness of the anti-oxidant was determined by observation and by testing. Triplicate tests were made on each anti-oxidant at each concentration tried and for each of the time periods used. The standard used for judging the effectiveness of the holding solution was the development of (1) no oxidative coloration and (2) no undesirable impairment to the flavor of the fruit.

Since the combination of 2 tablespoons distilled vinegar and 2 tablespoons iodized salt per gallon of water gave a holding solution which was judged most desirable of all the materials used in the preliminary tests, the apples prepared for freezer storage were treated using this formula.

Pre-freezing Treatments

When larger amounts of apples were used at a time, the whole peeled apples were kept in a holding solution as described above until a sufficient quantity was ready to be sliced. The sliced fruit was also held in the same type holding solution. This solution was kept in glazed earthenware crocks.

Before packaging the prepared fruit, pre-freezing treatments were used in order to firm the sliced apples and to inactivate the fruit enzymes.

In preliminary tests, five variations in the amount and kinds of anti-oxidants and the manner of using them and eight variations in the amount of calcium chloride, using two methods of incorporating the same were compared to determine which was the most desirable. A needle-type precision penetrometer was used to test the firmness of the apple slices. The penetrometer needle was allowed to penetrate the fruit for 5 seconds.

Readings were recorded as decimillimeters, i. e., the depth of penetration being indirectly proportional to the firmness of the fruit. The degree of firmness desired by the judges for the apple slices ranged from 120-170 decimillimeters. Results of these tests were recorded. The concentration of calcium chloride solution as expressed in per cent refers to weight of the dry salt. A fresh solution of calcium chloride was prepared for each triplicate sample. All samples were prepared in triplicate, packaged and held in frozen storage at 0°F. for 36-72 hours before testing. The various methods used were as follows:

1. Solutions containing 0.5, 0.75, and 1 per cent calcium chloride were prepared. The apple slices were placed in the above solutions and held at room temperature. At intervals of 5, 10, 15, and 20 minutes, respectively, samples were removed from each of the concentrations. Anti-oxidants used with each of the above concentrations of calcium chloride and respective dipping times were 1/4 teaspoon dry citric-ascorbic acid per 60 grams fruit for one group of tests and 20 per cent canned pineapple juice for another group.

Fresh pineapple juice at the 20 per cent concentration was used as the anti-oxidant for samples treated in 1 per cent calcium chloride solution for 5, 10, 15, and 20 minutes, respectively.

2. Solutions containing 1 and 2 per cent calcium chloride, were prepared and samples of apple slices were placed in the above solutions held at room temperature for 20, 30, 40, 50, and 60 minutes, respectively. The apple slices were then drained and all samples were dipped in a sodium sulfite solution (2 teaspoons per gallon water) for 5 minutes.
3. The apple slices were placed in 1.5 per cent calcium chloride solution held at room temperature. They were removed from the solution at intervals of 5, 10, 15, and 20 minutes, respectively. They were then drained and dipped in sodium sulfite solution (2 teaspoons per

gallon water) for 5 minutes.

4. Calcium chloride solutions containing 1, 2, and 3 per cent calcium chloride were prepared. The apple slices were dipped in a given solution and allowed to remain for 5 minutes. Each sample was then removed, drained and dipped in a sodium sulfite solution (2 teaspoons per gallon water) for 5 minutes. After removal from the sodium sulfite solution, the fruit from each of the above treatments was packed with a sugar to fruit ratio of 1:6 and 1:4.
5. Duplicate solutions each containing 1 per cent calcium chloride and 2 teaspoons sodium sulfite per gallon of water were prepared. One solution was held at room temperature (17.5°C.) and the other was heated to 45°C. Apple slices were placed in each of these solutions and held for 40 minutes.
6. Triplicate portions of sodium sulfite solution (2 teaspoons per gallon water) were prepared. Apple slices were held 10 minutes in the portion held at room temperature (17.5°C.) and 5 and 10 minutes, respectively, in the heated (45°C.) solutions. After draining 0.33 per cent dry calcium chloride was added to the fruit.
7. A 1 per cent calcium chloride solution was used in scalding the fruit for a 2 minute period and sodium sulfite (2 teaspoons per gallon water) served as a cooling medium for 5 minutes.
8. Calcium chloride in the dry form at concentrations of 0.33 per cent and 0.25 per cent was added to the fruit after the anti-oxidant treatment had been applied. The fruit was scalded in water for 2 and 3 minutes, respectively, cooled in sodium sulfite solution (2 teaspoons per gallon water) and in ice water, respectively, for 5 minutes. The fruit was then drained and the dry calcium chloride was added to the fruit.

The prepared apple slices were wrapped in a vegetable parchment paper for the storage period. The sweetened slices were placed in covered containers to prevent syrup leakage. The packaged slices were frozen and stored at 0°F. for periods varying from 36 to 72 hours in a commercial home freezer. Upon removal from the storage, the slices were thawed in the unopened package at room temperature before being baked into pies or tarts. Penetrometer readings were taken on the apple slices as previously described.

Since the anti-oxidants, sodium sulfite and scalding, were judged most desirable of all those tested, the fruit was prepared for storage using these methods. Calcium chloride was used dry and in the scalding solution as a firming agent in conjunction with the anti-oxidant treatment.

Treatment of Yellow Transparent Apple Slices

Packaged and Stored for Use in Pies

As a result of the preliminary tests, apple slices were prepared for storage using eight different combinations of anti-oxidants and firming agent. Triplicate samples of each of these variations were frozen at 0°F. and -20°F. The treatment for the apple slices are listed in Table 10.

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Table 10

Pre-freezing Treatments for Yellow Transparent Apple Slices

Test	Scalding Solution		Cooling Solution				0.33% dry CaCl ₂
	1% CaCl ₂	H ₂ O	Na ₂ SO ₃	Ice		H ₂ O	
	2 Min.	2 Min.	1"	3"	5"	5"	
1 B 1	X		X				
1 R 1	X		X				
1 B 2	X			X			
1 R 1	X			X			
1 B 3	X				X		
1 R 3	X				X		
1 B 4	X					X	
1 R 4	X					X	
11 B 1		X	X				X
11 R 1		X	X				X
11 B 2		X		X			X
11 R 2		X		X			X
11 B 3		X			X		X
11 R 3		X			X		X
11 B 4		X				X	X
11 R 4		X				X	X

It was decided that 550 grams of the raw sliced apples would be a sufficient amount to prepare for each quart carton. The term "Modified Scald" used throughout the report is so designated because at no time after adding the fruit did the temperature of the scalding solution reach boiling point. The temperature of the solution at the end of the scalding period ranged from 83° to 94°C. with 92°C. the average. The total scalding time was calculated from the moment the fruit was added to the hot liquid. The fruit was scalded in boiling water or a 1 per cent calcium chloride solution. After scalding, the fruit was removed from the hot solutions and cooled in sodium sulfite (17.5°C.) for 1, 3, or 5 minutes as shown in Table 10. The apple slices were then drained before packaging.

When ready for packaging, 500 grams of the scalded fruit was allowed for each package. The dry calcium chloride was added to the

water scalded, drained fruit just before being packaged. Care was taken to get it uniformly distributed throughout the apple slices.

The treated fruit was placed in moisture-vapor-proof cellophane bags which were heat-sealed, put into cartons, and labeled. The packaged fruit was held approximately 4 hours at room temperature to allow for penetration of the sulfite into the fruit before being frozen and stored. Following a 24 hour freezing period, the packages were transferred to a locker storage compartment having a temperature of 0°F. These remained in storage at this temperature until used. The storage time varied from three to four months.

Upon removal from storage, the apple slices were thawed in their heat-sealed-moisture-vapor-proof cellophane bag containers by placing them in an ice refrigerator at 45°F. for 16 hours. After removal from the refrigerator, they were taken out of the bags and placed in wire strainers and allowed to finish thawing and drain for 2 hours.

After thawing, the following tests were made and results recorded:

(a) on the uncooked apple slices; inspection for oxidation, penetrometer readings, and pH readings on both the juice and slices; palatability scores, pH readings, and penetrometer readings, (b) on the baked apple slices; palatability scores, pH readings, and penetrometer readings, and (c) volume of the juice which drained from the thawed apple slices. The standard agreed upon by the judges for apple slices to be used in pies were (1) tart sweet flavor, (2) translucent color, and (3) no discoloration. A copy of the score card used is shown on the following page.

Apple Pie Records

Series No. _____

Checking Charts for Pies Made from Frozen Apple Slices

Filling - Color of Fruit		Filling - Juiciness	
Sample No.	1 2 3 4 5	Sample No.	1 2 3 4 5
Translucent	1 2 3 4 5	Very Juicy	1 2 3 4 5
Whitish	1 2 3 4 5	Mod. Juicy	1 2 3 4 5
Grayish	1 2 3 4 5	Sl. Juicy	1 2 3 4 5
Yellowish W.	1 2 3 4 5	Sl. Dry	1 2 3 4 5
Greenish W.	1 2 3 4 5	Sl. Thick	1 2 3 4 5
Pinkish Y.	1 2 3 4 5	Thin	1 2 3 4 5
Brownish Y.	1 2 3 4 5	Starchy	1 2 3 4 5
Filling - Flavor of Fruit		Filling - Desirability of Flavor	
Sample Number	1 2 3 4 5	Sample Number	1 2 3 4 5
Very Acid	1 2 3 4 5	Desirable	1 2 3 4 5
Mod. Acid	1 2 3 4 5	Mod. Desirable	1 2 3 4 5
Sl. Acid	1 2 3 4 5	Sl. Desirable	1 2 3 4 5
Mild	1 2 3 4 5	Neutral	1 2 3 4 5
Bland	1 2 3 4 5	Sl. Undesirable	1 2 3 4 5
		Undesirable	1 2 3 4 5
Filling - Texture of Fruit		Desirability of Texture	
Sample Number	1 2 3 4 5	Sample Number	1 2 3 4 5
Mod. Firm	1 2 3 4 5	Desirable	1 2 3 4 5
Sl. Firm	1 2 3 4 5	Mod. Desirable	1 2 3 4 5
Sl. Soft	1 2 3 4 5	Sl. Desirable	1 2 3 4 5
Soft	1 2 3 4 5	Neutral	1 2 3 4 5
Mushy	1 2 3 4 5	Sl. Undesirable	1 2 3 4 5
		Undesirable	1 2 3 4 5
Filling - Sweetening of Fruit		Filling - Volume	
Sample Number	1 2 3 4 5	Sample Number	1 2 3 4 5
Very Sweet	1 2 3 4 5	Very Full	1 2 3 4 5
Mod. Sweet	1 2 3 4 5	Adequate	1 2 3 4 5
Sl. Sweet	1 2 3 4 5	Skinny	1 2 3 4 5
Preference of Judge		Key to Abbreviations:	
Ranking	1st 2nd 3rd	Sl. - Slightly	W. - White
Flavor		Mod. - Moderately	Y. - Yellow
Texture			
Color			
Sweetening			
Juiciness			
Amount of Filling		Signature of Judge	
		Date	

PASTRY

Manipulative techniques were developed, which gave an acceptable pastry, when used in conjunction with the calcium firmed apple slices. Since most people prefer the flavor of hydrogenated vegetable fat to lard, it was selected as the shortening to be used in these experiments with pastry. The pastry was rolled on a hardwood board. Two grams of flour was adequate to prevent dough made from 1 cup flour from sticking during rolling. The dough was rolled to uniform thickness as gauged by 3/32 inch hardwood strips tacked to the board and used as rolling guides. Wafers (3 1/2" X 2") were cut from the rolled pastry. The cut wafers were pricked and placed on tin baking sheets, allowing space between each wafer for uniform cooking. These were then baked in pre-heated gas ovens at a specified temperature and used for testing the variables throughout this phase.

The quality of the baked pastry in all the tests was determined by (a) breaking test, using the Bailey shortometer, and (b) palatability scoring. Triplicate tests were run on each series of pastry. The preliminary work on pastry included consideration of various factors listed below.

1. The influence of method of mixing upon pastry quality, using (a) pastry blender, (b) a foiey fork, or (c) a table fork, respectively was considered. The number of mixing strokes was noted.
2. The effect of the temperature of water and the amount of it used on pastry quality was noted. Water at room temperature as well as that heated to the temperature of 45°C., 50°C., and 60°C., respectively, was used, all other factors remaining constant. Shortometer readings and palatability scores were recorded.

3. The effect on pastry quality produced by conditions under which pastry was rolled included cooling the mixed pastry to 30°C. for comparison with that rolled as soon as mixed.
4. The effect on pastry quality produced by baking time, temperature, and position of the rack in the oven, included using a 12, 13, 14, and 15 minute, respectively, baking time at 400°F. and 425°F., respectively. Wafers were baked using a lower or middle (intermediate) placement of the oven rack for each of the baking time periods and for each oven temperature. As a result of these preliminary tests with pastry, a basic recipe and method of handling was formulated. This recipe was used for making the pastry for tarts and/or pies.

Tarts

The pastry was rolled to uniform thickness and cut in circles approximately 5 inches in diameter. For each tart, 60 grams of thawed apple slices and 25 grams of sugar were placed on the center of each pastry circle. The fruit was enclosed in the pastry and placed on a cookie sheet. The cookie sheet of tarts was placed on the middle rack of the oven and baked for 35 minutes at 425°F.

The method of judging the effectiveness of the calcium-firming treatment has been previously described.

Pies

As a result of some preliminary work not reported in this paper, the pie filling recipe was determined. This amount of filling was adequate for an eight inch pie.

Proportion of Ingredients in Pie Filling

Ingredient	Weight in Grams	Approximate Measure
Thawed apple slices	400	2 1/4 C.
Cornstarch	22	2 1/2 T.
Sugar	175	13 T.

Method

1. Mix cornstarch and sugar thoroughly.
2. Combine the above mixture with the apple slices.
3. Pour the apple mixture into a pastry lined pan.
4. Put the top crust on the pie and seal the edges.
5. Bake the pie for 45 minutes at 425°F. in a gas oven.

After baking, the pies were allowed to cool for 3 hours at room temperature and the fruit was tested as previously described.

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EXPERIMENTAL

Holding Solution

Because apples discolor readily when the flesh is exposed, it was necessary to find an effective anti-oxidant to use in the holding solution. In the literature many different anti-oxidants have been suggested, but little is known of their effect upon apples.

Preliminary investigation showed that the apple slices discolored within 20 minutes when using citric acid as the anti-oxidant for the pooled fruit. This acid gave adequate protection when used with peaches, according to Woodroof (1940). Citric acid aided in controlling enzymatic reaction in peaches by decreasing the pH of the fruit, but was not satisfactory for use with apples. Yellow Transparent apples have a high acid content as indicated by their tart flavor. The increased acidity supplied by the citric acid was not effective with this fruit.

When using ascorbic acid, as with citric acid, discoloration of the apples developed within 20 to 25 minutes. There was an undesirable increase in tartness of the apples when 450 mg. ascorbic acid per gallon of water was used.

Because neither the citric nor ascorbic acids at the concentrations used were satisfactory, lemon juice was tried because it contains 1.944 grams citric acid and 0.017 grams ascorbic acid per ounce fresh juice. It was thought that lemon juice might be effective since neither citric acid nor ascorbic acid gave anti-oxidant protection when used alone.

Lemon juice, although frequently used with fruits to delay discoloration, gave only moderate results when used in the holding solution. Even at the highest concentration used, 4 per cent (approximately 2/3

cup of juice per gallon water), the apple slices darkened at the core line within 20 minutes holding time and had a decided tart flavor. However, if lemon juice had proved effective as an anti-oxidant, the additional cost would limit its usefulness.

Since citric acid, ascorbic acid, and lemon juice did not provide adequate protection against oxidation for the slices, it was decided to try vinegar because it is a common condiment in the average home and is cheap. Vinegar contains acetic acid, l-malic acid and traces of formic and other organic acids.

Neither cider nor distilled vinegar when used singly as an anti-oxidant protected the fruit against discoloration. The apple slices discolored within 20 minutes.

Fruit Mix, a commercial blend containing 96 per cent citric and 4 per cent ascorbic acid, gave results similar to those obtained with the lemon juice. The apple slices darkened within 20 minutes holding time.

When a quantity of apples are being prepared, it may be assumed that the delay between the time of peeling and the time of packaging the prepared fruit would exceed 20 minutes. None of the acids tested thus far, therefore, could be considered as having any practical significance as an anti-oxidant. Workers at the Eastern Regional Research Laboratory (1947) recommend a 1 per cent salt solution as an anti-oxidant for fruits. Since these workers did not specify the kind of salt used, both the non-iodized and iodized salt were tried.

Iodized salt contains iodine, which is a reducing agent. It was thought that this property might be utilized as a factor in preventing discoloration of the apple slices without impairing the flavor of the fruit. Iodized salt contains 0.01 per cent potassium iodide, by weight.

The data in Table 1 A shows that in order to have the desired

anti-oxidant protection from non-iodized salt, it was necessary to use such a high concentration of this salt to insure protection for as much as 60 minutes that the flavor of the fruit was impaired. See Table 1. Slightly better protection against discoloration was given by iodized salt. Since only slight darkening was visible at the core line, after 40 minutes, when iodized salt at 2 per cent level was used, this could represent a time period of practical importance to the fruit processor. Concentrations of above the 2 per cent salt level gave a salty flavor to the fruit after a holding time of 60 minutes, although the slices were protected from discoloration.

Table 1 A

Effect of (1) Non-iodized Salt and (2) Iodized Salt on Apple Slices When Used As the Anti-oxidant in the Holding Solution

Test	Concentration in T. per gal. Water	Effect on Apple Slices	Time Limit With- in Minutes
1a	1 1/4 (1%)	Darkened at core line	20
1b	1 7/8 (1.5%)	Darkened slightly at core line	20
1c	2 1/2 (2%)	Darkened slightly at core line	40
1d	3 1/8 (2.5%)	Darkened slightly at core line; had undesirable salty flavor	60
1e	3 3/4 (3%)	Darkened at core line; had undesirable salty flavor	120
2a	1 1/4 (1%)	Darkened at core line	20
2b	1 7/8 (1.5%)	Darkened very slightly at core line.	20
2c	2 1/2 (2%)	Darkened very slightly at core line.	40
2d	3 1/8 (2.5%)	Darkened slightly at core line; undesirable salty flavor	60
2e	3 3/4 (3%)	Darkened at core line; had undesirable salty flavor	120

Since none of the anti-oxidants studied so far were entirely satisfactory at the concentrations used, several combinations of acids and salts were tried. One teaspoon salt per quart of water will give an approximate isotonic solution; therefore, the teaspoon basis with varying

amounts of the respective acids was used. The first combination was made of citric acid and iodized salt. See Table 1.

Apple slices held in the solution containing a 4:4 ratio of citric acid to iodized salt showed discoloration of the torus flesh within 20 minutes; while at 2:4 ratio the slices discolored within 25 minutes, and with a 1:6 ratio the fruit discolored within 40 minutes holding time.

Acid-salt combinations using ascorbic acid or lemon juice with iodized salt did not protect the apple slices from oxidation for any appreciable time.

Since none of the anti-oxidants so far studied have been entirely successful, a combination of salt and vinegar was the next variant to be tried. Sorber, et al (1944) had recommended the combination of 2 table-spoons salt and 2 tablespoons vinegar per gallon of water for a holding solution. These workers did not state the kind of salt and/or vinegar they used.

Table 1 B gives data on the vinegar salt combinations used.

Iodized salt in all the tests with vinegar afforded better protection than did those using the non-iodized salt. Distilled vinegar was found to be superior to cider vinegar in these tests. These vinegar-salt combinations gave acceptable results for a holding solution. Furthermore, these materials represent ones that are inexpensive and easily and readily obtainable.

Table 1 B

Effect of Vinegar and Salt Combinations on Apple Slices When Used as Anti-oxidants in Holding Solution

Test	Conc. of Salt		Conc. of Vinegar		Effect of Anti-oxidant on Apple Slices Solution on Apple Slices	Time at end of Min.
	Iodized	Non-Iodized	Distilled	Cider		
a		2 T.		2 T.	No oxidation of slices	120
					Slight oxidation at core line and some at the surface of torus flesh of slices which floated to the top	150
b	2 T.			2 T.	No oxidation of slices	120
					Slight oxidation of core line but no oxidation of torus flesh	150
c		2 T.	2 T.		No oxidation of slices	120
					Slight oxidation at core line, but no oxidation of torus flesh	150
d	2 T.		2 T.		No oxidation of slices	120
					No oxidation of slices	150

Pre-freezing Treatments

After having decided upon the holding solution, the next step was to determine the pre-freezing treatments for the apple slices. An investigation of the literature indicated that calcium chloride was an effective firming agent for apple slices. Therefore, it was decided to use calcium chloride as the firming agent in these experiments, using it both in solution and in the dry form. Certain selected anti-oxidants were to be combined with this procedure.

Since a number of anti-oxidants had been tried by other workers, the following anti-oxidants were chosen to be used in connection with the calcium chloride in the preliminary tests: (1) citric-ascorbic acid, (2) pineapple juice, (3) sodium sulfite, (4) sugar, and (5) scalding.

Pre-freezing treatments for apple slices should completely inactivate

the enzyme system in order to prevent oxidative discoloration. Woodroof (1940) and Wiegand (1946) used citric acid and ascorbic acid as anti-oxidants for preventing discoloration of fruit during frozen storage. As a result of their work, it was decided to try the effectiveness of citric-ascorbic acid, a commercial Fruit Mix, which contained 96 per cent citric and 4 per cent ascorbic acid.

Data in Table 2 shows that the apple slices in these tests darkened so quickly after thawing that citric-ascorbic acid at the concentration used was not satisfactory as an anti-oxidant. However, the apple slices from all tests were firm enough to hold their shape, with the exception of those dipped in 0.5 per cent calcium chloride solution for 5 minutes. These results indicate that the 5 minute dipping time in 0.5 per cent calcium chloride is inadequate to firm the slices. Variations in firmness may be noted with each concentration of calcium chloride used. Penetrometer readings on the baked apple slices show no correlation between the dipping time and the firmness of the fruit. It may be assumed that the maturity of the fruit and the size of the slices may partially account for consistency. Also, the fact that the concentration of calcium in the solution was not determined before succeeding batches of apples were treated, might be a factor contributing to the variation in firmness.

Table 2

Effect of Citric-Ascorbic Acid and Different Dipping Times in Various Concentrations of Calcium Chloride Solution on the Oxidation and Firmness of Apple Slices (1/4 t. Citric-Ascorbic Acid per 60 grams fruit)

Test	Calcium Chloride		Effect of Anti-oxidant on Uncooked, Thawed Apple Slices: Time at Which Discoloration Appeared*	Ave. Penetrometer Readings: Dam. Per 5 Seconds
	Conc. %	Dipping Time Minutes		
a	0.5	5	Upon thawing	None**
b	0.5	10	30 minutes after thawing	120.2
c	0.5	15	30 minutes after thawing	113.2
d	0.5	20	45 minutes after thawing	121.9
e	0.75	5	Upon thawing	120.2
f	0.75	10	25 minutes after thawing	127.2
g	0.75	15	1 hour after thawing	110.7
h	0.75	20	1 hour 20 minutes after thawing	126.1
i	1.0	5	1 hour after thawing	108.0
j	1.0	10	1 hour 25 minutes after thawing	123.0
k	1.0	15	1 hour 25 minutes after thawing	112.0
l	1.0	20	1 hour 30 minutes after thawing	103.2

* Samples done in triplicate

** Too soft to test with penetrometer

Since citric-ascorbic acid, at the level used, was unsatisfactory as an anti-oxidant, it was decided that pineapple juice, both canned and fresh, would be tried. Bauernfeind and Slemers (1946) stated that the sulphydryl derivatives occurring in pineapple juice would prevent discoloration of apple slices. They used a 20 per cent solution, but did not state whether it was fresh or canned pineapple juice.

Results with pineapple juice, both canned and fresh, are given in Table 3. Oxidative discoloration was not prevented when either canned or fresh pineapple juice was used. However, the apple slices dipped in calcium chloride solution of 0.75 or 1 per cent concentration for 15 and 20 minutes, respectively, before being given treatment with pineapple juice, gave slices satisfactory as to firmness for use in pies.

This was substantiated by palatability tests. These palatability scores are not included with these preliminary tests. As shown in Table 3, the increase in firmness was consistent with the increase in time during which the calcium reacted with the fruit. As previously stated, penetrometer readings of 120-170 decimillimeters were indicative of acceptable firmness for apple slices baked in pies.

Table 3

Effect of 20 Per Cent (1) Canned or (2) Fresh Pineapple Juice and Different Dipping Times in Various Concentrations of Calcium Chloride on the Oxidation and Firmness of Apple Slices

Test	Calcium Chloride		Effect of Anti-oxidant on Uncooked, Thawed Apple Slices: Time at Which Discoloration Appeared	Ave. Penetrometer Readings: Dmm. Per 5 Seconds
	Conc. %	Dipping Time Minutes		
			a. 5 min. dipping time:	
1a	0.5	5	Darkened upon thawing	None*
1b	0.75	5	Darkened upon thawing	176.8
1c	1.0	5	Darkened upon thawing	175.5
2a	1.0	5	Darkened upon thawing	106.2
			b. 10 min. dipping time:	
1d	0.5	10	Darkened upon thawing	None*
1e	0.75	10	Darkened upon thawing	171.3
1f	1.0	10	Darkened upon thawing	163.1
2a	1.0	10	Darkened upon thawing	104.2
			c. 15 min. dipping time:	
1g	0.5	15	Darkened upon thawing	None*
1h	0.75	15	Darkened upon thawing	121
1i	1.0	15	Darkened upon thawing	108
2c	1.0	15	Darkened upon thawing	90
			d. 20 min. dipping time:	
1j	0.5	20	Darkened upon thawing	None*
1k	0.75	20	Darkened upon thawing	106.9
1l	1.0	20	Darkened upon thawing	92.5
2d	1.0	20	Darkened upon thawing	81.9

* Too soft to test with penetrometer

Since pineapple juice was also found to be unsatisfactory as an anti-oxidant, it was decided that sodium sulfite should be used as the next variant. Filinger (1945) suggested that sodium sulfite at a concentration of 2 teaspoons per gallon of water would give satisfactory anti-oxidant protection for apple slices.

Data in Table 4 show that sodium sulfite gave better anti-oxidant protection when used with 2 per cent calcium chloride solution, but a condition of case-hardening developed, i.e., the slices were toughened on the surface but were still soft in the interior. This did not occur when a 1 per cent calcium chloride solution was used. These results substantiate those reported by Esselen, Hart, and Fellers (1946, 1947). They found that in addition to its firming action on apple slices, calcium chloride also helped in the prevention of oxidation.

Table 4

Effect of Sodium Sulfite and of Different Dipping Times in Various Concentrations of Calcium Chloride Solution on the Firmness of Apple Slices

Test	Calcium Chloride		Effect of Anti-oxidant on Uncooked, Thawed Apple Slices: Time at Which Discoloration Appeared	Penetrometer Readings: Dmm. Per 5 Seconds
	Conc. %	Dipping Time Minutes		
a	1	20	Core line upon thawing	117.5
b	1	30	Core line within 5 minutes	116.5
c	1	40	Core line within 30 minutes	109.3
d	1	50	Core line within 45 minutes	101.2
e	1	60	Core line within 1 hour	98.6
f	2	20	None, 1 1/2 hours	129.9 Some
g	2	30	None, 1 1/2 hours	112.2 Case-
h	2	40	None, 1 1/2 hours	103.2 harden-
i	2	50	None, 1 1/2 hours	98.8 ing at
j	2	60	None, 1 1/2 hours	90.1 2% level

Case-hardening did not occur when the 1 per cent calcium chloride solution was used, but did at the 2 per cent level. The higher concentration of the calcium chloride, in combination with sodium sulfite solution, gave better protection from oxidation. As a result of these findings, it was decided to try the effectiveness of 1.5 per cent calcium chloride solution as the firming agent.

At this level, discoloration occurred at the core line of the apple slices as shown in Table 5. Case-hardening also developed in these

slices, which made them less desirable for use in pies. The use of a solution of calcium chloride of more than 1 per cent concentration for less than 5 minutes contact time would hardly be practical because both firmness and retardation of oxidative changes must be controlled. To obtain a more satisfactory product, it would be necessary to use a lower concentration of calcium chloride as the firming agent.

Table 5

Effect of Sodium Sulfite and Different Dipping Times in 1.5 Per Cent Calcium Chloride Solution on the Oxidation and Firmness of Apple Slices

Test	Calcium Chloride		Effect of Anti-oxidant on Uncooked, Thawed Apple Slices: Time at Which Discoloration Appeared	Penetrometer Readings: Dmm. Per 5 Seconds
	Conc. %	Dipping Time Minutes		
a	1.5	5	Core line within 30 min.	102
b	1.5	10	Core line within 35 min.	80
c	1.5	15	Core line within 35 min.	70
d	1.5	20	Core line within 40 min.	69

Since the pre-freezing treatments thus far used, had not given entirely satisfactory products, it was decided to try sugar or syrup as the anti-oxidant in connection with calcium chloride. Powers and Esselen (1946) stated that sugar or syrup aided in the prevention of oxidation and recommended the addition of calcium chloride to fruit through the use of the syrup solution.

Data given in Table 6 shows that in these tests the addition of sugar aided in the prevention of oxidation. In each test, it was noted that the sugar drew considerable moisture from the apple slices. Other workers have reported similar results. This amount of liquid was in excess of that which could be used in the pie.

Table 6

Effect of Sodium Sulfite, Sugar, and Calcium Chloride on the
Oxidation and Firmness of Apple Slices

Test	Calcium Chloride		Ratio of Sugar to Fruit	Time at Which Oxidation Occurred When Uncooked, Thawed Apple Slices Were Exposed to Air 2 Hours	Penetro- meter Readings: Dmm. Per 5 Seconds
	Conc. %	Time Min.			
a	1	5	1:6	No discoloration	95
b	1	5	1:4	No discoloration	95
c	2	5	1:4	No discoloration	86.4
d	3	5	1:4	No discoloration	91

Because much time was consumed in dipping slices in the calcium chloride solution and sodium sulfite solution, respectively, it seemed desirable to try other means of applying the firming agent and the anti-oxidant to the fruit. As stated in the Procedure, two principal ways were considered. They were (1) combining the calcium chloride and sodium sulfite into one solution and (2) dipping the apple slices in the sodium sulfite solution and adding the dry calcium chloride to the drained fruit just before packaging it. Results of these two processes are shown in Tables 7 and 8, respectively.

According to data given in Table 7, the apple slices treated in the cold solution darkened more quickly after thawing than did those treated in the heated solutions. Apple slices from the heated solution were more acceptable both as to firmness and color than those from the cold solution. Penetrometer readings of 144.5 decimillimeters as compared with 158.1 decimillimeters indicate that heat may be a factor which facilitates the penetration of calcium into the fruit tissue. The sodium sulfite and calcium chloride reacted to form a white precipitate in both the cold and warmed solutions. Therefore, the apple slices did not receive full benefit of the action of the two salts. This formula expresses the chemical

reaction taking place: $\text{Na}_2\text{SO}_3 + \text{CaCl}_2 \longrightarrow \text{CaSO}_3 + 2 \text{NaCl}$

Table 7

Effect of Combined Sodium Sulfite and Calcium Chloride Solution on the Oxidation and Firmness of Apple Slices

Test	$\frac{1\% \text{ CaCl}_2 + 2 \text{ t. Na}_2\text{SO}_3 \text{ Per Gal. H}_2\text{O}}{^\circ\text{C.}}$	Time at Which Discoloration Occurred When Uncooked, Thawed Apple Slices Are Exposed to Air 2 Hours	Ave. Penetro-meter Readings: Dm. Per 5 Seconds
a	17.5	Darkened within 30 minutes	158.1
b	45	Darkened within 1 hour	144.5

The heated sodium sulfite solution (Test c), as well as the solution held at room temperature, (Test a) when used with dry calcium chloride, according to data in Table 8, gave comparable results on firmness and extended the protection time against oxidation beyond that afforded by the heated solution held for 5 minutes (Test b). Prolonged heating of the solution to maintain this temperature for treating successive batches of fruit and the reaction of the salts with the fruit would cause a diminution of the effectiveness of the salts. The length of contact time, as well as the concentration of sodium sulfite solution, affects the development of oxidative coloration. These slices were also less firm.

Table 8

Effect of Dipping Time and Temperature of Sodium Sulfite Solution and Addition of 0.35 Per Cent Dry Calcium Chloride on the Oxidation and Firmness of Apple Slices

Test	Sodium Sulfite $^\circ\text{C.}$ Dipping Time		Time at Which Oxidation Occurred in Uncooked, Thawed Apple Slices	Ave. Penetro-meter Readings: Dm. Per 5 Seconds
a	17.5	10 min.	Darkened in 2 hours	140.9
b	45	5 min.	Darkened in 1 hour	161.2
c	45	10 min.	Darkened in 2 hours	140.9

Since the sodium sulfite treatment, Table 8, did not provide satisfactory anti-oxidant protection, it was decided to try "modified scalding" as a supplementary treatment. As stated in the Procedure, the term "modified scalding" is so designated because at no time after adding the fruit did the temperature of the scalding solution reach boiling point. Powers and Esselen (1946) had recommended scalding as a means of inactivating the enzymes which cause discoloration in fruits.

Preliminary tests, not reported here in a table, showed that satisfactory anti-oxidant protection was afforded for apple slices scalded in the one per cent calcium chloride solution. No discoloration was apparent after 2 hours exposure of the thawed slices to the air. Penetrometer readings of 141.2 decimillimeters, on the baked apple slices from these tests indicated that the fruit was of acceptable firmness for use in pies. This reading compares favorably with those given in Table 9.

Data in Table 9 show that apple slices treated in the "modified scalding" medium followed by cooling the slices in sodium sulfite solution were adequately protected against oxidation when they were exposed to the air 2 hours after thawing. Baking tests showed that both concentrations of dry calcium chloride used produced apple slices with a satisfactory degree of firmness.

The penetrometer readings for these samples were somewhat at variance with those previously secured. The slices were less firm than in those in other tests, but were satisfactory for use. Factors of maturity and manner of incorporating the calcium may account, in part, for some of this difference. Similar results were obtained when ice water was used for cooling the water-scalded fruit, however, penetrometer readings showed them to be more firm. In Table 10, p. 22, are listed the variants which were chosen from the preliminary tests for further study.

Table 9

Effect of Scalding in Water, Cooling in Sodium Sulfite Solution or in Ice Water and Mixing with Dry Calcium Chloride on the Oxidation and Firmness of Apple Slices

Test	Scalding in Water Minutes	Cooling Solution Na_2SO_3 Ice H_2O Minutes	Time at Which Discolora- tion Occurred When Thawed, Raw Slices Were Exposed to Air 2 Hours	Ave. Penetro- meter Readings: Dmm. Per 5 Seconds
a	2	5	No discoloration	149.3
b	3	5	No discoloration	155.6
c	2	5	No discoloration	150.1
d	3	5	No discoloration	159.3
e	3		5 No discoloration	133.7
f	3		5 No discoloration	132.8

According to the results of these preliminary tests with Yellow Transparent apples, the most satisfactory methods of using calcium chloride as the firming agent seemed to be (1) scalding the apple slices in a 1 per cent calcium chloride solution, and (2) adding dry calcium chloride to the water-scalded drained fruit just before packaging.

The anti-oxidants which seemed to be most satisfactory for use in connection with the firming treatments were (1) scalding in water for 2 minutes, or (2) in 1 per cent calcium chloride solution for 2 minutes, followed by (1) cooling in sodium sulfite solution or (2) in ice water. Therefore, it is desired to investigate these procedures further. These data are reported under Main Experiments following the preliminary discussion on Pastry.

Pastry

Although the preliminary experiments on pastry were of secondary importance to the work with apples, they were necessary in order to obtain a uniform product.

According to data in Table 11, the dough mixed with the pastry blender had the lowest shortometer readings, i. e., was the tenderest. It also received the highest palatability score. Since the pastry blender has greater surface area available for use incorporating the fat with the flour, than either the foley or the table fork, fewer blender strokes were required for mixing pastry. This is in agreement with results reported by Lowe (1946). She found that the tenderness and flakiness of pastry was directly related to the number of strokes used in mixing it, i. e., the fewer the strokes the better.

Table 11

Effect of Methods of Mixing on Pastry Quality

Test	Mixing Method	Shortometer Readings Ounces	Palatability Score	Ave. Mixing Strokes For 198 gm. Pastry
a	Conventional, Pastry blender	13	21	64
b	Conventional, Foley fork	28	14	83
c	Conventional, Table fork	30	13	91

As a result of these tests, it was decided to use the pastry blender and as a few strokes as possible, and average of 60, for mixing pastry in the succeeding tests. After determining the method for mixing pastry, the next factor needing consideration was the temperature of and amount of water to be used in mixing the pastry.

Examination of Table 12 shows that mixing could be accomplished more easily and with less water as the temperature of the water was increased within the limits reported. Although the color and flavor on

palatability score for the pastry made with water heated to 55°C. was slightly higher than when the water of 60°C. was used, the latter gave a satisfactory product and was judged the most tender and flaky. It was decided to use the 60°C. water because it required slightly less water and fewer strokes to produce the pastry. The disadvantage of using this temperature of water was that it gave a rather soft dough which was somewhat difficult to roll. Because of this condition, tests were performed rolling the dough (1) immediately after mixing and (2) after being cooled to 30°C. Also, three different sizes of rolling pins were tested.

Table 12

Effect of Amount and Temperature of Water Used on Pastry Quality

Test	Water		Ave. Shortometer Readings Ounces	Ave. Palatability Scores	Ave. Mixing Strokes for 198 gm. Pastry
	Temp. °C.	Volume cc.			
a	17.5	38	15	17	63
b	45	38	13	19.5	60
c	50	38	13.4	19	60
d	55	37	13.5	21.5	58
e	60	36	12.5	20.5	55

From Table 13, it will be noted that in three out of four instances, both palatability scores and shortometer readings showed a slight preference for the pastry which was cooled to 30°C. before it was rolled. Also, in each of these three instances, the pastry which was chosen had been mixed with the smaller number of strokes.

Table 13

Effect of Time of Rolling after Mixing on Pastry Quality

Test	When Rolled	Dimensions of Rolling Pin		Ave. Shortometer Reading Ounces	Ave. Palatability Score	Ave. Mixing Strokes: 196 gm. Pastry
		Circumference Inches	Length Inches			
a	Immediately	6 1/8	10	14	20	84
b	Cooled to 30°C.	6 1/8	10	13.7	21.7	71
c	Immediately	7	10	15.1	22	79
d	Cooled to 30°C.	7	10	14.6	21	72
e	Immediately	7 1/2	9 3/4	14.8	23	73
f	Cooled to 30°C.	7 1/2	9 3/4	13.8	22	61
g	Immediately	8	11 3/4	15	23.5	75
h	Cooled to 30°C.	8	11 3/4	14.5	23	64

From a mechanical standpoint, the rolling pin with dimensions of 7 1/2 inches circumference and 9 3/4 inches long was preferred because of ease of handling during rolling. The shortometer and palatability scores for pastry rolled with this pin were acceptable as to range and the pastry was a satisfactory product.

The baking of the wafers included consideration of (1) temperature of the oven, (2) time, and (3) position of baking rack.

According to data given in Table 14, those wafers baked on the middle rack at 425°F. for 12 minutes received the highest palatability rating and had the best color. This score was approximately 20 per cent higher than for wafers baked at the corresponding temperature and time on the lower rack. The shortometer reading for these wafers showed that they were tender. It was found that when the shortometer reading fell much below this point, (16.3 ounces) the wafers were usually too brown in color, hence not acceptable.

Wafers baked on the lower rack of the ovens at 400°F. for each time period tested were less desirable because of the degree of browning. The palatability scores, as well as the shortometer readings,

substantiate this conclusion. A slight improvement in palatability scores and shortometer readings may be noted when the wafers were baked on the middle rack at 400°F. over those baked on the lower rack at the same temperature, but were not as desirable as those baked on the middle rack at 425°F.

Table 14

Effect on Quality of Pastry When Baked for Different Lengths of Time at Different Temperatures When Located on Middle and Lower Racks of the Oven

Test	Position in Oven	Temp. °C.	Time Min.	Ave. Shortometer Readings Ounces	Ave. Palatability Score	Ave. Mixing Strokes: 198 gm. Pastry
a	Lower Rack	400	12	27	8	64
b	Lower Rack	400	13	26	10	61
c	Lower Rack	400	14	25.5	12.5	58
d	Lower Rack	400	15	20	16	61
e	Middle Rack	400	12	15	18	57
f	Middle Rack	400	13	18	10	57
g	Middle Rack	400	14	23	19	60
h	Middle Rack	400	15	19	20	61
i	Lower Rack	425	12	21	16	58
j	Lower Rack	425	13	16	19.5	61
k	Lower Rack	425	14	22	14	59
l	Lower Rack	425	15	24	13	58
m	Middle Rack	425	12	16.3	21.3	59
n	Middle Rack	425	13	18.5	20	59
o	Middle Rack	425	14	17.3	16.5	64
p	Middle Rack	425	15	14	10	61

Based upon the results of these preliminary tests, the following recipe for pastry was formulated:

Proportion of Ingredients Used in Pastry

Ingredients	Weight in Grams	Approximate Measure
All purpose Flour	112.0	1 C.
Hydrogenated fat	50.0	4 T.
Salt	6.0	1 t.
Water	36.0	36 cc., or 2 1/2 T.

Method of Mixing

1. Sift the flour and salt together.
2. Cut the fat into the flour and salt to a consistency of a coarse meal, using a pastry blender, (approximately 27 strokes).
3. Add the water heated to 60°C. to form a stiff dough. Mix water in- to the fat and the flour mixture with the same implement used to cut the fat into the flour and salt, (approximately 33 strokes).
4. Cool the dough to 30°C.
5. Dust the board and rolling pin lightly with flour before rolling. Roll the dough to 3/32 inch thickness using rolling gauge strips as guides.
6. For wafers, cut 3 1/2" X 1/2" X 3/32" strips, prick, and place on a cookie sheet.
7. For pie, cut the dough in a circle with an 8 1/2 inch circumference and place in a paper pie pan.
8. Bake wafers in a pre-heated oven at 425°F. for 12 minutes, using the middle oven rack position.
9. For pie, see directions for pie filling under Procedure.

Main Experiments

As previously stated, Yellow Transparent apples possess the qualities of tartness and juiciness which are much desired in pies, but their poor keeping quality and their tendency to disintegrate when cooked limit their usefulness. If satisfactory pre-freezing methods can be developed for these apples, their importance to the farmer will be enhanced. This research is aimed at finding satisfactory procedures for the homemaker to use. The two main problems which present themselves in this connection are (1) how to satisfactorily firm apple slices, and (2) how to prevent their discoloration during freezing, storage, and thawing in order that they may be acceptable for use in making pies.

Preliminary work, herein reported, indicated that satisfactory pre-freezing treatments for these summer apples might be possible. Therefore, these tests are to determine whether or not these methods give desired results when Yellow Transparent apple slices are frozen and stored for longer periods of time. In the preliminary experiments, the apple slices were frozen and stored at 0°F. for a maximum of 72 hours. It seemed desirable to compare fruit frozen at 0°F. and -20°F., respectively, with storage at 0°F. A maximum of four months storage time was used. The variants selected for these experiments were (1) scalding the slices in water or in a 1 per cent calcium chloride solution, (2) cooling the slices in a sodium sulfite solution or in ice water, and (3) adding the dry calcium chloride to the water-scalded, drained apple slices before packaging. The variants are listed in Table 10 and details of the procedure follows the table.

Effort was made throughout these experiments to sort and grade the fruit according to size and maturity, thus minimizing in so far as possible the influence of maturity. Furthermore, samples for respective

tests were taken each time from a composite of apple slices.

Series 1

In this series, the variants were scalding the apple slices in a 1 per cent calcium chloride solution and then cooling them in (1) a sodium sulfite solution (2 teaspoons per gallon water) and in (2) ice water. In preliminary tests, the apple slices treated in this manner were satisfactorily firmed and no oxidative discoloration developed prior to use when the slices had been frozen and stored for brief periods of time. If this pre-freezing method proves satisfactory for Yellow Transparent apple slices kept for longer periods of time in frozen storage, an inexpensive and simple pre-freezing treatment would be available to the homemaker. Results obtained from these treatments with storage time of from three to four months are given in Table 15 with palatability scores in Table 16.

Penetrometer readings made on the apple slices after they were thawed and baked into pies showed that the apple slices cooled in sodium sulfite solution and frozen at -20°F . were firmer than those cooled in sodium sulfite solution and frozen at 0°F . More specifically, fruit from Test I R 1 was approximately 20 per cent firmer than I B 1, while slices from Test I R 2 were 7 per cent firmer than I B 2, and those from Tests I R 3 were 5 per cent firmer than I B 3. Penetrometer readings on the fruit which had been cooled in ice water for five minutes before freezing showed the reverse of the readings obtained from the fruit cooled in sodium sulfite solution for 5 minutes. That is, the fruit cooled in ice water and frozen at 0°F . (Test I B 4) was 5 per cent firmer than those slices frozen at -20°F . (Tests I R 4). The reaction of the apple slices cooled in the sodium sulfite solution gave the expected type of penetrometer readings. It is not understood why

Table 15

Comparison of the Effect on Yellow Transparent Apple Slices of Scalding in 1 Per Cent Calcium Chloride Solution for 2 Minutes and Cooling in Sodium Sulfite Solution for 1, 3, or 5 Minutes or in Ice Water for 5 Minutes

Test	Cooling		Penetrometer Readings: mm./ 5 Sec.*				Juice Drain- age cc.	Ave. pH Readings		
	Solution	Time Min.	Thawed Slices		Baked Slices			Juice	Thawed Slices	Baked Slices
			Range for 20 Readings	Ave. for 20 Read- ings	Range for 20 Readings	Ave. for 20 Read- ings				
"B" Frozen and Stored at 0° F.										
I B 1	Na ₂ SO ₃	1	48-58	53.6	164-170	167.5	93	3.65	3.82	3.83
I B 2	Na ₂ SO ₃	3	41-57	48.7	147-176	152.5	110.5	3.17	3.31	3.5
I B 3	Na ₂ SO ₃	5	49-60	55.0	140-150	146.6	137	3.31	3.46	3.56
I B 4	Ice H ₂ O	5	60-69	64.1	133-146	139.0	110	3.03	3.11	3.5
"R" Frozen at -20° F. and Stored at 0° F.										
I R 1	Na ₂ SO ₃	1	80-89	86.5	130-148	138.6	89.5	3.77	3.97	4.11
I R 2	Na ₂ SO ₃	3	38-57	48.1	139-145	141.8	118	3.47	3.5	3.75
I R 3	Na ₂ SO ₃	5	58-69	63.6	134-144	139.8	114.5	3.25	3.4	3.5
I R 4	Ice H ₂ O	5	57-65	60.7	150-170	156.3	111.0	3.44	3.5	3.7

*Penetrometer readings are based on readings taken on the best two out of three samples; the range represents the lowest and the highest readings from the two samples used as checks (20 readings). The average reported represents the average of these 20 readings. All penetrometer readings reported are treated the same.

those slices cooled in ice water and frozen at -20°F . were not firmer than those frozen at 0°F ., unless the slightly slower rate of freezing of the water cooled slices would allow longer time for the reaction between the calcium and the fruit to take place, thus forming calcium pectate, the firming substance in apples. While in the case of those slices cooled in sodium sulfite solution, some of the calcium ions might have been precipitated in the tissues as insoluble calcium sulfite instead of calcium pectate, during the additional reaction time which elapsed when freezing at 0°F . as apposed to -20°F . Although there was a lack of direct correlation in penetrometer readings, the apple slices in these tests were of a satisfactory texture for use in pies and were firm enough to hold their shape.

Data in Table 15 shows that the apple slices were approximately two or three times firmer before baking than afterward. Because of the influence of baking on the slices, this change in firmness would be expected and is necessary in order to have a palatable product.

The penetrometer readings on the thawed raw apple slices, from lots corresponding to those samples discussed under baked slices, do not show the same order of variation. In contrast to the readings on the baked fruit, data in Table 15 indicate that two out of three samples of the thawed raw apple slices cooled in sodium sulfite solution and frozen at 0°F . were firmer than the fruit frozen at -20°F . More specifically, the apple slices from Test 1 B 1 were 38 per cent firmer than Test 1 R 1, and fruit from Test 1 B 3 was 13 per cent firmer than Test 1 R 3. The thawed raw apple slices cooled in sodium sulfite solution for 3 minutes, showed little difference in penetrometer readings when frozen at either 0°F . or -20°F ., i. e., the slices from Test 1 R 2 tested slightly firmer than 1 B 2. Apple slices cooled in ice water for 5 minutes had slightly

lower penetrometer readings when frozen at -20°F. , than when frozen at 0°F. i. e., the thawed raw slices which had been cooled in ice water and frozen at -20°F. , (Test 1 R 4) were 5.1 per cent firmer than those frozen at 0°F. (Test 1 B 4). Penetrometer readings on the thawed raw slices, which had been dipped in sodium sulfite solution for 5 minutes before freezing and those dipped in ice water for 5 minutes and frozen at 0°F. or -20°F. , were the reverse of those readings from the corresponding baked slices. That is, the raw apple slices from Test 1 B 3 were firmer after thawing than those from Test 1 R 3, but upon baking, the slices from Test R 3 were firmer than those from Test 1 B 3. The raw fruit from Test 1 R 4 was firmer after thawing than that from Test B 4, but upon baking, the slices from Test 1 B 4 were firmer than those from Test 1 R 4. The exact reason for this reversal in firmness can not be attributed to any one factor.

The measure of juice drained from the fruit can not be correlated with the penetrometer readings of the thawed or baked fruit. The reason for the variations in juice drainage from the various samples is not known and needs further study.

Data in Table 15 indicated that in every instance the juice drained from the thawed apple slices is slightly more acidic than the slices, i. e., the juice gave a lower pH reading than did the slices. The baked slices were slightly less acidic than the thawed slices, i. e., they gave slightly higher pH readings. These differences in pH may be accounted for in that some of the sulfite and chloride ions could have been dissolved in the juices, thus making it more acidic than the slices. The influence of the sugar and cornstarch added to the apple slices before they were baked into pies may have contributed to the slight decrease in acidity of the slices. There was no positive correlation between the amount of juice

drained and the acidity of the juice.

Palatability scores were made on the apple slices after they were baked into pies. Results of these scores are given in Table 16.

Table 16

Palatability Scores on Baked Apple Slices from Series I*

Test	Flavor	Color	Texture	Sweetening	Desirability	
					Flavor	Texture
"B" Frozen and Stored at 0°F.						
IB 1	Sl. **Acid	Translucent	Sl. Firm	Mod. ***Sweet	Des. ****	Des.
IB 2	Sl. Acid	Translucent	Sl. Firm	Mod. Sweet	Des.	Des.
IB 3	Sl. Acid	Translucent	Mod. Firm	Mod. Sweet	Des.	Des.
IB 4	Very Acid	Pinkish W:****	Sl. Firm	Mod. Sweet	Mod. Des.	Des.
"R" Frozen at -20°F. and Stored at 0°F.						
IR 1	Mod. Acid	Translucent	Mod. Firm	Mod. Sweet	Des.	Des.
IR 2	Mod. Acid	Translucent	Sl. Firm	Mod. Sweet	Mod. Des.	Des.
IR 3	Mod. Acid	Yellowish W.	Mod. Firm	Mod. Sweet	Des.	Des.
IR 4	Mod. Acid	Pinkish W	Mod. Firm	Sl. Sweet	Mod. Des.	Des.

* The scores reported are the average of the scores given by three judges on duplicate samples for each test.

** Slightly
 *** Moderately
 **** Desirable
 ***** White

Palatability scores are not only influenced by the variations in the food product, itself but also by the preference and training of the judges. The ability of the judges to distinguish between slight variations in tastes and flavors, as well as their ability to translate into words these variations, influence the palatability scores.

The baked slices from the fruit which had been cooled in sodium sulfite solution and frozen at 0°F. were scored as being more palatable than those cooled in ice water and frozen at 0°F. Fruit frozen at -20°F. did not receive such uniform rating. However, of these samples frozen at -20°F. the samples which scored highest were those which had been cooled in sodium sulfite solution for 1 minute and 3 minutes, respectively. Part of this difference may have been due to variations in maturity of the

fruit, as well as to the differences in the taste and preferences of the individual judges. The samples which were cooled in water and frozen at 0°F. and -20°F. (1 B 4 and 1 R 4) showed oxidative changes which affected both the color and the flavor of the fruit. This discoloration was no doubt due to the fact that all oxidative enzymes had not been inhibited during the pre-freezing treatment. This seems to be further evidence that sodium sulfite offers definite protection against oxidative changes since the sodium sulfite cooled fruit did not show this discoloration.

Judging from the results reported in Table 15 and 16, the apple slices scalded in a 1 per cent calcium chloride solution for 2 minutes and cooled for 1 minute in sodium sulfite solution (2 teaspoons per gallon water) and frozen at -20°F. preserved the apple slices which had been held in frozen storage from three to four months more effectively for use in pies than did the other methods used in Series I.

Series II

The second variant which was tried as a pre-freezing treatment for Yellow Transparent apple slices consisted of scalding the fruit in water, and cooling them in (1) sodium sulfite solution or (2) in ice water and adding dry calcium chloride to the drained slices, Table 10.

Results obtained from these pre-freezing treatments after a storage time of from three to four months are given in Table 17, with palatability scores in Table 18.

Penetrometer readings from apple slices cooled in sodium sulfite solution and in ice water and frozen at 0°F. were firmer after being baked than were those slices frozen at -20°F. More specifically, the baked apple slices from Test II B 1 were 13.9 per cent firmer than II R 1, while those from Test II B 2 were 7.3 per cent firmer than II R 2, and slices from Test II B 3 were 12.1 per cent firmer than II R 3, and fruit

from Test II B 4 were 13.3 per cent firmer than II R 4. Since the apple slices in this series were scalded in water instead of the 1 per cent calcium chloride solution, the slightly slower rate of freezing at 0°F . as compared to -20°F . might allow some reaction between the dry calcium chloride and the fruit to take place, thus forming calcium pectate, the firming substance in apples. This may explain the reason for these results. Penetrometer readings on the thawed raw fruit which had been cooled in sodium sulfite solution or in ice water and frozen at 0°F . were firmer after freezing and thawing than was the corresponding samples of fruit frozen at -20°F . More specifically, the thawed raw apple slices from Test II B 1 were 14.8 per cent firmer than II R 1, slices from II B 2 were 1.4 per cent firmer than II R 2, slices from II B 3 were 2.4 per cent firmer than II R 3, and those from II B 4 were 15.5 per cent firmer than II R 4. These readings on the thawed raw fruit are in agreement with those secured on the baked slices. However, the thawed raw fruit was approximately two to three times firmer before baking than afterward, because of the cooking which is necessary in order to obtain a palatable product.

Data in Table 17 shows that irrespective of the pre-freezing treatments, the fruit frozen at 0°F . showed, sample for sample, greater juice drainage than did those frozen at -20°F . The greater amount of juice drained during thawing from the fruit frozen at 0°F . may be accounted for, at least in part, by the fact that the slightly higher freezing temperature allows the formation of larger ice crystals in the fruit, which, in turn would cause the rupturing of more cells, and thus result in a greater juice drainage.

In all samples, except two, (II B 1 and II B 4) the juice drained from the thawed slices was slightly more acidic than the thawed raw slices,

Table 17

Comparison of the Effect on Yellow Transparent Apple Slices of Scalding for 2 Minutes in Water and Cooling in Sodium Sulfite Solution for 1, 3, or 5 Minutes or in Ice Water with 0.33 Per Cent Dry Calcium Chloride Added

Test	Cooling		Penetrometer Readings: dmm./5 Sec.*				Juice Drainage cc.	Ave. pH Readings		
	Solution	Time Min.	Thawed Slices		Baked Slices			Juice	Thawed Slices	Baked Slices
			Range of 20 Readings	Ave. of 20 Readings	Range of 20 Readings	Ave. of 20 Readings				
"B" Frozen and Stored at 0°F.										
II B 1	Na ₂ SO ₃	1	43-60	53.6	130-144	136.8	113.0	3.55	3.44	3.71
II B 2	Na ₂ SO ₃	3	59-69	63.4	126-138	131.3	114.5	3.56	3.60	3.76
II B 3	Na ₂ SO ₃	5	48-59	53.0	133-145	141.1	123.5	3.66	3.80	3.83
II B 4	Ice H ₂ O	5	49-60	56.7	123-141	136.1	123.5	3.5	3.45	3.55
"R" Frozen at -20°F. and Stored at 0°F.										
II R 1	Na ₂ SO ₃	1	39-69	63.0	154-165	158.9	108.5	3.16	3.40	3.53
II R 2	Na ₂ SO ₃	3	60-69	64.3	110-155	141.8	111.5	3.7	3.71	3.68
II R 3	Na ₂ SO ₃	5	35-61	54.3	157-170	160.6	115.2	3.23	3.40	3.45
II R 4	Ice H ₂ O	5	61-83	67.1	150-185	157.0	114.5	3.13	3.30	3.5

* Penetrometer readings are based on readings taken on the best two out of three samples, the range presents the lowest and the highest readings from the two samples used as checks (20 readings). The average reported represents the average of these 20 readings. All penetrometer readings reported are treated the same.

i. e., the juice had a lower pH reading. In these two samples, the thawed slices were slightly more acidic than the juice. The baked slices were slightly less acidic than the thawed slices in all samples, i. e., they gave slightly higher pH readings. In keeping with the results in Series I, some of the sulfite and chloride ions could have been dissolved in the juice, thus making it more acidic than the slices. The influence of the sugar and cornstarch added to the apple slices before they were baked into pies may have contributed to the decrease of the acidity of the slices. There is no positive correlation between the amount of juice drained and the acidity of the juice.

Palatability scores were made on the apple slices after they were baked into pies. Results of these are given in Table 13.

Table 13

Palatability Scores on Baked Apple Slices from Series II*

Test	Flavor	Color	Texture	Sweetening	Desirability	
					Flavor	Texture
"B" Frozen and Stored at 0°F.						
II B 1	Mod.*Acid	Pinkish W.***	Sl.Firm	Mod.Sweet	Mod. Des.	Des.
II B 2	Mod. Acid	Pinkish W.	Mod.Firm	Mod.Sweet	Des.*****	Des.
II B 3	Sl.*Acid	Translucent	Mod.Firm	Very Sweet	Des.	Des.
II B 4	Mod. Acid	Pinkish W.	Mod.Firm	Mod.Sweet	Des.	Des.
"R" Frozen at -20°F. and Stored at 0°F.						
II R 1	Mod. Acid	Translucent	Mod.Firm	Mod.Sweet	Des.	Des.
II R 2	Mod. Acid	Translucent	Mod.Firm	Mod.Sweet	Des.	Des.
II R 3	Mod. Acid	Translucent	Mod.Firm	Mod.Sweet	Des.	Des.
II R 4	Very Acid	Pinkish W.	Mod.Firm	Sl. Sweet	Des.	Mod.Des.

* The scores reported are the average of the scores given by three judges on duplicate samples from each test.

** Moderately

*** White

**** Slightly

***** Desirable

From the palatability scores in Table 13, it will be noted that those apple slices which had been scalded in water, cooled in sodium sulfite solution, frozen at -20°F. and stored at 0°F. for from three to four

months (II R 1, II R 2, II R 3) received higher palatability scores than those cooled in ice water (II R 4). The water cooled (II R 4) fruit was more acid, was pinkish white instead of being translucent and was not as acceptable, according to palatability scores, as those cooled in sodium sulfite. Fruit frozen at 0°F . (the B group) did not receive such uniform palatability ratings. According to Table 17, the B group were slightly more desirable in texture as indicated by the penetrometer readings. Slight discoloration occurred at the core line in a few of the slices from samples cooled in sodium sulfite solution for 1 minute (Test II B 1) and 5 minutes (Test II B 2) and those cooled in ice water for 5 minutes (Test II B 4) upon thawing and before baking. This discoloration which made the fruit less desirable for use in pies, was no doubt due to the fact that all the oxidative enzymes were not inhibited before freezing the apple slices. The apple slices from Test II B 1 and II B 2 frozen at 0°F . discolored, while their corresponding tests (II R 1 and II R 2 group) frozen at -20°F . did not discolor.

According to results reported in Tables 17 and 18, the fruit frozen at 0°F . and cooled for 5 minutes in sodium sulfite (Test II B 3) seemed most desirable from both penetrometer tests and palatability scores. In case of the fruit frozen at -20°F ., the 5 minute cooling time in sodium sulfite solution did not give superior results over the 1 minute cooling time, especially in so far as palatability scores are concerned. These two samples (II R 1 and II R 3) gave approximately the same average penetrometer readings.

DISCUSSION

In these experiments, penetrometer readings on the thawed raw slices, which had been given the various pre-freezing treatments, were taken in order to see if they would give any indication as to the relative firmness of the baked slices, similarly treated. Data in Tables 15 and 17 show that the fruit which was firmer upon thawing was not necessarily the firmer after baking. For instance, of all those samples in Series I, which had been scalded in 1 per cent calcium chloride solution, in only one set of samples Tests I B 2 and I R 2, was the order of firmness of the raw and baked slices the same, i. e., those samples cooled in sodium sulfite for 3 minutes and frozen at -20°F . gave lower penetrometer readings (were firmer) than those cooled in sodium sulfite solution for 3 minutes and frozen at 0°F . It should be noted that there was no such regularity in the variations of the penetrometer readings on the raw and baked slices for the other pairs of samples given similar pre-freezing treatments and frozen at 0°F . or -20°F . While in those samples in Series II, which were scalded in water for 2 minutes, given different cooling treatments and to which 0.33 per cent dry calcium chloride was added after the slices were drained, a different picture was presented by the penetrometer readings. Here, all the samples frozen at 0°F . gave lower penetrometer readings than similar ones frozen at -20°F . This was true whether the tests were made on the raw or baked slices.

More work is needed on this particular phase. However, these tests seem to indicate that if the amount of calcium chloride per weight of apple slices is controlled, that penetrometer readings on the raw slices would give some indication as the relative firmness of the baked slices. The apple slices from all samples were approximately two to three times

firmer before baking than afterward. This is expected as heat softens cellulose during cooking.

When color, texture, appearance, and flavor of the baked apple slices, i. e., palatability scores, are taken into consideration, the pre-freezing treatments giving the more satisfactory products of those studied are: (1) scalding the slices in 1 per cent calcium chloride solution for 2 minutes, cooling them in sodium sulfite solution for 1 minute, and (2) scalding the slices in water for 2 minutes, cooling them in sodium sulfite solution for 5 minutes, drain, and add 0.33 per cent dry calcium chloride to the fruit. From the results obtained in this study, definite conclusions can not be drawn as to what is the most effective temperature for freezing apples.

In comparing data in Tables 15 and 16, and 17 and 18, there is little, if any, positive relationship to be found between the penetrometer readings on the baked samples and the palatability scores given by the judges.

An effort was made to see if there was any consistent relationship between the effect of the pre-freezing treatment upon the apple slices, the temperature at which they were frozen, and the amount of juice drainage during the process of thawing. It will be noted in Table 17 that those slices from II B group, those frozen at 0°F., had greater juice drainage, test for test, (i. e., I B 1 and II B 1, etc.) than those samples frozen at -20°F. However, for Series I (Table 15) this same order of variation does not hold. In fact, some of the samples frozen at -20°F. had greater juice drainage than some of the samples frozen at 0°F. The data seem to indicate that more consistent results, as to juice drainage, are obtained when the dry calcium chloride is added directly to the slices before freezing, than when the slices are scalded in a calcium

chloride solution.

The juice and apple slices from all samples were acidic. The pH of the juice from the samples ranged from 3.03-3.77, while the range for the thawed slices was 3.11-3.77, and the range from the baked slices was from 3.5-4.2.

This range of pH readings was within the limits secured by Hills, Meylan, and Heller (1937) on Yellow Transparent apples. In all samples, except two, II B 1 and II B 4, the juice distilled from the thawed apple slices was more acidic than the slices, i. e., the juice gave a lower pH reading. Sample for sample, the baked slices were slightly less acidic than the thawed slices, i. e., they gave slightly higher pH readings. The influence of the sugar and cornstarch added to the apple slices before they were baked into pies may have contributed to the decreased pH of the cooked slices. The data indicates that there is no consistent relationship between the length of time the samples were held in the cooling solution before freezing and their pH.

The reliability scores, as to flavor of the baked slices, given by the judges do not show direct correlation with the pH readings made on the juice, thawed and baked slices. Since the difference in pH readings is slight, it is difficult for most people to detect these small differences by taste tests.

A few of the apple slices from samples which had been sealed in water and then cooked in sodium sulfite solution for 1 and 5 minutes, respectively, (Tests II B 1 and II B 2) and frozen at 0°F., and those sealed in water or in 1 per cent sodium chloride solution and cooked in ice water (Tests I B 4, I R 4, (Table 15), II B 4, II R 4, (Table 17)) and frozen at both 0°F. and -20°F. showed discoloration at the core line upon removal from frozen storage. These results seem to indicate that

a longer cooling time in sodium sulfite or more thorough scalding in 1 per cent calcium chloride solution is necessary for complete inactivation of fruit enzymes which cause the discoloration.

From these data, it seems that a fairly satisfactory pre-freezing treatment for preserving Yellow Transparent apples, which may be held in frozen storage for three to four months, was found. However, there are still many problems in connection with these processes which need further study. Some suggested problems are (a) how to limit amount of juice drainage from the frozen Yellow Transparent apple slices upon thawing, (b) determine satisfactory ways for using all of the extra liquid drained from the frozen apple slices, since the fruit seems to retain enough juice for making the pie; (c) store as well as freeze, the slices at -20°F . to note the effect on liquid drainage from the apples, and (c) study the effect of freezing Yellow Transparent apple slices in unbaked pies.

CONCLUSIONS AND SUMMARY

Studies are reported on the effectiveness of calcium chloride as a firming agent used in connection with two different anti-oxidants for Yellow Transparent apple slices. The slices were stored for from three to four months, removed, and baked into pies. As a result of these pre-freezing treatments, the following conclusions were made.

1. Preliminary work showed that a solution consisting of 2 tablespoons iodized salt and 2 tablespoons distilled vinegar per gallon of water was the most effective holding solution to use in preventing oxidation of peeled and/or sliced apples prior to the pre-freezing treatment.
2. The pre-freezing treatments giving the more satisfactory products of those studied were: (1) scalding the apple slices for 2 minutes in a 1 per cent calcium chloride solution and cooling then in sodium sulfite solution (2 teaspoons per gallon water) for 1 minute, and (2) scalding the fruit in water for 2 minutes and cooling it in sodium sulfite solution for 5 minutes.
3. Results with these pre-freezing treatments seem to indicate that in order to prevent oxidative changes of Yellow Transparent apple slices during freezing and thawing a longer cooling time in sodium sulfite solution (5 minutes) or more thorough scalding in 1 per cent calcium chloride solution is necessary to completely inactivate the fruit enzymes for three to four months storage periods.
4. From the results obtained in this study, definite conclusions can not be drawn as to whether 0° or -20°F. is the more effective temperature for freezing Yellow Transparent apple slices.

5. The most desirable range in penetrometer readings for the baked Yellow Transparent apple slices was from 120-170 decimillimeters. The average readings for all samples studied fell within this range.
6. More consistent results as to juice drainage and firmness of the slices were obtained when the dry calcium chloride was added directly to the fruit than when the slices were scalded in the calcium chloride solution.
7. The juice drained from the thawed slices was more acidic in all samples except two, than were the thawed raw slices, i. e., the juice had a lower pH reading. The baked slices were slightly less acidic than the thawed slices in all samples, possibly due to the influence of the sugar and cornstarch added in making the pies.
8. The palatability scores given by the judges to the baked Yellow Transparent apple slices do not entirely agree with the objective tests. Variations in palatability scores are to be expected when subjective tests are used.
9. As a result of preliminary work with pastry, a modified form (water heated to 60°C.) of the conventional pastry method was used for making pie crust for use in these tests.

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