EFFECT OF ADDED COLLOIDS ON THE PALATABILITY AND THE QUANTITY OF JUICE DRAINED FROM THAWED STRAWBERRIES

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EFFECT OF ADDED COLLOIDS ON THE PALATABILITY AND THE QUANTITY OF JUICE DRAINED FROM THAWED STRAWBERRIES

By

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

INTRODUCTION

Fruits and vegetables deteriorate rapidly after they reach prime condition in the garden or orchard. Many of the choicest kinds have lost their freshness by the time they reach the consumer. A possible solution to the problem is to freeze fruits and vegetables shortly after they are picked. In that way, the color, flavor, and nutritive value are preserved for a much longer time. Freezing preserves the freshness of foods better than any other method of food preservation.

Small fruits are especially adapted to freezing. In fact, small fruits are not easily preserved by other methods because they are fragile and delicate in flavor. In addition, the preparation of small fruits for freezing is comparatively simple.

Among the small fruits which are frozen, strawberries have been a favorite item for a long time. However, the texture and appearance of the frozen strawberries are not always satisfactory. Sometimes an excess of juice leaks from the berries when they are thawed. This results in a flabby texture and apparent reduction in volume. When the berries appear flabby, they are unpalatable and do not resemble the fresh product.

A possible way to reduce the amount of leakage during thawing would be to treat the berries with a protective agent prior to freezing. The additive must be one which will decrease the leakage without impairing the appearance or flavor of either the berries or the sirup.

The following study was made with a view toward finding a possible protective agent for frozen strawberries. Some investigators had found that low methoxyl pectin was effective in reducing leakage by the formation of a gel on the cut surfaces of the berries. This colloid was included in the study, therefore, for comparative purposes. Since low methoxyl pectin is not readily available to the homemaker, it seemed advisable to include other substances which were capable of forming gels and which were easily obtained. Powdered commercial pectin and plain gelatin were selected. A powdered methylcellulose was also used for one of the treatments. This colloid has been reported to be useful as a thickening agent in a number of foods. It was thought, therefore, that the product might be used as a protective agent for frozen strawberries.

Since one of the best tests for any food is its eating quality, organoleptic evaluations were made by a scoring panel. However, certain objective measurements were necessary for a more complete study. Drained weights of the berries were obtained to calculate the amount of juice lost on thawing. Specific gravities of the sirups were determined before freezing and after thawing, and converted to the equivalent per cent sucrose solutions. The difference between the two values was some indication of the dilution of the sirup by the juices exuded from the berries. Per cent moisture contents were determined to compare with the results of the leakage and the specific gravity tests. Since each of the colloids was expected to form a gel, it seemed advisable to include viscosity tests in the study to compare the final consistencies of the sirups.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Workers in the field of frozen foods early recognized that one of the problems in the freezing of strawberries was the great loss of juice when the product was thawed.

Woodroof (28) reported that the loss of plant juices was due to the irreversible precipitation of cell contents. There was a liberation of "bound water" and water previously present in the vacuoles. Most of this water was not reabsorbed on thawing. Thus, flabbiness and loss of structure were due to the breakdown of cell contents which formerly gave support to the walls.

Josyln (12) stated that the decrease in weight of frozen fruits after thawing was due to (a.) water which was separated as ice during freezing and not reabsorbed during thawing, (b.) leakage of fluids through the tissues which were injured by freezing, and (c.) osmotic action of the sugar or sirup in which the fruit was packed.

Considerable study was made on the protective action of various salts, sugar, and sirup which would affect the osmotic properties of the fruit. Sucrose sirups aided in the retention of fresh appearance and texture (6, 7, 13, 14, 18, 22), but they were not effective in bringing about an appreciable decrease in the amount of exuded juice. Calcium salts did not have a noticeable firming effect on frozen strawberries (1, 11). The use of pectin to protect fruit tissues by the formation of a gel was also reported in the literature.

The Pectic Substances

Rosa (21) pointed out in 1921 that the naturally present pectic substances helped to influence the texture and firmness of plants. He believed that if the pectin content of fruits could be regulated, an improvement in the freezing preservation could be expected.

Although it was impossible to regulate the pectin content of the cell, some investigators pointed out that it was possible to add pectin to frozen foods as an external protective agent. One of the first available reports on the subject was a patent issued to Cowgill (5) in 1938 for the use of a "non-acid pectin in non-hydrated, non-gelatinous condition". In the case of berries, the pectin was dispersed throughout the fruit with or without sugar. The concentration of colloid was such that the pectin content of the exuded juice was approximately the same as the natural pectin content of the original berries. Apparently, the pectin in Cowgill's sirup helped to prevent oxidative changes.

Other investigators, especially Baker (1), believed that a pectin gel on the surface of the berries would reduce the leakage of juice as well as prevent oxidation. It was found that certain pectins were able to form gels without a high concentration of sugar. The ability of pectins to form gels varied according to the methoxyl content of the pectin molecules. Pectins with more than seven per cent methoxyl groups required a soluble solids content of over 50% for proper jelly formation. When pectins contained less than seven per cent methoxyl, they were able to produce firm gels with traces of polyvalent cations (usually calcium) at a much lower solids content. These discoveries led to investigations on the possibility of using low methoxyl pectins for frozen strawberries.

Baker (1) in 1941 reported the addition of pectins ranging from 3.5 to 11% methoxyl content to frozen strawberries. He found that the methoxyl content was the most important factor in determining the behavior of the pectin. A cold two per cent solution of a pure pectin having a five per cent methoxyl content reduced the loss of juice upon thawing by one-third. Pectins of high methoxyl content, including the commercial pectins, were not effective in reducing the loss of juice. The pectin solutions produced the best results when they were below 60° F. Better comparisons were found with sliced than with whole berries, because there was not as much variation in size and surface conditions. Baker also found that the sliced berries treated with low methoxyl pectin had better color, shape, and general appearance than the other samples. Small amounts of calcium salts, alone or in combination with pectin, were not as effective as pectin alone. Evidently, these salts combined readily with the added low methoxyl pectin, preventing the formation of a gel with the natural salts present in the strawberry juice.

Since Baker's work gave promising results with the use of low methoxyl pectin, further studies were made a few years later. Buck, Baker, and Mottern (3) reported that pectinates reduced the leakage of juice from frozen sliced strawberries, cherries, raspberries, and peaches. In addition, the fruit was more glossy and retained more of its natural color. The pectinates combined with the calcium of the fruit to form a gel on the surface. Although some juice was withdrawn from the fruit, most of it was held in a gel state and did not drain off or separate from the fruit on thawing. These investigators found that 0.42% of a pectin with a methoxyl content of 6.10% gave a 50% reduction in drainage. Increased quantities of the pectin continued to reduce the drainage, but the lumps of gel detracted from the appearance of the product. In their work there was no correlation between the amount of drained juice and the different characteristics and properties of the pectins, such as methoxyl content, calcium optimum, gel power, or method of demethoxylation.

Grab, Wegener, and Baer (11) treated strawberries with low methoxyl pectin and with alginates. Both types of samples showed a definite increase in per cent drained weight, though the low methoxyl pectin gave the most marked results. The flavor was unchanged in both treatments, but the color and appearance were improved by the low methoxyl pectin. The authors recommended low methoxyl pectin in a concentration of 0.2 to 0.3% by weight of berries for optimum results.

The California Fruit Growers' Exchange (4) published information on freezing strawberries with the addition of low methoxyl pectin to the sugar sirup. The colloid caused a sealing of cut berry surfaces and a subsequent decrease in leakage. More apparent results were obtained with sliced berries than with whole ones. The benefits of the low methoxyl pectin were more noticeable when it was added in sirup rather than with dry sugar. The recommended concentration of low methoxyl pectin was 0.10 to 0.15% by weight of berries. Untreated berries

usually lost 60-65% of their total weight on thawing. Losses from berries treated with low methoxyl pectin usually did not exceed 45%.

Wegener, Baer, and Rodgers (25) experimented with the addition of low methoxyl pectin, kelp extractive, and Irish moss extractive to whole and sliced strawberries. They found that there was a marked increase in drained weight in all samples. However, the low methoxyl pectin was considered best from the standpoint of increasing drained weight with the smallest quantity of colloid. There was a greater increase in drained weight with 60% sirup than with dry sugar. The differences between the controls and the sirup packed samples were more noticeable with the whole berries than the sliced ones, except with the low methoxyl pectin. In addition to an increase in drained weight, the treated samples were more glossy and retained their shape better than the controls. The authors recommended a level of 0.15% low methoxyl pectin and 0.3 to 0.4% of the other colloids for best results.

Kaloyereas (16) studied the preservation of color, flavor, and texture of strawberries as affected by the addition of various substances, including a combination of 0.1% pectin and 0.1% calcium chloride. It is assumed that a high methoxyl pectin was used, but the report does not state this fact specifically. The pectin-calcium chloride increased the firmness of the berries but did not improve the taste, color, and aroma.

The addition of a minute quantity of pectin to frozen cherries was suggested by Fitzgerald (10). He pointed out that cherry juice contained mostly invert sugar which resisted crystallization. In addition, the juice was low in natural pectin. The untreated juice was more or less liquid even at 0° F. because of the soluble solids content. Fitzgerald felt that the pectin would increase the viscosity of the juice and reduce the possibility of package leakage.

All of these reports in the literature indicated that improvements in the quality of frozen fruits were possible with the addition of pectic substances.

Gelatin

To the author's knowledge, no mention is made in the literature concerning the use of gelatin to improve the quality of frozen strawberries. There are many accounts of its use in other foods, however. The ability to form a reversible gel makes gelatin a very important addition to many foods. According to Bronson (2) one of the principal uses of gelatin is that of a stabilizer in ice cream. A relatively small amount of gelatin was found to prevent the growth of large ice crystals. It also gave other desirable characteristics to ice cream which, in his opinion, were not obtained from other stabilizers. Bronson also mentions that gelatin is used widely in packing houses for coating specialty meat products and in canned meats to absorb juices which separate during the cooking process.

Methylcellulose

Although there are reports in the literature advocating the use of powdered methylcellulose in certain foods, there is no information on its use in frozen strawberries. Certain properties of this colloid make it useful in food applications. Among these are its thickening ability and colloidal suspending properties. Methylcellulose differs from agar-agar and gelatin in that it forms a gel on heating instead of on cooling. As the temperature increases, the viscosity of the solution decreases until a gel point is reached (8).

Methylcellulose was suggested as a thickening agent in sugar-free sirups for diabetic patients (8). It was also recommended for patients with wheat allergies in the preparation of breads without gluten (8).

Characteristics of a Standard Product

The ultimate goal in the freezing preservation of strawberries is to maintain the natural state of the fruit as much as possible. However, freezing does cause certain inevitable changes in the fruit. It is necessary to consider a standard product as one which has the least amount of these changes. The United States Department of Agriculture (24) has set up certain standards for grades of frozen strawberries. These standards, though intended primarily for commercially-packed berries, can be applied in part to any frozen strawberries. "U. S. GRADE A or U. S. FANCY is the quality of frozen strawberries that possess similar varietal characteristics; possess a bright, practically uniform, typical color; are practically free from defects; possess a good character; possess a normal flavor and odor..." (22). According to these specifications, strawberries of top quality have a good characteristic bright red or pink color. They are reasonably free from a dull, grey, or reddish-brown cast. There are no extraneous materials and no undeveloped or damaged berries in the carton. The berries are free from off-flavors and objectionable odors of any kind. The factor of character refers to the texture and degree of disintegration, as evidenced by crushed or mushy strawberries. If the berries possess a good character they are fleshy, reasonably firm, and practically intact. (24)

Tressler and Evers (23) state that probably the best index of the quality of frozen fruit is the determination of the drained weight when thawed under standard conditions. They point out that if fruit is overmature, roughly handled, or frozen slowly, the drained weight will be low.

Objective Tests

In order to evaluate the effect of the added colloids on frozen strawberries, certain objective tests have been performed on the berries and sirups. The per cent soluble solids of the drained sirup was usually determined with a refractometer (3, 25). The concentration of the drained sirup was determined by the use of a hydrometer and read directly as Balling degrees. Kethley and co-workers (17) and Marsh (20) determined the specific gravity of the sirups. Baker (1) also included tests on the viscosity of the drained juices. These workers determined the leakage of juice by obtaining the drained weight of the berries.

Unfortunately, there is no standard method for determining the leakage of juice. Each investigator who studied the leakage of frozen fruits followed his own plan or modified another worker's method. All of the determinations were based on the same principle, however. It was believed that the loss in weight on thawing was due to a loss in moisture from the berries. A comparison of the drained weight with the original weight was an indication of the per cent leakage from the frozen product. Since there were many sources of error in the various methods, the figures for leakage found in the literature were not taken as absolute values. However, the tests were useful for qualitative comparisons to evaluate various procedures in the freezing preservation of fruits.

One of the first methods described in the literature was used by Woodroof (28). He thawed a weighed frozen mass in an aluminum funnel lined with filter paper. After 24 hours at room temperature, the filtrate and residue were weighed and the per cent loss of juice was calculated.

Woodroof (27) later modified this method. He thawed the fruit in 100 c. c. separatory funnels with lids and stopcocks and in 1,000 c. c. metal funnels with lids. The liquid was collected in graduated cylinders. When the product reached 60° F. under laboratory conditions, the liquid portion was measured and the fruit was weighed. Woodroof found that the longer the material stood, or the higher the temperature attained, the greater the amount of leakage.

Joslyn and Marsh (14) thawed their samples for 16 hours and drained the fruit for two minutes on a screen. They pointed out that it was difficult to remove all of the juice, sirup, or water from the product by draining. They felt that the data could be used only for comparative purposes.

As part of a quality control program, Evers and Hutchings (9) suggested using the drained weight of frozen fruits as a criterion of quality. They drained the thawed fruit for two minutes on a standard screen and compared the drained weight with the weight after removal from the freezer.

Wiegand (26), working with small containers of frozen berries, determined the drained weight after thawing the product at room temperature for 24 hours.

The thawing conditions used by Marsh (20) consisted of thawing the fruit for 16 hours at room temperature. After that time, the material was drained for two minutes on an 8-mesh screen. Marsh weighed the fruit and sirup and determined the specific gravity of the sirup.

The investigators who studied the effect of low methoxyl pectin on the leakage of strawberries used the following methods: Baker (1) exposed the fruit to a temperature of 80° F. for two hours. He did not give further details of the leakage test, however. Buck, Baker, and Mottern (3) allowed the fruit to stand in open packages until the berries reached room temperature. This usually took four to five hours. Then, they drained the fruit on a four-inch hemispherical twelve-mesh sieve for ten minutes. They determined the weight of the drained juice, soluble solids content, and viscosity. Wegener, Baer, and Rodgers (25) defrosted the fruit in a room with a temperature of 21° C. until the center of the frozen mass reached 10-16° C. The berries were drained for two minutes on an eight-mesh screen. Records were kept of the drained weight of the fruit, and the volume, weight, and per cent soluble solids of the sirup.

Some investigators felt that when the fruit was thawed in air, moisture from the air condensed on the product. When the food reached room temperature, evaporation occurred. This led to many errors. Kethley, Cown, and Bellinger (17) mentioned that in their earlier studies, they used a procedure similar to Woodroof's (28) first method. They found that there was such a wide variation in the results that only qualitative conclusions could be made. After further study, they found that the errors could be decreased by thawing the frozen mass in a solvent immiscible with water. Strawberries were thawed under mineral spirits (previously saturated with water) in a room maintained at 68° F. ± 1 °. The leakage was determined one hour after the fruit reached room temperature. The berries were rolled on two paper towels in succession and weighed. When leakage was expressed by weight loss, the variation was ± 16% of the mean. When the volume of the juice was considered, as in their previously used method, the variation was ± 30% of the mean.

Kaloyereas (15) suggested thawing frozen fruit for 24 hours in a beaker containing petroleum ether or Skelly Solve B, previously saturated with water. He believed that the use of the immiscible solvent gave better results because it helped to reduce the crushing effect of the berries.

METHODS OF PROCEDURE

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Design of Experiment

Sliced Dunlap strawberries were frozen under laboratory conditions in 50% sucrose sirup to which one of the following colloids was added: powdered methylcellulose, commercial pectin, low methoxyl pectin and pure gelatin. The samples were compared objectively and subjectively with a control in 50% sirup to determine whether the colloids affected the leakage of juice and the palatability of the product.

After the strawberries had been stored for 0, 1, 4, 7, and 9 months, they were tested for leakage of juice, viscosity and specific gravity of sirup, and moisture content of both berries and sirup. The palatability was judged by members of the Foods and Nutrition staff. Two replications of the objective tests and three replications of the subjective tests were made at each storage period.

For each evaluation period, three pint-sized cartons of strawberries were needed: one for scoring, one for leakage and specific gravity tests, and one for moisture content and viscosity tests.

Preparation for Freezing

In order that the berries would be fresh when prepared for freezing, they were processed within 24 hours of picking. The berries were approximately of the same maturity. They were stored in a walk-in cooler until needed throughout the day.

One crate at a time was removed from the cooler. Four or five quarts at a time were washed in a large pan of cold tap water until there was no sand or grit present. The berries were drained in colanders, hulled, and cut into slices five to six millimeters thick.

A two-hundred gram portion was put into each pint-sized waxed freezer carton. One-hundred sixty grams of the appropriate sirup was added. Crumpled parchment paper was placed on top before the lid was closed so that the top berries would remain immersed in sirup. The carton was covered, labeled, and put into the freezer immediately. After 48 hours, the samples were taken to the locker plant to be stored at 0° F. until needed.

The average yield was about two cartons per quart of fresh strawberries.

Preparation of Sirups

A sufficient amount of each sirup was made at one time for all fifty pint-sized cartons of each sample. The proportion of colloid added to each sirup was calculated on the basis of per cent by weight of berries in each freezer carton. The sugar-water ratio in the 50% sucrose sirup was calculated on the basis of per cent by volume of solution; that is, on the basis of one cup water (237 grams) and one cup sucrose (200 grams).

The contents per carton are listed in Table 1. The total amounts of ingredients and the methods of preparation of the sirups for fifty cartons of each treatment are listed in Table 2.

Table 1

QUANTITY OF INGREDIENTS PER CARTON

Treatment	Grams of Berries Per Carton	Per Cent[1] Colloid Per Carton	Grams of Colloid Per Carton	50 Per Cent[2] Sucrose Sirup		
				Grams Sucrose Per Carton	Grams Water Per Carton	Total Grams Sirup Per Carton (Including Sucrose, Water, and Colloid.)
Control	200	none	none	73.2	86.8	160
Low methoxyl pectin[3]	200	0.15	0.3	73.1	86.6	160
Commercial pectin[4]	200	3.5	7	70.0	83.0	160
Plain gelatin[5]	200	.5	1	72.7	86.3	160
Methylcellulose[6]	200	.5	1	72.7	86.3	160

1 Per cent by weight of berries.
2 Per cent by volume of solution.
3 No. 466, California Fruit Growers' Exchange.
4 Sure-Jell brand powdered pectin.
5 Continental brand pure gelatin.
6 Methocel, Viscosity 4,000 cps, Grade NF, Dow Chemical Company.

Table 2

SIRUP FOR FIFTY CARTONS OF EACH TREATMENT

Treatment	Water Used (Grams)*				Sugar Used (Grams)*	Colloid Used (Grams)	Method of Preparation
	Unheated	Heated	Temperature	Total Water			
Control	4340			4340	3660	none	The sucrose was added to the water, and stirred until the sugar was dissolved.
Low methoxyl pectin	4230	100	71° C.	4330	3655	15	The heated water was added to the pectin, stirring until the pectin was dispersed. The cold water was added with constant stirring. The sugar was added last, stirring until all of the sugar was dissolved.
Commercial pectin	3950	200	71° C.	4150	3500	350	Same method as for low methoxyl pectin.
Gelatin	4115	200	71° C.	4315	3635	50	Same method as for low methoxyl pectin.
Methylcellulose	3452	863	85° C.	4315	3635	50	The colloid was allowed to soak in the heated water for ten minutes. The cold water was added slowly, stirring until all of the colloid was dispersed. The sugar was added, stirring until dissolved.

* Calculated on basis of 50% by volume of solution.

Preparation for Scoring

One carton of each sample was thawed for 18 hours in a household refrigerator. At the end of the thawing time, the berries were placed in appropriately marked vessels for the judges to score.

Objective Tests

Leakage Test

A modification of the method of Kethley, Cown, and Bellinger (17) was used to determine the amount of juice which leaked from the thawed berries. The principle of the procedure is the comparison of the weight of the thawed, drained berries with the original weight of the berries before freezing. The difference between the two weights is the amount of juice which leaked from the berries on thawing.

The thawing was carried out in beakers containing mineral spirits[1] in a 20° C. water bath. The solvent was first saturated with distilled water by filling a separatory funnel about one-half full with the solvent and adding distilled water until the funnel was three-fourths full. The mixture was shaken vigorously fifty times and allowed to settle for one minute. The distilled water, which settled to the bottom, was drained off and discarded.

One-thousand grams of the solvent was weighed into a 3,000 ml. beaker which was placed in the water bath. A sample of berries was removed from

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1 Stoddard's Solvent.

the freezer. The cardboard carton was removed by slitting it on the sides and tearing it away from the frozen mass as quickly as possible without loss of sample. Then, the frozen mass was placed in the mineral spirits. Each beaker was covered to prevent undue exposure to the air. The samples were left in the solvent for three and one-fourth hours (one hour after the center of the mass had reached 20° C.).

After the berries were thawed, they were drained for three minutes on a wire screen. The drained berries were placed on a pad of paper towels and rolled gently for one minute to absorb some of the moisture on the outside of the berries. Then, they were placed on a second set of paper towels and rolled gently for one minute more. The drained and blotted berries were weighed.

Moisture Content

A semi-automatic moisture tester[2] was used to determine the moisture content of the berries and of the juice.

Each sample was thawed for 18 hours in a household-type refrigerator. After thawing, the sample was drained for three minutes on a wire screen. The drained berries were placed on a pad of paper towels and rolled gently for one minute to remove the surface liquid. This was repeated. The blotted berries were blended in a Waring blender for one minute. Duplicate ten-gram portions of the blended sample were transferred to weighing pans by means of a wide-mouthed pipette. The samples were dried at 95° C. for approximately six and one-half hours, or until the difference between two successive half-hour readings was no greater than 0.05%

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2 Brabender

moisture content.

A similar method was used to determine the moisture content of the sirup-juice combination which drained from the berries on the wire screen. Duplicate ten-gram samples were obtained by pipetting the liquid into the weighing pans. The sirups were dried at the same temperature and for approximately the same length of time as the berries.

Specific Gravity

The specific gravity of the sirup-juice combination was determined by using a hydrometer. The sample for this test was obtained from the liquid which was drained from the berries in the leakage test. (The sirup-juice combination had been separated from the solvent by means of a separatory funnel.) The specific gravity of the thawed sirup-juice was compared with the specific gravity of the sirup before freezing.

Viscosity

An Ostwald Viscosimeter was the instrument used in this test. The source of the sample was the sirup-juice combination which drained from the berries for the moisture tests. This liquid contained tiny seeds and other solid particles from the strawberries. In addition, there were gel particles present in some of the sirups. All of these substances tended to interfere with the flow of the sirup through the capillary. To overcome this difficulty, the liquid was strained through six layers of clean cheese cloth into small beakers. By means of a pipette, 5 ml. of the liquid was placed in the bottom bulb of the viscosimeter in a 20° C. water bath. Readings were recorded in minutes required to flow from the top bulb through the capillary tube.

Subjective Tests

The berries were scored for general appearance, color, luster, odor, flavor of berry, flavor of juice, texture of berry, consistency of juice, and general conclusion. The judges were asked to record their comments on any outstanding features noted. A sample of the score card is given in the Appendix.

DISCUSSION OF RESULTS

DISCUSSION OF RESULTS

Palatability Scores

The mean scores of the strawberries in each evaluation period are given in Table 3. The samples were scored on the basis of one to seven, as shown on the sample score card in the Appendix. A score of seven indicated an excellent product, a score of one a very poor product, in a given characteristic.

General Appearance

The samples containing the commercial pectin were judged as having the best general appearance. They had a deeper red color than the others and were quite lustrous. The slices appeared to be fairly firm in texture.

The samples containing the low methoxyl pectin received good scores, also. The berries probably were more responsible for the relatively high appearance scores rather than the sirup, however. The sirup tended to have a somewhat mottled appearance, especially when the samples were first opened. The pectin caused a certain amount of gel formation. The presence of colorless particles detracted from the appearance, according to some of the judges.

Good scores were also given to the controls and to the methylcellulose samples, though the latter samples were more lustrous than the controls.

The lowest scores for general appearance were given to the samples

Table 3

MEAN PALATABILITY SCORES

Characteristic	Storage Time	Methyl-cellulose	Gelatin	Control	Low Methoxyl Pectin	Commercial Pectin
General appearance	0 months	5.5	5.0	5.5	5.2	5.9
	1 month	5.4	4.5	5.1	5.8	5.8
	4 months	5.1	4.7	5.5	5.4	5.5
	7 months	5.3	4.4	5.4	5.5	5.9
	9 months	4.8	4.0	5.4	5.5	5.6
Color	0 months	5.6	5.3	5.8	5.8	6.0
	1 month	5.3	4.4	5.1	6.2	5.9
	4 months	5.0	4.1	5.7	5.6	5.6
	7 months	5.3	3.9	5.1	5.8	5.9
	9 months	4.9	3.9	5.6	5.6	5.7
Luster	0 months	5.6	5.3	5.1	5.9	6.0
	1 month	5.6	4.7	4.7	6.3	5.6
	4 months	5.4	5.6	5.0	5.8	5.3
	7 months	5.8	6.0	5.1	5.9	5.6
	9 months	4.9	5.0	4.9	6.0	5.2

Table 3 (Continued)

Characteristic	Storage Time	Methyl-cellulose	Gelatin	Control	Low Methoxyl Pectin	Commercial Pectin
Odor	0 months	5.4	5.5	5.4	5.4	5.7
	1 month	6.0	5.4	5.9	5.7	5.7
	4 months	5.7	5.5	5.9	5.8	5.4
	7 months	5.4	4.8	5.5	5.4	5.4
	9 months	4.7	5.1	5.4	4.8	5.6
Flavor of berry	0 months	5.2	5.0	5.1	5.0	5.2
	1 month	5.2	5.2	5.5	4.7	4.8
	4 months	4.1	4.6	5.4	4.7	4.7
	7 months	4.8	4.0	4.7	4.6	4.9
	9 months	3.8	3.8	4.4	4.2	4.5
Flavor of juice	0 months	4.8	5.4	5.6	5.2	5.1
	1 month	5.1	5.2	5.7	4.7	4.9
	4 months	4.2	4.9	5.6	4.9	4.9
	7 months	4.6	4.6	5.5	4.8	5.0
	9 months	4.0	4.4	4.9	4.7	4.9

Table 3 (Continued)

Characteristic	Storage Time	Methyl-cellulose	Gelatin	Control	Low Methoxyl Pectin	Commercial Pectin
Texture of berry	0 months	5.3	5.2	5.2	4.9	5.0
	1 month	4.8	5.0	5.2	4.5	4.8
	4 months	4.8	4.6	5.3	4.9	5.1
	7 months	5.0	4.0	4.6	4.7	4.6
	9 months	4.6	3.9	4.8	4.7	4.6
Consistency of juice	0 months	5.1	4.6	5.6	5.2	5.8
	1 month	4.9	5.3	5.8	3.7	5.6
	4 months	5.2	4.2	5.8	4.2	5.5
	7 months	5.2	4.7	5.4	3.9	5.9
	9 months	4.8	4.5	5.5	3.9	5.4
General conclusion	0 months	5.0	4.9	5.2	5.2	5.3
	1 month	5.2	4.8	5.5	4.8	5.0
	4 months	4.3	4.3	5.4	4.7	4.9
	7 months	4.8	4.0	4.9	4.6	4.9
	9 months	4.3	3.7	4.7	4.2	4.5

treated with gelatin. At every scoring period they were much paler than the others and much less lustrous. The sirup contained fairly large pieces of gel which appeared unpleasant. The slices appeared mushy and soft in texture. Sometimes the sirup was objectionably frothy.

Though the differences in general appearance scores were highly significant between samples, the differences between storage periods were not significant. Apparently, the use of the colloids affected the appearance of the strawberries, but storage did not.

Color

Differences in scores for color were highly significant between treatments and storage periods. There was also a significant interaction between storage and replication, indicating that the judges did not always score the same sample the same way for each replication at a given storage period.

The commercial pectin and low methoxyl pectin samples were given the highest scores for color. Both of these samples had a deeper red color in the berries than in the sirup.

Good scores were also given to the methylcellulose samples and the controls. The gelatin samples received the lowest scores for color. These samples were the only ones which were pale throughout the study. Apparently, the presence of the gelatin had a bleaching effect on the pigment in the berries as soon as they were frozen. However, the color scores for all samples were slightly lower at the last storage period than they were at the beginning. Some oxidation might have occurred causing a slight change in color in all of the samples.

A possible explanation for the significant interaction between storage and replication is the relative position of each sample with respect to the window in the scoring room. The order of the displayed samples varied at each replication. When a given sample was near the window it might have appeared to have a different color than when it was farther away. This source of error was controlled as much as possible, however, by lowering the shades and using artificial light during scoring.

Luster

There was a highly significant difference between luster scores for different treatments. The low methoxyl pectin samples were judged to be the most lustrous. This contributed greatly to the appetizing appeal of the product.

Good scores were also given to the commercial pectin, methylcellulose, and gelatin samples, the latter having the lowest of the three. The controls received the lowest luster scores among the five samples. The results indicated that the addition of colloids had a definite effect on the luster of the final product.

Odor

In general there was not much difference in scores for odor between the treatments. The scores for all of the samples were good, though they tended to go down somewhat with storage. The decrease in odor scores may have been due to a slight oxidation of the "fruity" odor during storage, as suggested by the work of Fitzgerald (10) and Lutz and co-workers (19).

One of the judges felt that a true strawberry odor was lacking at the beginning of the project.

Flavor of Berry

There were no significant differences between flavor scores for the various treatments. It would appear that the addition of the colloids did not influence the flavor of the berries. A few judges did detect an "off-flavor" in the methylcellulose samples, however. One judge called it an "oxidized" flavor. The flavor of the gelatin samples was referred to as "sour" and "old" by two different judges.

In general the scores decreased with an increase in storage. These results are in agreement with the reports of Joslyn and Marsh (14). They state that during freezing and thawing some fruits and vegetables acquire a peculiar flavor and odor which are sometimes undesirable. They believe that anaerobic respiration in closed containers may be the cause.

Sometimes off-flavors are attributable to the permeability of paper containers, allowing absorption of foreign cold storage odors and flavors. The foreign flavors may even come from the containers themselves.

Joslyn and Marsh (14) found that fruit exposed to air during freezing or thawing became dark and discolored and developed unnatural flavors if active oxidases were present. It was impossible to inactivate the oxidases by heat without destroying the delicate fruit textures and flavors.

Flavor of Juice

The control sample was rated the highest for flavor of juice at four out of the five storage periods. In addition, there was a significant difference between the scores for all the treatments. These results indicate that the addition of these colloids influenced the flavor of the sirups.

One of the judges stated that the low methoxyl pectin sirup had a slightly "glue-like" flavor. Several judges commented on an "off-flavor" in the methylcellulose sirup.

The methylcellulose sirup was rated lowest for flavor. It had a definite "woody" flavor which was detrimental to the product. In general, however, the judges did not reject this sample completely.

Texture of Berry

In general all of the samples had good texture after thawing. None of them were consistently flabby or unduly soft, though occasionally a few of the judges felt that some of the berries were somewhat soft in texture.

A significant difference between storage periods was noted. The berries tended to become softer and less desirable in texture as the storage time increased.

Consistency of Juice

The commercial pectin samples and the controls received the highest scores for consistency of juice. The methylcellulose scores were also good for this characteristic.

The low methoxyl pectin and the gelatin samples were not rated as high as the others. Apparently, the judges did not favor the presence of gel particles and the thickness of these sirups, as evidenced by the significant difference between treatments.

There was also a significant interaction between storage and treatment, indicating that the treatments did not give the same effect at the different storage periods. The changes were erratic rather than consistent with increasing storage.

General Conclusion

The controls were given the highest scores for general conclusion, probably due to superior flavor and consistency of the juice. Fairly good scores were also given to the samples containing the commercial pectin, methylcellulose, and low methoxyl pectin. The gelatin samples received the lowest scores for this characteristic.

As one might expect from the scores for the individual characteristics, there were highly significant differences in general conclusion between the various treatments and storage periods. In general, the scores decreased as the storage period increased. Most of the strawberries were acceptable to the majority of the judges up to the seven months' storage period. After that time, however, the development of off-flavors in some of the samples caused individual judges to reject them. The sample which received the largest number of rejections was the gelatin sample. The methylcellulose sample also received a relatively large number of rejections from individual judges. The average mean scores and F-values are listed in Table 4.

Table 4

AVERAGE MEAN SCORES AND F-VALUES

Treatment	General Appearance	Color	Luster	Odor	Flavor of Berry	Flavor of Juice	Texture of Berry	Consistency of Juice	General Conclusion
Methyl-cellulose	5.2	5.2	5.5	5.4	4.6	4.5	4.9	5.0	4.7
Gelatin	4.5	4.3	5.3	5.3	4.5	4.9	4.5	4.7	4.3
Control	5.4	5.5	5.0	5.6	5.0	5.5	5.0	5.6	5.1
Low methoxyl pectin	5.5	5.8	6.0	5.4	4.6	4.9	4.7	4.2	4.7
Commercial pectin	5.7	5.8	5.5	5.6	4.8	5.0	4.8	5.6	4.9
Storage									
0 months	5.4	5.7	5.6	5.5	5.1	5.2	5.1	5.3	5.1
1 month	5.3	5.4	5.4	5.7	5.1	5.1	4.9	5.1	5.1
4 months	5.2	5.2	5.4	5.7	4.7	4.9	4.9	5.0	4.7
7 months	5.3	5.2	5.7	5.3	4.6	4.9	4.6	5.0	4.6
9 months	5.1	5.1	5.2	5.1	4.1	4.6	4.5	4.8	4.3
F-Values from Analysis of Variance									
Storage	1.46	4.35**	2.59	5.17**	7.99**	2.58	3.25*	2.38	7.42**
Treatment	19.12**	33.16**	10.15**	1.71	1.86	4.70**	1.70	32.83**	5.48**
Replication	.80	.45	.16	.17	.24	.29	.61	1.07	.20
Storage x treatment	1.00	1.59	1.45	.97	.96	.48	.67	2.02*	.55
Storage x replication	.82	2.62*	1.80	1.76	.26	.64	.91	.57	.50
Treatment x replication	.59	.71	.40	.68	.79	.67	.29	1.20	.29

** $p < 0.01$
* $p < 0.05$

Objective Tests

Leakage of Juice

The results of the leakage tests are given in Table 5. The differences in leakage were highly significant between treatments and storage periods. The samples which lost the least amount of juice were those which had been treated with low methoxyl pectin. The gelatin samples lost the most juice through leakage.

In general, the berries lost less juice as the storage period increased. The average for the seven months' storage period was less than the average for the nine months' period, however.

Although the differences in amount of leakage were great enough to be statistically significant, they do not appear to be large enough to have any practical significance. Indeed, with the exception of the low methoxyl pectin, the addition of colloids seemed to increase rather than decrease the leakage.

Specific Gravity

Table 6 shows the mean specific gravity of each sirup after thawing. There was a significant difference between treatments. The control sirup had the lowest average specific gravity. The low methoxyl pectin and commercial pectin sirups had the highest average specific gravity. One might have expected the specific gravity of the low methoxyl pectin sirup to be relatively high because this sample had the lowest per cent leakage. It is difficult to explain the reason for the high specific gravity of the commercial pectin sirup, since this sample had a

Table 5

MEAN PER CENT LEAKAGE OF JUICE

Storage Time	Control	Low Methoxyl Pectin	Commercial Pectin	Methyl-cellulose	Gelatin	Average Per Storage Period
0 months	27.3	27.3	27.3	29.8	27.8	27.9
1 month	26.8	26.0	27.3	27.3	27.8	27.0
4 months	22.8	22.5	27.0	22.3	25.8	24.1
7 months	21.0	21.0	22.8	22.3	24.5	22.3
9 months	22.3	20.5	23.5	22.3	25.8	22.9
Average per treatment	24.0	23.5	25.6	24.8	26.3	

F-Values from Analysis of Variance

Storage	48.50**
Treatment	10.34**
Replication	.04
Storage x treatment	2.20
Storage x replication	1.10
Treatment x replication	1.96

** $p < .01$

Table 6

MEAN SPECIFIC GRAVITY OF SIRUP

Storage Time	Control	Low Methoxyl Pectin	Commercial Pectin	Methyl-cellulose	Gelatin	Average Per Storage Period
0 months	No Data Obtained					
1 month	1.140	1.143	1.148	1.138	1.135	1.141
4 months	1.138	1.150	1.145	1.140	1.145	1.144
7 months	1.135	1.148	1.143	1.135	1.138	1.140
9 months	1.135	1.143	1.148	1.148	1.145	1.144
Average per treatment	1.137	1.146	1.146	1.140	1.141	

F-Values from Analysis of Variance

Storage	1.77
Treatment	4.85*
Replication	.42
Storage x treatment	1.25
Storage x replication	1.39
Treatment x replication	.29

* $p < .05$

Table 6

MEAN SPECIFIC GRAVITY OF SIRUP

Storage Time	Control	Low Methoxyl Pectin	Commercial Pectin	Methyl-cellulose	Gelatin	Average Per Storage Period
0 months	No Data Obtained					
1 month	1.140	1.143	1.148	1.138	1.135	1.141
4 months	1.138	1.150	1.145	1.140	1.145	1.144
7 months	1.135	1.148	1.143	1.135	1.138	1.140
9 months	1.135	1.143	1.148	1.148	1.145	1.144
Average per treatment	1.137	1.146	1.146	1.140	1.141	

F-Values from Analysis of Variance

Storage	1.77
Treatment	4.85*
Replication	.42
Storage x treatment	1.25
Storage x replication	1.39
Treatment x replication	.29

* $p < .05$

Table 6

MEAN SPECIFIC GRAVITY OF SIRUP

Storage Time	Control	Low Methoxyl Pectin	Commercial Pectin	Methyl-cellulose	Gelatin	Average Per Storage Period
0 months	No Data Obtained					
1 month	1.140	1.143	1.148	1.138	1.135	1.141
4 months	1.138	1.150	1.145	1.140	1.145	1.144
7 months	1.135	1.148	1.143	1.135	1.138	1.140
9 months	1.135	1.143	1.148	1.148	1.145	1.144
Average per treatment	1.137	1.146	1.146	1.140	1.141	

F-Values from Analysis of Variance

Storage	1.77
Treatment	4.85*
Replication	.42
Storage x treatment	1.25
Storage x replication	1.39
Treatment x replication	.29

* $p < .05$

comparatively high per cent leakage.

Table 7 lists the mean specific gravity and the equivalent per cent sucrose solution for each sirup before freezing and after thawing. In each case, the specific gravity initially was equivalent to a 48-49% sucrose solution. After the sirups were thawed, their specific gravities were equivalent to 32-33% or 33-34% sucrose solutions. Though statistically there was a significant difference between the specific gravities of the sirups after thawing, the data show that the values for specific gravity in terms of equivalent sucrose solutions were similar. Apparently, the dilution by exuded juice was about the same for all treatments.

These per cent sucrose solution equivalents are only approximate because there were other substances present in the sirups besides sucrose and water.

Viscosity

Table 8 is a summary of the viscosity of the sirups after thawing. The sirup containing the methylcellulose was the most viscous. The least viscous sirup was the one treated with gelatin. The gelatin sirup might be expected to be the least viscous, since this treatment resulted in the most leakage of juice and consequent dilution of the sirup after thawing. None of the other figures for viscosity, however, are consistent with the data for leakage. In general, the viscosities increased with storage.

Unfortunately, there are no valid figures for viscosity before freezing so that comparisons could be made to determine the relative

Table 7

MEAN SPECIFIC GRAVITY OF SIRUP AND

EQUIVALENT PER CENT SUCROSE SOLUTION

	Average Specific Gravity of Sirup Before Freezing	Concentration of Equivalent Sucrose Solution*	Average Specific Gravity of Sirup After Thawing	Concentration of Equivalent Sucrose Solution
Control	1.22	48-49%	1.137	32-33%
Low methoxyl pectin	1.22	48-49%	1.146	33-34%
Commercial pectin	1.22	48-49%	1.146	33-34%
Methylcellulose	1.22	48-49%	1.140	32-33%
Gelatin	1.22	48-49%	1.141	32-33%

* Handbook of Chemistry and Physics, ed. 2, Charles D. Hodgman, editor, Chemical Rubber Publishing Company, Cleveland, Ohio, 1943, p. 1556.

Table 8

MEAN VISCOSITY OF SIRUP AS INDICATED BY MINUTES IN OSTWALD VISCOSIMETER

Storage Time	Control	Low Methoxyl Pectin	Gelatin	Commercial Pectin	Methyl-cellulose	Average Per Storage Period
0 months	10.7	14.5	8.8	25.9	24.5	16.9
1 month	10.7	18.4	6.7	21.8	27.2	17.0
4 months	11.3	18.6	9.4	24.6	26.4	18.1
7 months	11.7	18.3	9.4	24.6	29.6	18.7
9 months	9.3	19.7	10.5	26.6	25.4	18.3
Average per treatment	10.7	17.9	9.0	24.7	26.6	

amounts of dilution by exuded juice. The unfrozen sirups tended to gel in the viscosimeter before the readings could be taken.

The data for viscosity after freezing can be used to compare the relative thickness of each sirup.

Moisture Content

Tables 9 and 10 list the data for mean per cent moisture content of berries and juice, respectively. The berries treated with low methoxyl pectin had the highest per cent moisture content. Those which were treated with commercial pectin had the lowest per cent moisture content. All of the averages were similar, indicating that the colloids did not markedly influence the loss of moisture from the berries.

The figures for moisture content of sirup are in close agreement with the data for specific gravity.

Table 9

MEAN MOISTURE CONTENTS OF BERRIES
(PER CENT MOISTURE)

Storage Time	Control	Low Methoxyl Pectin	Commercial Pectin	Methyl-cellulose	Gelatin	Average Per Storage Period
0 months	79.725	81.850	80.800	80.600	78.975	80.390
1 month	79.425	80.250	78.750	80.150	80.700	79.855
4 months	80.800	82.625	79.100	81.475	81.325	81.065
7 months	77.725	77.875	78.075	79.150	78.825	78.330
9 months	79.230	79.030	78.980	80.600	80.000	79.568
Average per treatment	79.381	80.326	79.141	80.395	79.965	

Table 10

MEAN MOISTURE CONTENTS OF SIRUP
(PER CENT MOISTURE)

Storage Time	Control	Low Methoxyl Pectin	Commercial Pectin	Methyl-cellulose	Gelatin	Average Per Storage Period
0 months	69.515	67.875	65.475	68.545	66.825	67.647
1 month	68.785	67.210	66.625	66.615	67.520	67.351
4 months	68.925	68.100	70.100	70.000	69.000	69.225
7 months	68.575	66.350	64.850	65.700	65.400	66.175
9 months	68.800	66.300	68.000	66.475	66.225	67.160
Average per treatment	68.920	67.167	67.010	67.467	66.994	

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

Sliced Dunlap strawberries were frozen in 50% sucrose sirup under laboratory conditions. The experimental treatments included addition of one of the following colloids: gelatin, methylcellulose, commercial pectin, or low methoxyl pectin. The samples were stored for 0, 1, 4, 7, and 9 months at approximately 0° F. At each storage period the berries were scored subjectively for palatability. In addition, tests were made for leakage of juice, viscosity and specific gravity of sirup, and moisture content of berries and sirup.

The results indicated that in some cases the colloids affected the palatability and, in one case, the leakage of juice. The gelatin yielded an unpalatable product with pale, flabby berries and mottled, frothy sirup. Methylcellulose caused an off-flavor in the sirup, though the luster of the berries was somewhat increased. Low methoxyl pectin improved the appearance of the berries in luster and color, but marred the appearance of the sirup with particles of gel. Commercial pectin improved the appearance of berries and sirup in color and luster.

The only colloid which reduced the leakage was the low methoxyl pectin, but the reduction was very slight and of no apparent practical significance. Most of the other treated samples had a higher per cent leakage than the controls.

From the foregoing experiment, the following conclusions can be made:

1. The addition of gelatin in a concentration of 0.5% by weight of berries did not improve the frozen strawberries.
2. Commercial pectin in a concentration of 3.5% by weight of berries improved the appearance of the strawberries, but did not reduce the leakage of juice.
3. Low methoxyl pectin in a concentration of 0.15% by weight of berries reduced the leakage of juice slightly. It also improved the color and luster of the berries, but marred the appearance and consistency of the sirup.
4. Methylcellulose in a concentration of 0.5% by weight of berries did not reduce the leakage of juice, but it did affect the flavor of the sirup unfavorably.

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APPENDIX

F&N Res.

Score Card for Frozen Strawberries

Name____________________ Date____________________

Sample Number						
General Appearance						
Color						
Luster						
Odor						
Flavor of Berry						
Flavor of Juice						
Texture of Berry						
Consistency of Juice						
General Conclusions						
Acceptability						

Scoring Key:
- 7 - Excellent
- 6 - Very good
- 5 - Good
- 4 - Medium
- 3 - Fair
- 2 - Poor
- 1 - Very poor

Defects to note particularly:

General Appearance: shrinking, collapsing, undue separation of juice from berry.
Color: fading or darkening, browning.
Odor: oxidized or unnatural odors, natural odor lacking.
Luster: lack of luster, sheen, gloss, dullness.
Flavor: foreign or off-flavor, natural flavor lacking, too sweet.
Texture of Berry: flabbiness or undue softening.
Consistency of Juice: excess runniness, excess thickness, evidence of particles of gel in juice.