PRETREATMENT OF PREPARED APPLES SLICES FOR BAKERS' USE

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C L Bedford
Major professor

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PRETREATMENT OF PREPARED APPLE SLICES FOR BAKERS' USE

By

JOHN PARSONS VOGT

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INTRODUCTION

The object of this thesis is to find out what has been done in the past to prevent browning of apple slices, to evaluate the past treatments and to experiment and present new data.

PRETREATMENT OF PREPARED APPLE SLICES FOR BAKERS' USE

REVIEW OF LITERATURE

Many treatments have been proposed for the treating of apple slices to prevent darkening during storage, both cold and frozen. These include treatment with SO_2, sugars, salt, and other antioxidants.

SULFUR:

Sulfur treatment to date has been the standard of the industry; although an early government publication condemned its use as harmful to digestion and health. In 1906 H. W. Wiley (1) wrote: "The verdict which must be pronounced in this case is decidedly unfavorable to the use of this preservative in any quantity for any period of time, and shows the desirability of avoiding the addition of any form of sulfurous acid to products intended for human food".

Further studies (50) have not shown SO_2 in the quantities required to be harmful to health, however, and considerable work has been done using it. Thatcher (6) in 1915 found that browning was retarded when apples were sealed in an atmosphere of SO_2 under as nearly sterile conditions as possible. A year later V. Valvassori (7) successfully subjected peeled and halved apples to the action of SO_2 before steaming and drying them. In 1925 boiling SO_2 was used successfully

by NaVarre (13) to bleach browned slices.

Although flowers of sulfur was used effectively by Nichols and Christie (16) in 1930 to retard browning by subjecting a ton of fruit to the fumes from two to three pounds of burning sulfur, by far most of the experimental work has been done using compounds which release SO_2 when in a water solution. Cruess and Overholser (10) in 1923 reported the immersion of slices of apple tissue in a 5% Na_2SO_3 solution for five minutes to be effective. In 1932 Nichols and Cruess (18) showed that sulfured dried apples required only a few hundred parts of SO_2 per million to prevent browning, and in 1933 Joslyn and Mrak (20) showed that immersion for a few minutes in Na_2SO_3 solutions required only 3000-4000 ppm SO_2 to prevent browning. Joslyn and Marsh (22) also reported that ten minutes in 500 ppm SO_2 preserved the color of Gravenstein apples. In 1932 Murri, et al (23), believing that the retention of Vitamin C (usually destroyed by freezing) would prevent apple browning, reported that SO_2 effectively preserved Vitamin C in apples which were frozen and stored at 0°F. Very satisfactory results from the use of a two minute dip in a 2800-3000 ppm SO_2 solution, preferably as $K_2S_2O_5$, at 70°F were reported in 1945 by McArthur (47). H_2SO_3 and Na_2SO_3 treatments (48) gave partial to complete elimination of browning. If the apples are to be reprocessed later, 1500-2000 ppm SO_2

was claimed to be effective by Woodroof and Cecil (49). In 1946 Smith (54) showed that a dip of only a few seconds in Na_2SO_3 or SO_2 solutions was preferable to the several minute dips used by earlier experimenters. Further work on H_2SO_3 by Schrader and Thompson (57) in 1947 showed that an initially high H_2SO_3 content and low moisture content in the dehydrated apples were necessary to lengthen the storage life to practical limits under conditions of high temperature. In 1949 Western Regional Research Laboratories recommended (60) using 200-300 ppm SO_2 for vacuum treated, filled apple slices. Other solutions which have been used effectively are dilute (1-3%) metabisulfite and bisulfite solutions. Mrak (59) found that simply dipping apple slices in these solutions was more effective than sulfuring, and Western Regional Research Laboratories (44) in 1944 reported that dipping in $NaHSO_3$ was superior to solutions of sulfurous acid or sodium acid sulfite. Thiourea has also been used successfully. In 1935 Denny (25) found a 0.1% solution of thiourea prevented or retarded browning of cut surfaces during drying, and in 1943 he developed (42) a drying process using that solution. The apples do not brown when later soaked in water. Denny (43) also patented a process for the substantially complete inactivation of the browning system not only in apples but also in other freshly cut surfaces of plant tissue. An

aqueous solution of thioamide (0.1-0.2% strength) was used, although thiourea can by substituted. However the Food and Drug Administration in a recently announced policy does not approve its use because of possible injury to humans.

SUGAR:

Sugars have received considerable attention as preservatives, but their usefulness to the apple industry does not seem to compare to that of SO_2 in the prevention of browning. As long as the slices remain in the sugar solution, oxygen within the slices is used up in respiration and atmospheric oxygen is prevented from reaching the slice and initiating browning. It is to be noted that most of the sugar solutions described contain an antioxidant. Lodge (3) in 1911 found that dipping fruit in a boiling sugar solution containing a small amount of citric acid, prevented browning during drying. A 5% solution of sucrose was used to prevent darkening even after removal from the solution by Overholser and Cruess (10) in 1923. In 1925 Navarre (13) found that after treating his apples with SO_2, subjecting them to the action of a sugar syrup helped preserve the color. Experimenters were beginning to use partial vacuums in 1932 to gain a better permeation of the syrups. Todd(19) received a patent on this process in that year, and in 1935

Tierney (27) received a patent for a partial vacuum process in which the solution contained a major portion of sugar and citric acid and a minor proportion of salt. The International Sugar and Alcohol Company (28) also received a French patent to use dextrose or xylose as a preservative for foods containing much water, such as apples. The following year Wiegand (31) stated that fruits packed in syrup retained their quality better than without the syrup. In 1940 Greene (38) published that in spray freezing an invert sugar solution gave the most satisfactory performance in preventing browning and spotting. Tressler and DuBois (45) in 1944 found that a sugar syrup containing 0.2% l-ascorbic acid prevented the development of oxidized flavor and discoloration in apples. McArthur (47) in 1945 found that the addition of pure, dried sugar to apple sections gave little protection. In 1949 the Western Regional Research Laboratory (60) described a method of sugar impregnation of filled apple slices for the prevention of browning.

SODIUM CHLORIDE:

Salt has been used by man for many years more than most preservatives. It is common knowledge that a weak brine solution (1-5%) has been used by housewives and the apple baking industry for years to prevent browning. In 1923 Overholser and Cruess (10) found that apple

slices immersed in a 5% NaCl solution for three days did not brown even after removal from the solution. By allowing peeled and cut fruit to stand under a 2% NaCl solution before canning, Kohman, Eddy, and Carlson (12) in 1924 and again in 1937 (33) showed that the effect of subsequent heat on the Vitamin C in the fruit was almost negligible. The addition of 2% NaCl to a SO_2 solution was found by Joslyn and Mrak (20) in 1933 to aid in the prevention of browning. In 1935 Johnson and Wallström (29) received a British patent for treating food products prior to storage with a vacuum, allowing NaCl to be forced into the materials by pressure. McArthur (4) in 1945 stated that if the sectioned apples are not used immediately, they should be held in a 1.0-1.5% brine to prevent browning. In 1948 Noyes (58) specified that they should be put in a 3-5% NaCl solution immediately upon cutting and then subjected to a vacuum treatment to get permeation of the brine solution. Cruess (59) in 1948 recommended the same 3-5% NaCl solution to shorten the period of sulfuring.

PRESERVATIVE COATING:

The function of a preservative coating is to hold the antioxidant directly upon the slice. As long as the antioxidant is effective, the coating will prevent browning. A patent doing this was issued to the I.G. Farben Industries (British patent, 1927) for coating the fruit with a compound formed from a condensation

product of urea and formaldehyde to which various preservatives might be added. Two French patents have also been granted. The Stabavite Syndicate, Limited, (15) patent in 1928 was for the covering of food with a gum to which antiseptics or preservatives such as SO_2 had been added. The other patent was issued to N.V.Industrieele (35) in 1938 for foods and other mixtures coated with a nonhygroscopic substance to which ascorbic acid was added.

VACUUM:

Treatment under reduced pressure has been gaining in popularity in recent years. Its beneficial effects were first observed by Kohman (9) in 1923 while studying the stability of Vitamin C towards heat. He found that insufficient account had been taken of the role of oxygen in its destruction, and that when solid foods were subjected to a high vacuum and the vacuum then released with nitrogen, oxygen could be removed without heat, thus preventing browning. In 1926 a German patent was granted to Hessel (13a) for a fruit drying process in which the comminuting was done under reduced pressure. Other patents using a vacuum process to draw a solution into apple slices have been issued for the following solutions: The United States granted a patent to Tierney (27) in 1935 for a solution containing a major portion of sugar and citric acid and a minor

proportion of salt. Johansson and Wallström (29) received a British patent in 1935 using a NaCl solution. Webb (40) in 1942 was issued a patent by the United States for a pore filling for dried apples of such edible material as fat or milk solids. In 1948 Noyes (58) received a patent for a 3-5% NaCl solution and special vacuum process for freezing apples. Vacuum pack storage of dehydrated apples was also recommended by Schrader and Thompson (57) in 1947. As mentioned before, the Western Regional Research Laboratory (60) in 1949 was using a vacuum process on apple slices prepared for freezing in which the solution used contained 40% sucrose and 200-300 ppm SO_2 or 0.2-0.3% ascorbic acid.

CALCIUM:

Kertesz (34) reported in 1938 that calcium added to certain plant tissues unites with the pectic acid present, giving a firmer tissue. This treatment of sliced apples before freezing not only caused a better preservation of the natural structure, but, he believed, also prevented the browning upon defrosting. That the calcium salts cause the firming of the apple slices through the formation of calcium pectates or pectinates was also shown by Baker (55) in 1947. That same year, Esselen, Hart, and Fellers (56) used a solution containing 0.05-0.1% calcium chloride in an investigation of

forty-eight varieties of apples prior to freezing or storage, finding that it maintained a desirable firmness.

ASCORBIC ACID:

In the belief that the presence of ascorbic acid in apples prevented their browning, several investigators have tried various techniques of retaining the Vitamin C. As early as 1923 Kohman (9) used a partial vacuum process and an atmosphere of nitrogen effectively before heating the apples. Immersion in a 2% NaCl solution was used successfully by Kohman, Eddy, and Carlson (12) in 1924 before they heat sterilized the apples. Several investigators have found SO_2 helps retain the Vitamin C. These include Murri, et al (23) who in 1924 found SO_2, and to a lesser degree sodium benzoate, effective in retaining Vitamin C in frozen apples. In 1930 Nichols and Christie (15) also reported SO_2 effective in the retention of ascorbic acid. Much of this work followed directly from the observations on 1920 of Johnson and Zilva (32) who stated that no enzyme capable of oxidizing l-ascorbic directly is present in apples.

Some men have tried the use of additions of ascorbic acid to prevent browning. A French patent issued in 1928 to N.V.Industrieele (35) covered the preservation of foods and other mixtures by adding

ascorbic acid together with a nonhygroscopic substance. In 1922 Tressler and DuBois (45) published that a syrup containing 02% l-ascorbic acid prevented the development of an oxidized flavor and the discoloration of apples during 0°F storage. McArthur (47) in 1945, however, reported that the addition of 0.098% ascorbic acid on the weight of the apples gave only slightly better results than dry sugar alone. McArthur further believed that ascorbic acid preservation would not be popularly used in industry because of its relatively high cost (1.82¢ per pound of apples in 1945).

CITRIC ACID:

While citric acid is frequently used by housewives to prevent the browning of apples and other fruits, investigators have reported mainly on its use in solution combined with other antioxidants. Lodge (3) in 1911 received a patent for the preservation of fruit, i.e. apples, by immersing them in a boiling solution of sugar in water to which a small amount of citric acid was added. Another patent was issued to Tierney in 1935 (27) in which he immersed apple pieces in a solution containing sugar, citric acid, and some salt in a partial vacuum process for frozen apples.

LACTIC ACID:

Lactic acid has been found to be cheaper and more effective than citric acid in decreasing browning by Schoonens (37) in 1940.

HYDROGEN, NITROGEN, OXYGEN, AND CARBON DIOXIDE:

Atmospheres of various gases have been used to prevent apple browning. Thatcher (6) in 1915 tried sealing the apples under as nearly sterile conditions as possible in air, hydrogen, nitrogen, oxygen, carbon dioxide, and sulfur dioxide. Only the latter two seemed to retard ripening. Later work by Overholser and Cruess (10) in 1923 showed that apples could be stored for one month in nitrogen without changing in appearance even after removal of the gas, but that browning developed rapidly in the presence of hydrogen, oxygen, and carbon dioxide. That same year, Kohman (9) successfully used nitrogen in a partial vacuum process. In 1936 Elwell (30) received a patent in which apple slices are immersed in aqueous carbon dioxide solution.

GENERAL DISCUSSION OF THE MECHANISM OF BROWNING IN APPLES

Basset and Thompson (2) in 1910 suggested that there is generally present in apples an oxidizing enzyme capable of producing a tannin-like substance having the power to precipitate protein nitrogen. This enzyme is active only in slightly acid solutions, and when the concentration is above a certain minimum. This tannin-like substance, or substances, does not exist in the normal fruit on the tree but is rapidly formed on injury or removal of the fruit from the tree. Its function is to inhibit fungus and bacterial growth on injury of the fruit, in part, probably, by the conversion of the protein into an insoluble form and, in part, by the germicidal action of the substance itself. In 1915 Woker (4) reported that catalase and peroxidase undergo similar changes when submitted to increasing temperatures. At first a new substance which has no peroxidizing effect in the presence of hydrogen peroxide is produced; but, if the temperature is further increased, another new substance is formed which caused both changes to take place. This enzyme, which is stable to heat, is different from the enzymes from which it was formed, and it is the presence of this which enables one to speak of the reactivation of a dead ferment by means of heat. These changes were

further clarified in 1920 when Onslow (8) published that three components are present in the oxidase systems: A "catechol" compound, which may give rise to a peroxide, and two enzymes: an oxygenase, which helps the formation of the peroxide, and the peroxidase, which decomposes the peroxide forming "active" oxygen. The peroxidase may be partially separated from the oxygenase by fractional precipitation with alcohol. Such substances as organic acids, tannins, etc. may interfere with the reactions. In 1923 Overholser and Cruess (10) reported that on the basis of experiments with Yellow Newton apples, the oxidising system concerned in the browning of apple tissue is considered as consisting of a peroxidase and an organic peroxide. The chromogen is a tannin which has been shown by qualitative tests to belong to the catechol group and to be distributed evenly throughout the fruit with a slightly greater concentration in the epidermis. Color reactions indicating a peroxidase were given by fresh apple tissue and juice in the presence of suitable indicators of which benzidine (1% aqueous solution) was found to be the best. With boiled tissue, benzidine showed no evidence of reaction even after 72 hours. Since these reactions occurred without the addition of hydrogen peroxide, the presence of an organic peroxide is suggested; furthermore positive tests for peroxides were obtained with potassium chromate in the juice and

with starch iodide in the tissue. Treatment of the apple juice with two volumes of 95% ethyl alcohol precipitated the peroxidase and organic peroxide, leaving the tannin in the solution. The filtrate, containing the tannin freed from alcohol, darkened only on the addition of an aqueous solution of the enzyme precipitate, indicating that the tannin and organic peroxide are separate entities. Boiled juice did not darken in the presence of various oxidizing agents until the acidity was reduced to nearly the neutral point and manganese dioxide or platinizing solution and hydrogen peroxide were added. That the organic peroxide is much more sensitive to heat than the peroxidase is demonstrated by the inactivation of the former on heating at 73.5 to 78°C; while the latter was rendered inactive only at 90 to 100°C. Reformation of the peroxide did not occur in heated tissue or juice within 48 hours. Apples stored in nitrogen for one month remained unaltered in appearance and continued so after removal from the gas, giving positive reactions for peroxidase and organic peroxide. In the presence of carbon dioxide, hydrogen, or oxygen, and the vapors of carbon disulfide, formaldehyde, carbon-tetrachloride, ether, gasoline, or ethyl alcohol, browning developed rapidly and tests for organic peroxide were negative. The effect of these substances is apparently due to increases in the permeability of the

cells, permitting the oxidation reaction to take place. Immersion of slices of apple tissue in 5% solutions of sodium chloride, hydrochloric acid, sodium sulfite, or sucrose for three days prevented darkening, even after removal. With tap water and 5% solutions of sodium nitrite, sodium nitrate, or sodium carbonate, darkening occurred. With hydrochloric acid and sodium sulfite, five minute immersion was as effective as three days; but under the same conditions, sodium chloride, sucrose, and sodium nitrate reduced but did not prevent browning. The action of hydrochloric acid and sodium sulfite appears to be due to the destruction of organic peroxide in a manner comparable to the action of free sulfur dioxide in practise;while destroying neither the organic peroxide nor the peroxidase, sodium chloride appears to inhibit their activity. With sodium nitrite and sodium carbonate, the tissue became alkaline in reaction, a condition favoring rapid darkening of the tannin. Laboratory experiments indicated that three to five percent sodium chloride gives a satisfactory dried apple product, although slightly darker in color than when treated with sulfur dioxide; but fruit thus treated required much shorter exposure to sulfur dioxide. Nitrates of 0.01 and 0.1 normal concentrations increased the rate of browning; this was probably due to their oxidizing action.

Drain (11) in 1923 found that the oxidase activity is rather closely localized in the fruit of many apple varieties. Here the cut surfaces of many varieties were treated with reagents, including violamin, guiacum gum, and benzidine. Of the three reagents tried, the last named proved most satisfactory in point of cost, ease of handling, and in furnishing satisfactory photographic material. Tests made at various seasons (during the time of fruit development, at harvest, and late in the storage season) enabled Drain to divide varieties into three groups according to the location of oxidase activity. The majority of the varieties fell in that class where the greatest activity was noted in the vicinity of the core and core line.

The effect of allowing, previous to canning, the peeled and cut fruit to stand under 2% sodium chloride was studied by Kohman, Eddy, and Carlson (12) in 1924. During this period, the oxygen in the fruit is used up by respiration. It was found that after the preliminary treatment the effect of the sterilizing heat on Vitamin C was almost negligible.

In 1933 Joslyn and Marsh (21) gave a preliminary report of data tending to show that peroxidase activity is not responsible for all of the undesirable changes in certain materials preserved by freezing.

In some cases blanching at a lower temperature than will inactivate the peroxidase is sufficient to preserve satisfactory flavor and color.

The work of Johnson and Zilva (32) in 1937 showed that in the presence of l-ascorbic acid and catechol, the oxidation of catechol does not start until all the l-ascorbic acid has been oxidized. No enzyme capable of oxidizing l-ascorbic acid directly is present in the apple. The phenolase present in this plant can oxidize l-ascorbic acid, however, when the juice or catechol is present.

The importance of this enzyme action has gained increasing recognition; Balls (41) in 1941 defined food preservation as a matter of stopping enzyme action, whether the enzymes come from microorganisms or are inherent in the food itself.

In 1944 Ponting (46) published that pretreatment to decrease the activity of oxidizing enzymes controls darkening of the fruit before freezing, during frozen storage, and after defrosting. The extent of inactivation can be detected by spreading on an approximately 1% aqueous solution of pyrocatechol on the cut surface of the fruit. After a few minutes, the portion of the fruit still containing active enzymes will turn black. The test is negative if no dark color appears in twenty minutes.

Contrary to Johnson, et al (32), Hackney's (52) experiments in 1946 on the respiration of slices of apples indicated that in Granny Smith apples, ascorbic acid might be directly oxidized by an enzyme. The presence of this enzyme was confirmed by cutting Granny Smith apples into small pieces, freezing them, and expressing the juice by squeezing the tissue through muslin. The filtered juice oxidized ascorbic acid but showed no phenolase activity. Juice boiled for a few seconds showed very little activity towards ascorbic acid.

PRETREATMENT OF PREPARED APPLE SLICES FOR BAKER'S USE

In processing for canning, freezing, or drying, apple slices are commonly immersed in various aqueous solutions aimed at enzyme inactivation for the retarding or prevention of browning of the slices for a reasonable length of time, or until these slices can be used in various baked goods.

VARIETIES USED IN THIS EXPERIMENT

McIntosh, Northern Spy, Grimes Golden, and Delicious apple varieties were used in this experiment.

SOLUTIONS USED:

Ascorbic acid, sodium chloride, and combinations of these solutions were used at atmospheric pressure and at reduced pressure. All four apple varieties were treated in the following mixed solutions at atmospheric and reduced pressure:

0.1% ascorbic acid and 2% sodium chloride

0.2% ascorbic acid and 2% sodium chloride

0.1% ascorbic acid and 4% sodium chloride

0.2% ascorbic acid and 4% sodium chloride

In the second series of treatments, five lots (I, II, III, IV, V) of Delicious apples were dipped in SO_2 solutions of the following concentrations: 274 ppm, 445 ppm, 664 ppm, 817 ppm, and 1252 ppm.

McIntosh apples were treated with the following solutions at reduced pressures:

LOT VI: 2% sodium chloride

LOT VII: 296 ppm SO_2

LOT VIII: 2% sodium chloride and 254 ppm SO_2

LOT IX: 2% sodium chloride, 1% calcium lactate, and 290 ppm SO_2

LOT X: 1% calcium lactate and 265 ppm SO_2

LOT XI: 2% sodium chloride and 1% calcium lactate

LOT XII: 2% sodium chloride and 570 ppm SO_2

LOT XIII: 2% sodium chloride, 549 ppm SO_2, and 1% calcium lactate

LOT XIV: 1% calcium lactate and 528 ppm SO_2

LOT XV: 40% sucrose, 275 ppm SO_2, and 1% calcium lactate

LOT XVI: 40% sucrose, 549 ppm SO_2, and 1% calcium lactate

PREPARATION OF SOLUTIONS:

The solutions were prepared for equal weight of apples, i.e.: six pounds of apples to six pounds of solution. Distilled water was used in all solutions.

The solutions containing SO_2 were prepared from sodium bisulfite (anhydrous). These solutions were roughly prepared on the assumption of 48% available SO_2 in sodium bisulfite. They were then analyzed by the Ponting-Johnson titration method(51) for accurate determination of SO_2 content of the solutions before and after soaking. The apple slices were similarly analyzed.

The calcium lactate and sucrose syrups were made up on the percentage by weight basis.

PROCEEDURE:

The solutions for each sample or lot were prepared immediately before use. The apples were washed, peeled, and sliced in twelve slices parallel to the longitudinal axis of the apple. These slices were dropped directly into the solution and allowed to soak for one hour. It required about ten minutes to peel and slice each batch. These slices were then removed, drained, and one pound each held at room temperature (70°F) and at 32°F. Four pounds were frozen at 0°F.

The vacuum treatments were standardized at a reduced pressure of 26 inches of mercury for twenty minutes and, following removal of the air from the slices, thirty minutes in solution. The system used required ten minutes of pressure come-down time; so that the apple slices were in solution for one hour.

THE RESULTS OF THE SOAKING TREATMENTS AT ATMOSPHERIC PRESSURE, USING ASCORBIC ACID AND SODIUM CHLORIDE

McIntosh Variety

The untreated McIntosh apple slices browned in 12 minutes. They responded to the soaking treatments at atmospheric pressure as follows (summarized in Table I):

At room temperature, after soaking one hour in the solution and draining: the 2% NaCl with 0.1 and 0.2% ascorbic acid held for 48 hours before browning; at around 18 hours the surface had become yellow and slightly dry. The interior of the slice was white and firm. The slices at room temperature in the 4% NaCl, and 0.1% ascorbic acid held for only 22 hours before browning, while those in 0.2% ascorbic acid were brown at 48 hours. The slices in the 4% NaCl were very salty to the taste.

The slices held at 32°F after draining from one hour in the solution, gave the following results: The 2% NaCl and 0.1% ascorbic acid gave the longest time in this group before browning, 240 hours. The 2% NaCl and 0.2% ascorbic acid treated slices browned at 168 hours. The 4% NaCl and 0.1% ascorbic acid treated slices were brown at 96 hours, while those with 4% NaCl and 0.2% ascorbic acid held for 120 hours.

Including the thawing time as part of the browning

time, the McIntosh slices which were frozen and held at 0°F until used, responded to treatment as follows:

All slices were thawed under refrigeration, requiring 18 to 24 hours to thaw in all cases. Two observations were made on the slices; the first observation was on slices stored for one month at 0°F, and the second observation was made after other slices had been stored for six months.

The slices stored one month at 0°F, thawed, and placed at room temperature (70°F), showed:

2% NaCl and 0.1% ascorbic acid browned after 42 hours;
2% NaCl and 0.2% ascorbic acid browned after 28 hours;
4% NaCl and 0.1% ascorbic acid browned after 46 hours;
4% NaCl and 0.2% ascorbic acid browned after 56 hours.

The slices stored six months at 0°F, thawed, and observed at room temperature, showed:

2% NaCl and 0.1% ascorbic acid browned after 78 hours;
2% NaCl and 0.2% ascorbic acid browned after 44 hours;
4% NaCl and 0.1% ascorbic acid browned after 54 hours;
4% NaCl and 0.2% ascorbic acid browned after 90 hours.

Another group of McIntosh apple slices stored for one month at 0°F, thawed, and observed at 32°F, showed:

2% NaCl and 0.1% ascorbic acid browned after 42 hours;
2% NaCl and 0.2% ascorbic acid browned after 32 hours;
4% NaCl and 0.1% ascorbic acid browned after 50 hours;
4% NaCl and 0.2% ascorbic acid browned after 60 hours.

The slices which were stored for six months at 0°F, thawed, and observed at 32°F, showed:
2% NaCl and 0.1% ascorbic acid browned after 258 hours;
2% NaCl and 0.2% ascorbic acid browned after 330 hours;
4% NaCl and 0.1% ascorbic acid browned after 306 hours;
4% NaCl and 0.2% ascorbic acid browned after 462 hours.

Northern Spy Variety

The normal browning time for the fresh, untreated slices of Northern Spy apples was ten minutes. This time was extended by soaking slices at atmospheric pressure for one hour in various solutions containing sodium chloride and ascorbic acid, as follows (summarized in Table I):

Of the slices which were drained and observed at room temperature (70°F), the 2% NaCl and 0.1% ascorbic acid had a browning time of 5 hours; the 2% NaCl and 0.2% ascorbic acid browned after 17 hours; the 4% NaCl and 0.1% ascorbic acid had a browning time of 18 hours; and the 4% NaCl and 0.2% ascorbic acid had a browning time of 40 hours.

Drained and observed at 32°F, the slices treated with 2% NaCl and 0.1% ascorbic acid browned in 24 hours, while the slices treated with 2% NaCl and 0.2% ascorbic acid didn't brown for 198 hours. The slices treated with 4% NaCl and 0.1% ascorbic acid held for 168 hours before browning, and the slices given 4% NaCl and 0.2% ascorbic acid lasted for 192 hours.

The Northern Spy apple slices which were frozen and stored at 0°F for one month, thawed, and placed at room temperature (70°F), showed:

2% NaCl and 0.1% ascorbic acid browned after 28 hours;
2% NaCl and 0.2% ascorbic acid browned after 32 hours;
4% NaCl and 0.1% ascorbic acid browned after 42 hours;
4% NaCl and 0.2% ascorbic acid browned after 32 hours.

Slices frozen and stored at 0°F for six months, thawed, and placed at room temperature, showed:

2% NaCl and 0.1% ascorbic acid browned after 27 hours;
2% NaCl and 0.2% ascorbic acid browned after 27 hours;
4% NaCl and 0.1% ascorbic acid browned after 78 hours;
4% NaCl and 0.2% ascorbic acid browned after 66 hours.

The slices which were frozen and stored at 0°F for one month, thawed, and observed at 32°F, showed:

2% NaCl and 0.1% ascorbic acid browned after 28 hours;
2% NaCl and 0.2% ascorbic acid browned after 25 hours;
4% NaCl and 0.1% ascorbic acid browned after 122 hours;
4% NaCl and 0.2% ascorbic acid browned after 38 hours.

The frozen slices which were stored for six months, thawed, and observed at 32°F, showed:

2% NaCl and 0.1% ascorbic acid browned after 33 hours;
2% NaCl and 0.2% ascorbic acid browned after 44 hours;
4% NaCl and 0.1% ascorbic acid browned after 78 hours;
4% NaCl and 0.2% ascorbic acid browned after 162 hours.

Grimes Golden Variety

The untreated slices of Grimes Golden apples browned in 12 minutes.

The slices soaked for one hour and drained, the soaking being done at atmospheric pressure, gave these results at room temperature (70°F) (summarized in Table I):

2% NaCl and 0.1% ascorbic acid browned after 48 hours;
2% NaCl and 0.2% ascorbic acid browned after 48 hours;
4% NaCl and 0.1% ascorbic acid browned after 120 hours;
4% NaCl and 0.2% ascorbic acid browned after 72 hours.

The slices of apples placed at 32°F after draining, showed:

2% NaCl and 0.1% ascorbic acid held for 264 hours;
2% NaCl and 0.2% ascorbic acid browned after 336 hours;
4% NaCl and 0.1% ascorbic acid browned after 288 hours;
4% NaCl and 0.2% ascorbic acid browned after 288 hours.

The apple slices which were frozen and stored for one month at 0°F, thawed, and observed at room temperature, showed:

2% NaCl and 0.1% ascorbic acid browned after 28 hours; 2% NaCl and 0.2% ascorbic acid browned after 46 hours; and the 4% NaCl solutions with 0.1% and 0.2% ascorbic acid, molded in 158 hours.

The slices which were stored for six months at 0°F, thawed, and observed at room temperature, showed:

2% NaCl and 0.1% ascorbic acid browned after 54 hours;
2% NaCl and 0.2% ascorbic acid browned after 78 hours;
4% NaCl and 0.1% ascorbic acid browned after 90 hours;
4% NaCl and 0.2% ascorbic acid browned after 78 hours;

The slices frozen and stored at 0°F for one month, thawed, and placed at 32°F for observation, showed:
2% NaCl and 0.1% ascorbic acid browned after 46 hours;
2% NaCl and 0.2% ascorbic acid molded in 288 hours;
Both 4% NaCl solutions with 0.1% and 0.2% ascorbic acid were moldy after 288 hours.

The Grimes Golden slices frozen and stored at 0°F for six months, thawed, and observed at 32°F, gave the following results:
2% NaCl and 0.1% ascorbic acid browned after 78 hours;
2% NaCl and 0.2% ascorbic acid molded in 378 hours;
4% NaCl and 0.1% ascorbic acid molded in 426 hours;
4% NaCl and 0.2% ascorbic acid molded in 462 hours.

Delicious Variety

The Delicious apples had a fresh slice browning time of approximately 10 minutes.

The slices, after being treated at atmospheric pressure in the soaking solutions, responded as follows: The slices placed at room temperature (70°F) following soaking for one hour and draining, showed: (Summarized in Table I).
2% NaCl and 0.1% ascorbic acid browned after 90 hours;

2% NaCl and 0.2% ascorbic acid and the 4% NaCl with 0.1% and 0.2% ascorbic acid all molded in 84 hours.

The slices which were placed at 32°F immediately after draining all molded. The 2% NaCl and 0.1% ascorbic acid molded in 336 hours; while the rest of the samples, 2% NaCl with 0.2% ascorbic acid and 4% NaCl with 0.1% and 0.2% ascorbic acid, all molded in 288 hours.

The slices which were frozen and stored at 0°F for one month, thawed, and observed at room temperature, showed:

2% NaCl with 0.1% and 0.2% ascorbic acid browned after 22 Hours; while the 4% NaCl and 0.1% ascorbic acid slices browned after 25 hours, and the 4% NaCl and 0.2% ascorbic acid browned in 32 hours.

The slices observed at room temperature (70°F) after six months storage at 0°F, showed:

2% NaCl with 0.1% and 0.2% ascorbic acid browned after 27 hours; while the 4% NaCl with 0.1% and 0.2% ascorbic acid browned after 33 hours.

The slices of Delicious apples observed at 32°F after one month's atorage at 0°F, showed:

2% NaCl and 0.1% ascorbic acid browned in 25 hours;
2% NaCl and 0.2% ascorbic acid browned after 25 hours;
4% NaCl and 0.1% ascorbic acid browned after 28 hours;
4% NaCl and 0.2% ascorbic acid browned after 38 hours.

The slices of Delicious apples observed at 32°F after six month's storage at 0°F, showed:

2% NaCl and 0.1% ascorbic acid browned after 25 hours;

2% NaCl and 0.2% ascorbic acid browned after 44 hours;

4% NaCl and 0.1% ascorbic acid browned after 54 hours;

4% NaCl and 0.2% ascorbic acid browned after 54 hours.

TABLE I

Browning Time of Apple Slices after Soaking Treatment at Atmospheric Pressure, Using Sodium Chloride and Ascorbic Acid Solutions

Storage Temp. °F	Time months	Obs. Temp. °F	2% NaCl 0.1% Ascorbic Acid hrs.	2% NaCl 0.2% Acid hrs.	4% NaCl 0.1% Ascorbic hrs.	4% NaCl 0.2% Acid hrs.
			McIntosh Variety			
		70	48	48	22	48
		32	240	168	96	120
0	1	70	42	28	46	56
0	6	70	78	44	54	90
0	1	32	42	32	50	60
0	6	32	258	330	306	462
			Northern Spy Variety			
		70	5	17	18	40
		32	24	198	168	192
0	1	70	28	32	42	32
0	6	70	27	27	78	66
0	1	32	28	25	122	38
0	6	32	33	44	78	162
			Grimes Golden Variety			
		70	48	48	120	72
		32	264	336	288	288
0	1	70	28	46	158[1]	158[1]
0	6	70	54	78	90	78
0	1	32	46	288[1]	288[1]	288[1]
0	6	32	78	378[1]	426[1]	462[1]
			Delicious Variety			
		70	90	84[1]	84[1]	84[1]
		32	336[1]	288[1]	288[1]	288[1]
0	1	70	22	22	25	32
0	6	70	27	27	33	33
0	1	32	25	25	28	38
0	6	32	33	44	54	54

[1]molded

GENERAL OBSERVATIONS OF THE SOAKING TREATMENTS AT ATMOSPHERIC PRESSURE

In the soaking treatments at atmospheric pressure, using ascorbic acid and sodium chloride, we find the 4% sodium chloride kills the tart of the apple slices and, therefore, loss of flavor appeal.

The 2% sodium chloride solutions gave an acceptable flavor.

In most cases the 4% sodium chloride treated apples stood up the longest without browning or molding. But the gain in time was counteracted by loss in apple flavor.

The 0.1% ascorbic acid solution appears to retard browning as effectively as the 0.2% ascorbic acid in the 2% sodium chloride, unfrozen slices.

In the frozen slices, the 0.2% ascorbic acid treatment prevents browning for a longer period of time, as shown in the case of the Northern Spy and Grimes Golden varieties (Table I).

Of the four varieties used, Grimes Golden and McIntosh were the most acceptable as to flavor and color of slices(before molding or fermenting). Among the unfrozen apples, the Delicious held up as well as the Grimes Golden apples.

The Northern Spy appears to brown or mold the quickest of the varieties tested.

PREPARATION OF THE APPLES AND RESULTS OF THE REDUCED PRESSURE TREATMENTS USING ASCORBIC ACID AND SODIUM CHLORIDE

The apples were washed, peeled, and sliced into twelve sections which were dropped directly into the treating solution. It required approximately ten minutes to peel and slice each treatment group. The slices were submerged in the solution and placed in the vacuum chamber. The pump was started, and about ten minutes were required to reduce the pressure to 26" of Hg. This was held for twenty minutes and then released. The slices were held submerged for thirty minutes following removal of the air from the slices. The atmospheric pressure forced the solution into the exhausted tissue. The apple slices were in the solution for one hour, drained, and gave the following results (summarized in Table II):

McIntosh Variety

The McIntosh apple slices treated at reduced pressure showed: at room temperature(70°F) the 2% NaCl for both the 0.1% and 0.2% ascorbic acid fermented in 36 hours; the 4% NaCl and 0.1% ascorbic acid fermented in 40 hours; and the 4% NaCl with 0.2% ascorbic acid fermented in 36 hours.

The slices placed at 32°F immediately following draining from the solution, showed: 2% NaCl with both

the 0.1% and 0.2% ascorbic acid browned after 120 hours; the 4% NaCl with both the 0.1% and 0.2% ascorbic acid browned after 144 hours.

The McIntosh apple slices which were frozen and stored at 0°F for one month, thawed, and placed at room temperature (70°F), showed:

2% NaCl and 0.1% ascorbic acid browned after 38 hours;
2% NaCl and 0.2% ascorbic acid browned after 50 hours;
4% NaCl and 0.1% ascorbic acid molded after 158 hours;
4% NaCl and 0.2% ascorbic acid molded after 158 hours.

The slices which were frozen and stored at 0°F for six months, thawed, and placed at room temperature, showed:

2% NaCl and 0.1% ascorbic acid browned in 44 hours;
2% NaCl and 0.2% ascorbic acid browned after 90 hours;
4% NaCl with 0.1% and with 0.2% ascorbic acid molded after 90 hours.

The McIntosh apple slices frozen and stored at 0°F for one month, thawed, and held at 32°F, gave:

2% NaCl and 0.1% ascorbic acid browned after 46 hours;
2% NaCl and 0.2% ascorbic acid browned in 78 hours;
4% NaCl with 0.1% and with 0.2% ascorbic acid molded in 288 hours.

The slices which were frozen and stored at 0°F for six months, thawed, and held at 32°F, gave:

2% NaCl and 0.1% ascorbic acid browned after 54 hours;

2% NaCl and 0.2% ascorbic acid molded in 310 hours;
4% NaCl with 0.1% and with 0.2% ascorbic acid molded in 462 hours.

Northern Spy Variety

The Northern Spy apple slices treated at reduced pressure and placed at room temperature (70°F) immediately following draining from the solution, showed:
2% NaCl and 0.1% ascorbic acid fermented in 24 hours;
2% NaCl and 0.2% ascorbic acid fermented in 36 hours;
4% NaCl and 0.1% and 0.2% ascorbic acid fermented in 36 hours.

The slices placed at 32°F after draining, showed:
2% NaCl and 0.1% ascorbic acid browned after 48 hours;
2% NaCl and 0.2% ascorbic acid browned after 96 hours;
4% NaCl with 0.1% and with 0.2% ascorbic acid browned after 120 hours.

Slices which were frozen and stored at 0°F for one month, thawed, and placed at room temperature for observation, showed:
2% NaCl and 0.2% ascorbic acid browned after 50 hours;
2% NaCl and 0.1% ascorbic acid browned after 38 hours;
4% NaCl and 0.1% ascorbic acid browned after 78 hours;
4% NaCl and 0.2% ascorbic acid browned after 46 hours.

The apple slices which were frozen and stored at 0°F for one month, thawed, and held at 32°F , showed:
2% NaCl and 0.1% ascorbic acid browned after 42 hours;

2% NaCl and 0.2% ascorbic acid browned after 78 hours;
4% NaCl and 0.1% ascorbic acid browned after 108 hours;
4% NaCl and 0.2% ascorbic acid molded in 238 hours.

Grimes Golden Variety

Treated at reduced pressure, the Grimes Golden apple slices gave the following results (summarized in Table II):

The slices held at room temperature (70°F) after draining were all fermented in 40 hours.

The slices placed in the 32°F room, showed:
2% NaCl and 0.1% ascorbic acid browned after 144 hours;
2% NaCl and 0.2% ascorbic acid browned after 168 hours;
4% NaCl and 0.1% ascorbic acid browned after 144 hours;
4% NaCl and 0.2% ascorbic acid browned after 176 hours.

Apple slices frozen and stored at 0°F for one month, thawed, and observed at room temperature, showed:
2% NaCl and 0.1% ascorbic acid browned after 78 hours;
2% NaCl and 0.2% ascorbic acid browned after 60 hours;
4% NaCl with 0.1% and with 0.2% ascorbic acid browned after 158 hours.

The slices frozen and held for six months at 0°F, thawed, and observed at room temperature, showed:
2% NaCl with both 0.1% and 0.2% ascorbic acid browned after 78 hours; while 4% NaCl with 0.1% ascorbic acid browned after 90 hours.

The Grimes Golden slices frozen and stored at 0°F for one month, thawed, and held at 32°F, showed:
2% NaCl and 0.1% ascorbic acid browned after 84 hours;
2% NaCl and 0.1% ascorbic acid molded in 288 hours as did the 4% NaCl with both the 0.1% and 0.2% ascorbic acid.

The slices held for six months at 0°F, thawed, and observed at 32°F, showed:
2% NaCl and 0.1% ascorbic acid molded in 378 hours;
2% NaCl and 0.2% ascorbic acid molded in 426 hours;
4% NaCl and 0.1% ascorbic acid molded in 462 hours.

Delicious Variety

The Delicious apple slices treated at reduced pressure responded as follows: All the slices treated, drained, and left at room temperature fermented in 36 hours. The slices which were placed at 32°F after draining, showed:
2% NaCl and 0.1% ascorbic acid browned after 96 hours;
2% NaCl and 0.2% ascorbic acid browned after 120 hours;
4% NaCl with both 0.1% and 0.2% ascorbic acid browned after 96 hours.

The slices which were frozen and stored at 0°F for one month, thawed, and observed at room temperature (70°F) showed:
2% NaCl and 0.1% ascorbic acid browned after 38 hours;
2% NaCl and 0.2% ascorbic acid browned after 50 hours;

4% NaCl and 0.1% ascorbic acid browned after 38 hours;
4% NaCl and 0.2% ascorbic acid browned after 38 hours.

The Delicious apple slices observed after six month's storage at 0°F, showed browning when held at room temperature as follows: 2% NaCl and 0.1% ascorbic acid browned in 33 hours.

The slices which were frozen and stored at 0°F for one month, thawed, and observed at 32°F, showed:
2% NaCl and 0.1% ascorbic acid browned after 54 hours;
2% NaCl and 0.2% ascorbic acid browned after 46 hours;
4% NaCl and 0.1% ascorbic acid browned after 38 hours;
4% NaCl and 0.2% ascorbic acid browned after 42 hours.

Slices frozen and stored at 0°F for six months, thawed, and observed at 32°F, showed:
2% NaCl and 0.1% ascorbic acid browned after 38 hours.

TABLE II

Browning Time of Apple Slices after Soaking Treatment at Reduced Pressure, Using Sodium Chloride and Ascorbic Acid Solutions

Storage Temp. °F	Storage Time months	Obs. Temp. °F	2% NaCl 0.1% Ascorbic hrs.	2% NaCl 0.2% Acid hrs.	4% NaCl 0.1% Ascorbic hrs.	4% NaCl 0.2% Acid hrs.
			McIntosh Variety			
		70	36[2]	36[2]	40[2]	36[2]
		32	120	120	144	144
0	1	70	38	50	158[1]	158[1]
0	6	70	44	90	90[1]	90[1]
0	1	32	46	78	288[1]	288[1]
0	6	32	54	310[1]	462[1]	462[1]
			Northern Spy Variety			
		70	24[2]	36[2]	36[2]	36[2]
		32	48	96	120	120
0	1	70	38	50	78	46
0	1	32	42	78	108	238[1]
			Grimes Golden Variety			
		70	40[2]	40[2]	40[2]	40[2]
		32	144	168	144	176
0	1	70	78	60	158	158
0	6	70	78	78	90	
0	1	32	84	288[1]	288[1]	288[1]
0	6	32	378[1]	426[1]	462[1]	
			Delicious Variety			
		70	36[2]	36[2]	36[2]	36[2]
		32	96	120	96	96
0	1	70	38	50	38	38
0	6	70	33			
0	1	32	54	46	38	42
0	6	32	38			

[2] fermented

[1] molded

GENERAL OBSERVATIONS ON THE SOAKING TREATMENTS AT REDUCED PRESSURES, USING SODIUM CHLORIDE AND ASCORBIC ACID SOLUTIONS

In the soaking treatments at reduced pressures, using ascorbic acid and sodium chloride, the results follow about the same pattern as the soaking treatments at atmospheric pressure. The solutions containing 4% NaCl were too salty to the taste.

The 2% NaCl is more noticable to the taste in the slices at reduced pressure than in those treated at atmospheric pressure.

There is very little difference in browning time between the 0.1% and the 0.2% ascorbic acid except in the frozen slices.

There is very little difference in the browning rate of the slices which were soaked at atmospheric pressure and those which were vacuum treated.

The slices which are processed at reduced pressure are more desirable than those processed at atmospheric pressure for pies, because these slices retain their shape in baking, making for a thicker, fuller pie.

SULFUR DIOXIDE TREATMENTS

Sulfur dioxide (SO_2) was used in the second series of treatments. The solutions containing SO_2 were prepared from sodium bisulfite (anhydrous). The first five lots of Delicious apples were soaked for one hour in distilled water solutions containing varying concentrations of SO_2 (summarized in Table III).

I. This SO_2 solution initially contained 274 ppm SO_2. The solution, after the slices had soaked for one hour, contained 171 ppm SO_2, the slices showing 41 ppm SO_2 had been taken up by the fruit. The slices placed at room temperature (70°F), browned after 24 hours. The slices placed at 32°F, browned after 36 hours. Slices which were frozen and stored at 0°F for one month, thawed, and placed at room temperature, browned after 25 hours. Other slices after being stored for one month at 0°F, browned after 28 hours when held at 32°F. The slices which were frozen and stored for six months at 0°F, thawed, and placed at room temperature, browned after 27 hours; while those held at 32°F browned after 33 hours.

IL. These apple slices were soaked for one hour in a solution containing 445 ppm SO_2. At the end of the soaking period, the slices showed 75 ppm SO_2, while the solution had 369 ppm SO_2 left. The slices thus treated gave the following results: Left standing at room temperature, the slices browned in 45 hours;

Held at 32°F, other slices browned after 96 hours. Slices frozen and stored at 0°F for one month, browned after 50 hours after being thawed and held at room temperature (70°F); while those stored at 0°F for six months, browned in 66 hours after being placed at room temperature. Slices frozen and stored at 0°F for one month, browned after 63 hours when held at 32°F; while the slices stored for six months at 0°F, browned after 126 hours when placed at 32°F.

III. Lot III was put in a solution containing 664 ppm SO_2 for one hour. After the one hour soak, the slices were drained and found to contain 116 ppm SO_2, while the solution tested 588 ppm SO_2 left. The slices given such treatment reacted as follows: at room temperature, they browned after 60 hours; while at 32°F, they browned after 208 hours. Slices frozen and stored at 0°F for one month and then placed at room temperature, molded in 182 hours; while those placed at 32°F, molded in 288 hours. The slices frozen and stored at 0°F for six months, molded in 102 hours when placed at room temperature and in 426 hours when placed at 32°F.

IV. The solution into which the lot IV slices were dipped contained 817 ppm SO_2. After the one hour soaking period, the solution retained 722 ppm SO_2, while the fruit had 137 ppm SO_2. Drained and placed at room temperature, the slices browned in 68 hours;

while those held at 32°F browned after 260 hours. Slices frozen and stored at 0°F for one month molded in 182 hours when placed at room temperature (70°F); while those placed at 32°F, molded in 288 hours. The slices frozen and stored at 0°F for six months, molded in 102 hours when placed at room temperature; while those placed at 32°F, molded in 426 hours.

V. In the original solution for lot V there were 1252 ppm SO_2. After the one hour soaking period, the drained slices were found to contain 232 ppm SO_2; while the used solution retained 1060 ppm SO_2. These slices gave the following results: those placed at room temperature, browned in 80 hours; the ones held at 32°F, molded in 310 hours; slices which were frozen and stored at 0°F for one month and then placed at room temperature, molded in 182 hours; while those placed at 32°F, molded in 288 hours. The frozen slices which were held for six months at 0°F and then placed at room temperature, molded in 114 hours; while those held at 32°F, molded in 462 hours.

McIntosh apples were given the following treatments at reduced pressures:

VI. This lot was the first of the vacuum treatments and was used as a control, containing no SO_2. The solution used contained 2% NaCl. The slices were dropped directly into the solution and placed in the

vacuum chamber. The come-down time was approximately ten minutes to reach 26" of Hg vacuum. The vacuum was held for twenty minutes and then released, allowing the solution to be forced into the slices by atmospheric pressure. The slices were taken from the solution following thirty minutes submersion at atmospheric pressure. They were then drained. The slices placed at room temperature browned after 52 hours. Slices placed at 32°F browned after 96 hours. The apples frozen and stored at 0°F didn't fare so well; the refrigeration broke down during the storage period, and the slices were thawed for about thirty hours. This lot was brown when refrozen, The same pressure reducing procedure was followed for all lots.

VII. For this vacuum treatment, the original solution contained 296 ppm SO_2. After being treated and drained, the slices contained 63 ppm SO_2; while the used solution tested 169 ppm SO_2. The slices thus treated molded at room temperature in 58 hours. Slices placed at 32°F, molded in 288 hours. The slices which were frozen and stored at 0°F were thawed for about thirty hours when the refrigeration system broke down. They were then refrozen. These abused slices, after storage for one month, were placed at room temperature and some at 32°F and molded in 72 and 264 hours, respectively. Other refrozen slices kept in storage for six months, molded in 114 hours

when placed at room temperature and in 462 hours when placed at 32°F. These slices were not too firm and quite slippery.

VIII. 2% NaCl was added to lot VIII, the SO_2 solution containing 254 ppm SO_2. After the vacuum treatment, the slices were drained and found to contain 63 ppm SO_2. The used solution contained 169 ppm SO_2. These slices molded in 58 hours when placed at room temperature (70°F) and in 360 hours at 32°F. The slices which were frozen and stored at 0°F were also thawed for thirty hours when the refrigeration system broke down. They were refrozen and, after one month's storage at 0°F, they molded at room temperature in 72 hours and in 264 hours at 32°F. After six month's storage at 0°F, other slices molded in 90 hours at room temperature and in 426 hours at 32°F. The sodium chloride had a tendency to shroud the taste of the SO_2 in these slices. It also seemed to decrease the surface slime.

IX. The original solution for this lot contained 290 ppm SO_2, 2% NaCl, and 1% calcium lactate. After being put through the vacuum treatment, the slices were drained and found to contain 42 ppm SO_2; while the solution retained 169 ppm SO_2. At room temperature, these slices molded in 60 hours. At 32°F they browned and molded in 144 hours. The slices which were frozen and stored at 0°F were unfortunately thawed for thirty hours when the refrigeration system broke down.

These were refrozen. Those slices which were then stored for one month at 0°F, molded in 72 hours on being placed at room temperature, while those placed at 32°F, molded in 264 hours. The slices stored for six months at 0°F, browned in 54 hours when placed at room temperature (70°F), and those held at 32°F, molded in 354 hours. These slices remained quite firm with very little gooeyness on the surface. The taste of SO_2 was diminished. These slices were crunchy after cooking.

X. The McIntosh slices of this lot were vacuum treated in a solution containing 1% calcium lactate and 265 ppm SO_2 originally. After draining, the slices contained 42 ppm SO_2, while the treating solution still had 190 ppm SO_2. Slices placed at room temperature molded in 72 hours, while the slices placed at 32°F, molded in 336 hours. The slices which were frozen and stored at 0°F were also thawed for thirty hours while the refrigeration system was repaired. Following such treatment, the slices which were stored at 0°F for one month, molded in 72 hours when placed at room temperature and in 384 hours when held at 32°F. Slices which were stored for six months at 0°F, molded in 114 hours at room temperature; while the slices held at 32°F were discarded after they had lasted 462 hours without molding or browning. These slices were nice, although the surface was more slimy

than those with sodium chloride added to the solution. The SO_2 taste was much more predominant than in lot IX, and the slices were not quite as crisp after cooking, but still quite firm.

XI. This lot was another control group because it contained no SO_2, but did contain 2% NaCl and 1% calcium lactate. Slices held at room temperature (70°F) browned in 40 hours, while those placed at 32°F browned after 96 hours. The slices which were frozen and stored at 0°F and which thawed for the thirty hour period while the refrigeration system was broken down, browned before the thirty hour period was complete and were discarded.

XII. 2% NaCl and 570 ppm SO_2 were in the solution used in the vacuum treatment of these apples. After being drained, the slices contained 106 ppm SO_2, while the soaking solution retained 422 ppm SO_2. The slices which were placed at room temperature, molded in 70 hours, while those placed at 32°F, molded in 360 hours. Once again those slices which were frozen and stored and thawed for about thirty hours during the refrigeration system break down, were refrozen and stored for one month at 0°F. These slices molded in 72 hours at room temperature and in 384 hours at 32°F. Slices stored for six months, molded in 114 hours at room temperature, but in 462 hours those held at 32°F had neither molded

nor browned. These slices were quite limp and broke down very easily and completely in cooking. Their SO_2 t aste was very strong, almost covering the apple flavor.

XIII. The vacuum treatment solution used on these McIntosh slices, originally contained 549 ppm SO_2 and 1% calcium lactate. The drained slices contained 127 ppm SO_2, and the soaking solution retained 420 ppm SO_2. Slices placed at room temperature molded in 72 hours, while those observed at 32°F molded in 244 hours. The frozen and stored at 0°F slices were thawed for thirty hours during a refrigeration break-down. But the slices which were then refrozen and stored for one month, molded after 72 hours when held at room temperature and after 384 hours when held at 32°F. The slices which were stored for six months, molded in 114 hours when placed at room temperature and in 426 hours at 32°F. These slices had a very high sulfur taste. The slices were very firm with only some slip on the surface.

XIV. The original solution contained 1% calcium lactate and 528 ppm SO_2. After the vacuum treatment and drain - ing, the slices contained 106 ppm SO_2, while the solution showed 380 ppm SO_2. These slices molded in 72 hours at room temperature and in 192 hours at 32°F. The slices which were frozen and stored at 0°F, also were thawed for thirty hours while refrigeration repairs were made. Refrozen and stored for one month,

the slices placed at room temperature molded in 72 hours, while those placed at 32°F, molded in 384 hours. The frozen slices thawed after six month's storage at 0°F, molded after 114 hours when placed at room temperature and after 334 hours when placed at 32°F. These slices were quite firm and had little slime on the surface, but had a very strong SO_2 flavor.

XV. The vacuum treatment solution for this lot of McIntosh apples contained 40% sucrose, 1% calcium lactate, and 275 ppm SO_2. After being drained, the slices contained 42 ppm SO_2, and the used solution had 211 ppm SO_2. These slices browned in 60 hours at room temperature and molded in 216 hours at 32°F. The slices which were frozen and stored at 0°F, thawed for thirty hours due to a refrigeration break-down, and were then refrozen. After one month's storage, some of these slices were placed at room temperature and molded in 72 hours, and some were placed at 32°F and browned after 96 hours. The slices which were held at 0°F for six months, browned in 78 hours at room temperature and molded in 232 hours at 32°F. These slices were firm, sweet, and had only a slight taste of SO_2. When these slices were cooked, they remained firm, medium sweet, and the SO_2 was still detectable.

XVI. The original solution contained 549 ppm SO_2, 40% sucrose, and 1% calcium lactate. After being vacuum treated, the McIntosh slices were drained and found

to contain 85 ppm SO_2, while the solution after soaking the slices, contained 422 ppm SO_2. These slices at room temperature molded in 72 hours, at 32°F they molded in 244 hours. The slices which were frozen and stored at 0°F were accidently thawed for thirty hours during the refrigeration system break down. They were refrozen and observed at the end of one month at 0°F. At room temperature, they molded in 72 hours, and at 32°F, they molded in 386 hours. The frozen slices observed after six month's storage at 0°F and then placed at room temperature, molded in 114 hours;and at 32°F, they molded in 462 hours. These slices were firm, but were still slightly slimy on the surface. The sulfur taste was very strong.

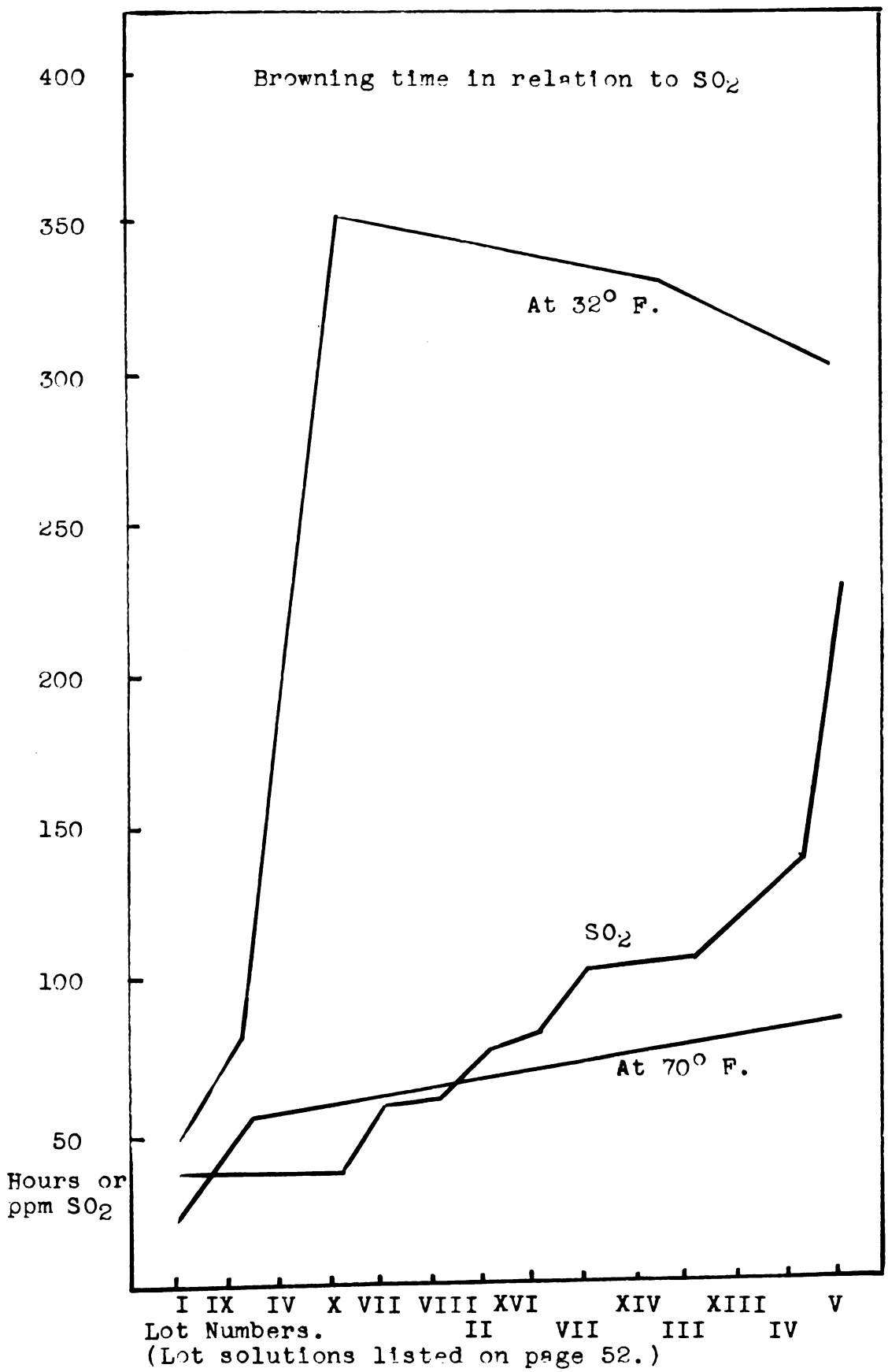
TABLE III

A Summary of The Sulfur Dioxide Treatments

Lot	Contents of The Original Solution				Used Solution	Fruit Slices	Browning Time in Hours					
							Stat		Storage: 1 month, 0°F		Storage: 6 months, 0°F	
	%NaCl	%Ca Lactate	%Sucrose	ppm SO_2	ppm SO_2	ppm SO_2	Obs.Temp. 70°F	32°F	Obs. Temp. 70°F	32°F	Obs. Temp. 70°F	32°F
I				274	171	41	24	36	25	28	27	33
II				445	369	75	45	96	50	63	66	126
III				664	588	116	60	208	182[1]	288[1]	102[1]	426[1]
IV				817	722	137	68	260	182[1]	288[1]	102[1]	426[1]
V				1252	1060	232	80	310[1]	182[1]	288[1]	114[1]	462[1]
VI	2						52	96	0	0		
VII				296	169	63	58[1]	288[1]	72[1]	264[1]	114[1]	462[1]
VIII	2			254	169	63	58[1]	360[1]	72[1]	264[1]	90[1]	426[1]
IX	2	1		290	169	42	60[1]	144	72[1]	264[1]	54	354[1]
X		1		265	190	42	72[1]	336[1]	72[1]	384[1]	114[1]	462
XI	2	1					40	96	0	0		
XII	2			570	422	106	70[1]	360[1]	72[1]	384[1]	114[1]	462
XIII	2	1		549	420	127	72[1]	244[1]	72[1]	384[1]	114[1]	426[1]
XIV		1		523	380	106	72[1]	192[1]	72[1]	384[1]	114[1]	334[1]
XV		1	40	275	211	42	60	216[1]	72[1]	96	78	272[1]
XVI		1	40	549	422	85	72[1]	244[1]	72[1]	386[1]	114[1]	462

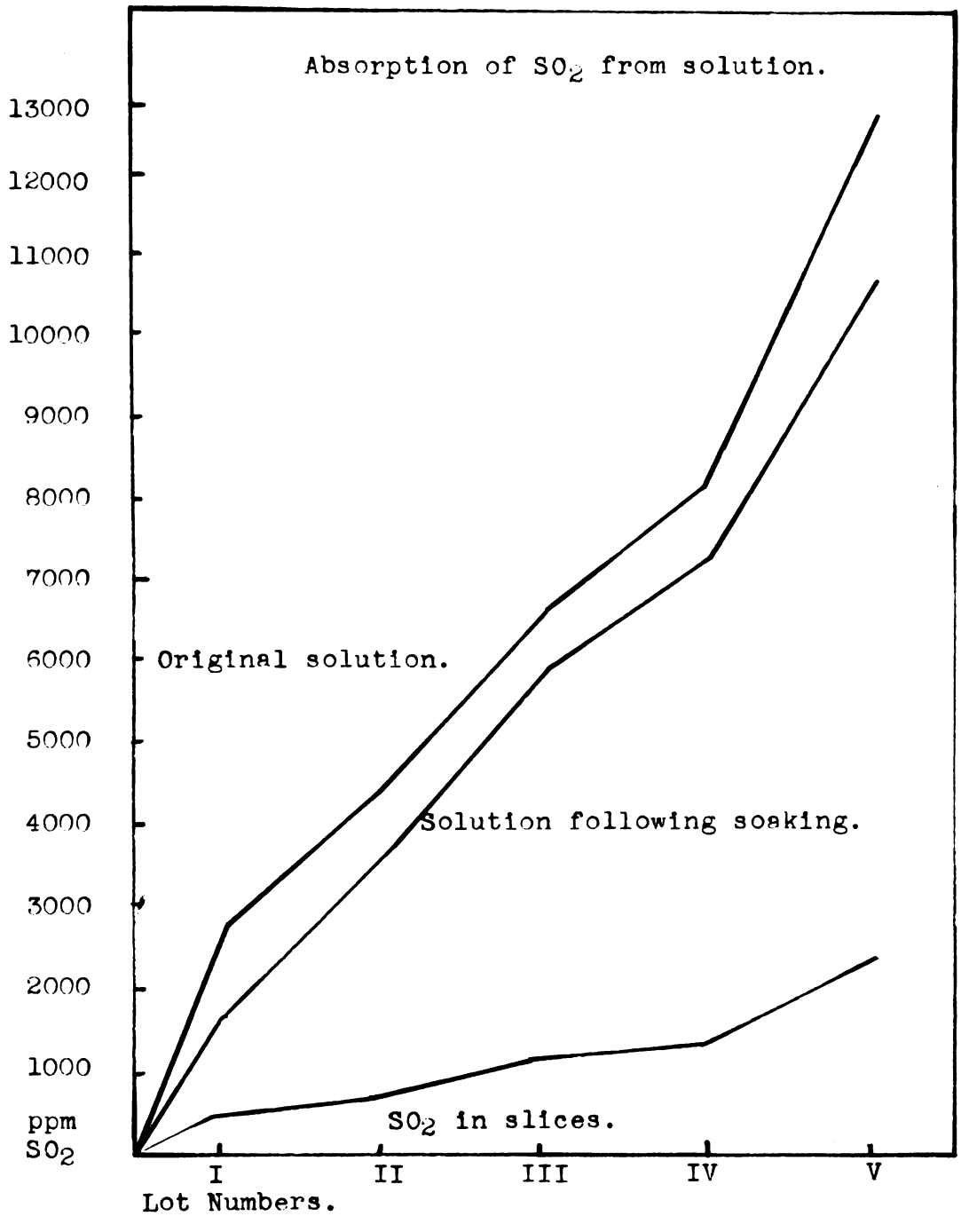
[1]Molded

Graph **A.**



(Lot solutions listed on page 52.)

Graph B.


Absorption of SO_2 from solution.
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
ppm SO_2
Original solution.
Solution following soaking.
SO_2 in slices.
I
II
III
IV
V
Lot Numbers.

GENERAL OBSERVATIONS ON THE SO_2 TREATMENTS

Those slices treated with the highest concentrations of SO_2 retained their color for the longest time, ie., the higher the SO_2 concentration, the better the color retention. All treatments tended to mold before browning.

Table III and graph A show the changes in browning time with changes in SO_2 content; graph A being arranged according to increases in SO_2 content.

Graph B shows the parts per million in the original solution compared to the ppm absorbed by the apple slices and remaining in the solution after soaking.

In the first five lots and lot VII, the SO_2 had a noticeable effect on softening and the production of a surface slime on the slices. The sodium chloride used in lots VI, VIII, and XII, yielded a firmer structure and less surface slime.

In lots X, XIV, and XVI in which calcium lactate was used, the structure was firm, but there was still some surface slime.

Lots IX, XI, and XIII in which both sodium chloride and calcium lactate were used, the slices were in very good physical condition; very little slip to the surface, and the slices held up firmly and presented a full, firm slice after cooking.

Lots VI and XI had the best flavor and slice texture, but turned brown on thawing. This showed that

in these lots the SO_2 was the inhibitor to browning. The inhibiting action was greatly improved by the use of either sodium chloride or calcium lactate or both.

CONCLUSIONS

Of the treatments used in this experiment, those containing ascorbic acid in 2% sodium chloride and treated at atmospheric pressure were the most palatable. The slices so treated were inferior in browning time to those treated with SO_2. The flavor or aroma which the SO_2 imparted, whether or not the slices were cooked and even at low concentrations, was an unpleasant metallic flavor. The aroma was distinguished as a high sinus aroma which covered the delicate apple flavor.

The 4% NaCl was too strong a flavor and also covered the apple flavor. The 2% NaCl was noticeable, but not as objectionable as the 4% NaCl or the SO_2 in the apples.

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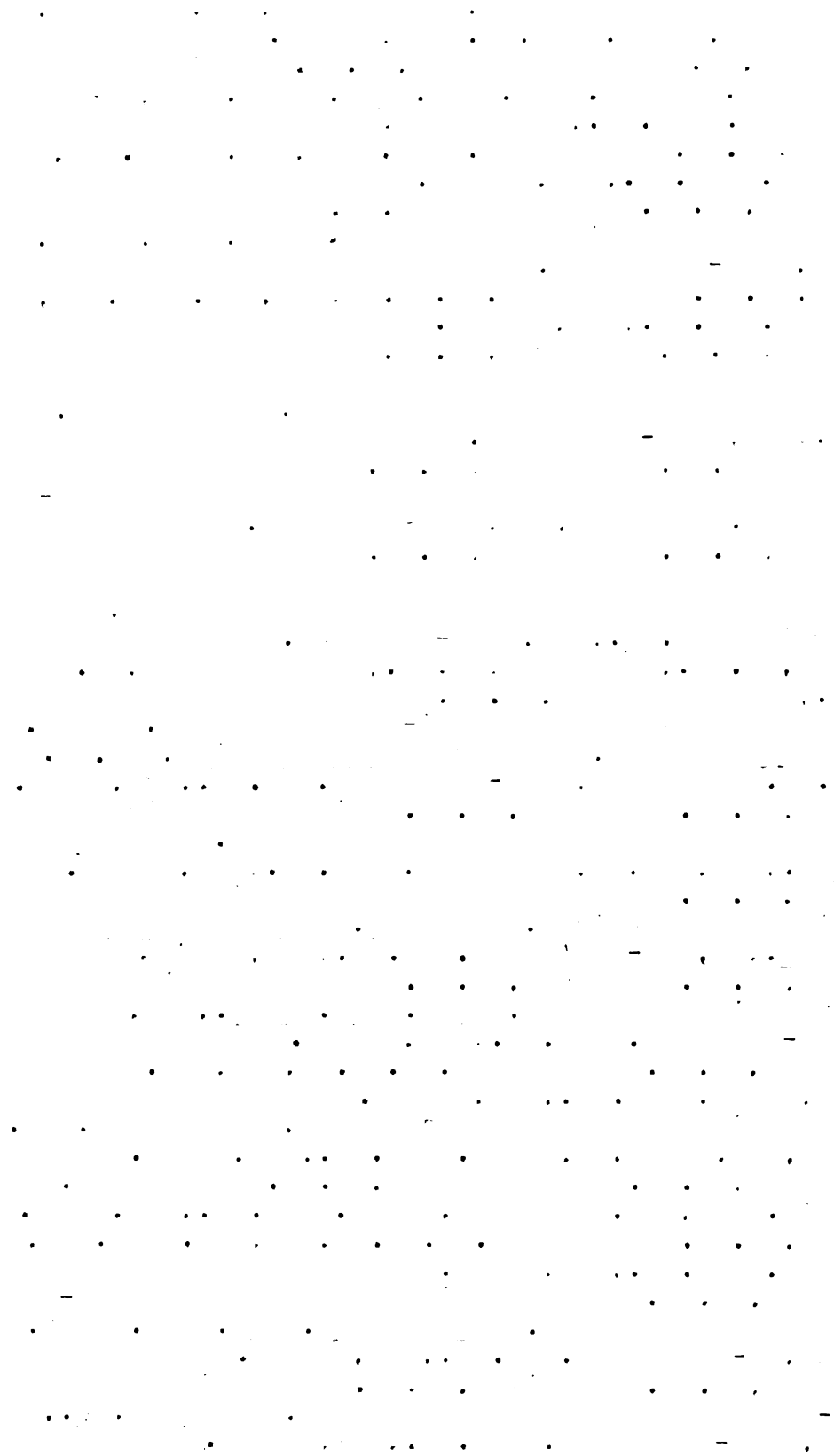

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