THE EFFECTS OF CERTAIN TREATMENTS ON THE QUALITY OF FRESH AND HOME FROZEN KANSAS STRAWBERRIES

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1956

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1958

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INTRODUCTION

Frozen strawberries are a fruit desired in many homes because of the short season for fresh ones. However, after freezing and thawing, the berries often develop off odors and flavors, and become soft, mushy, and broken down in structure. Thus, the thawed product is inferior to the fresh.

Kansas homemakers have asked what can be done to improve the texture, flavor and color of frozen strawberries. Investigations reported in the literature indicate that applications of certain additives aid in preserving the good quality of fresh fruits during freezing and frozen storage. Therefore, a relatively simple treatment to be applied at the time of freezing would be desirable.

The purpose of the present study then was fourfold: (1) to ascertain the effects of freezing and frozen storage on two common varieties of Kansas strawberries, Blakemore and Premier; (2) to determine the effects of the application of low methoxyl pectin, with and without calcium chloride, on both varieties; (3) to make a comparison of the effects of adding sucrose and of adding corn sugar to the Blakemore variety and (4) to determine the results of the application of sorbitol to Premier berries. Criteria for determining the effect of all treatments were palatability, particularly texture, and ascorbic acid content of the fresh, frozen and stored strawberries.

REVIEW OF LITERATURE

Factors Affecting the Quality of Frozen Strawberries

Effects of Freezing. One of the major problems encountered in the early work of preserving fruits by quick freezing was a mushy texture upon thawing, resulting from a collapse in structure. In the case of frozen strawberries, in particular, workers throughout the years have investigated ways of selecting or treating the berries to gain a firm yet tender texture similar to that of fresh berries. At present no decisive procedure has been reported.

According to the studies of Joslyn and Marsh (1933), the mushy texture of the strawberries was attributed to the osmotic loss of gases, to water separated as ice and not reabsorbed, and to the leakage of fluids through injured tissues.

Photomicrographs of plant cells presented by Woodroof (1931) showed that mushiness of strawberries was brought about by precipitation of the cell contents with the liberation of bound water and release of support of the cell walls. Tressler and Evers (1936) stated that the changes in texture may be due to irreversible changes from the natural turgid gel to a dehydrated or coagulated gel. Kethley et al. (1950) pointed out that the greatest damage to berry structure occurred during the zone of crystallization when water contained in the berries was converted to ice. Studies of Kaloyereas (1947a) stressed that low freezing temperatures affected the bound water in the tissues, and the desirable freezing temperature varied with the product. In an anonymous article (1951), about a Danish freezing process called "bland cold preserving," it was stated that the greatest cellulose rupture occurred during the critical stage of freezing.

Other changes that are brought about by freezing and thawing strawberries, and that were discussed in the literature, were related to color and flavor and loss of ascorbic acid. Darkening of color was observed by Guerrant (1957). This was one of the first signs of deterioration according to Olcott (1954). Joslyn and Marsh (1933) attributed a loss of flavor to oxidation. A 20 per cent loss of ascorbic acid after five months storage was reported by Scott and Schrader (1947). Robinson et al. (1947) found no relationship between the quality of strawberries and their chemical constituents such as pH and ascorbic acid content.

Variety of Berries. Different varieties of strawberries were found to have different freezing qualities in work cited by Robinson et al. (1947) and Schrader and Scott (1947). The former authors found no excellent freezing varieties, and rated Howard 17 or Premier as fair. The latter workers rated Blakemore and Howard 17 or Premier as acceptable, if used at the proper stage of maturity. Murphy et al. (1954) considered Howard 17 of inferior freezing quality and Barton (1951) stated that Premier bleached and softened excessively on freezing and thawing. Scott and Schrader (1947) found fresh berry varieties of good eating quality to range in ascorbic acid content from 53.0 to 85.3 mg per 100 grams.

Maturity of Berries. Schrader and Scott (1947) stressed using berries at the proper stage of maturity. Firm-ripe berries had low color and flavor scores, whereas very-ripe ones scored low in texture and flavor. Loeffler (1946) found that when the strawberries were frozen and stored for three months without the addition of sugar, immature berries retained 99 per cent ascorbic acid, the mature ones retained 66 per cent, and the overmature, 55 per cent. When berries were packed with sugar, the sugar seemed to have a protective effect on the ascorbic acid in the berries during thawing.

Preparing the Berries. Washing the berries in 40° F. water resulted in better berries than those washed in 76° F. water, and washing before trimming gave a highly significant increase in drained weight in investigations reported by Hoover and Dennison (1955). In their study, berries treated under vacuum were not improved.

Packing with Sirup Versus Sugar. Berries packed in sugar sirup, in a study reported by Lee and Slate (1954), had better texture than those packed with dry sugar because mixing with the sugar was thought to injure the berries. Woodroof (1930) stated that the advantages of the sirup pack over the sugar pack were that a constant volume was kept, that the osmotic pressure and freezing point of the sirup was near that of the berry juice, and that uniform distribution with no air holes could be achieved. He mentioned the importance of the correct concentration of the sirup. Fruits packed in sirup retained their structure although weight loss was greater than that for sugar-packed berries in studies cited by Joslyn and Marsh (1933). Curing in the cold sirup, for 24 to 72 hours before freezing to equalize osmotic pressure in the cells of the fruit, gave questionable results. In work by Wiegand (1931) pre-cooled sirup coated the berry against oxygen and preserved it well. Dry, coarse sugar on top of the pack of berries formed a protective coat against oxidation and the fruit remained normal except for lack of sweetness in flavor. Some of the sugar coating did not dissolve. Fieger et al. (1946) found better quality berries when they were packed in dry sugar rather than in sirup. The quality seemed to relate to the amount of sugar absorbed; therefore, the sliced berries with dry sugar were the best in the study. Flavor of the berries was retained best with dry sugar, and the color was not affected.

Packing with Corn Sugar. Gilbert (1956) recommended the use of granular corn sugar in frozen berries because the heavy coating it formed prevented oxidation of the fruit during thawing and prior to use. Berries packed with granular corn sugar were found to have bright color, fresh flavor and turgid texture. The increased protective effect of the corn sugar over sucrose was attributed to the comparatively high molecular weight of corn sugar. Dried corn sirup solids caked on the fruit in work cited by Caul and Sjöström (1951). In their study the appearance of blackberries and raspberries ranged from good to excellent and the sweetness was judged a different type from the sweetness of sucrose, with more sour and bitter notes. Aref et al. (1956) reported that corn sugar-capped berries had a lighter color and had been injured more because of the large crystals, than the sucrose-capped berries, although the ascorbic acid content was not affected. The differences which were found in the study related to the ratio and method of application of the sugar rather than to the kind of sugar.

Adding Sorbitol to the Pack. The humectant, sorbitol, improved texture and palatability of dietetic pack fruits in a report by the Food Protection Committee of the Foods and Nutrition Board (1956). Sorbitol was useful for its technological properties, it was stated. In an anonymous review (1956) it was stated that sorbitol had a diuretic and a laxative effect. Studies by Ellis and Krantz (1941) showed that human beings could tolerate as much as 40 g of sorbitol if spread throughout the day.

Packing With Colloidal Agents and Calcium Salts. Addition of colloidal materials to the berries increased the drained weight of the thawed berries, indicating less breakdown of the berry structure, in work by Baker (1941), Barton (1951), Wegener et al. (1951b), Hoover and Dennison (1955), and Sidwell and Cain (1955). Baker (1941) found improvement in strawberries with the addition of dry pectin and sugar, sliced berries giving the best results. Variety influenced the time required for the pectin to show effects. Added calcium salts prevented the pectin from combining with salts in the fruit.

The colloids used by Barton (1951) were sodium alginate, high methoxyl pectin, and low methoxyl pectin mixed with dry sugar in 0.05 and 0.10 per cent proportions based on berry weight. The berries, sugar and colloids were blended and subjected to a vacuum so that the firming agents could penetrate the berry and form a gel throughout. The drained weights ranged from 91.5 to 100 per cent of the fresh berry weight. The berries held their shape and with the higher percentage of low methoxyl pectin, soft jelly clumps were noted. The flavor seemed better in berries with the higher drained weights.

Wegener et al. (1951a,b) packed berries with low methoxyl pectin, a kelp extractive (propylene glycol alginate) and Irish moss extractive. When mixed with the sirup, these colloids improved the drained weight of the berries and maintained their effectiveness when the berries were redrained. Percentages of 0.15 and 0.20 low methoxyl pectin based on berry weight, increased the drained weight as much as when percentages of 0.30 and 0.40 were used. The two higher percentages of low methoxyl pectin left a gel after thawing while the kelp extractive and the Irish moss extractive were viscous and hard to handle at 0.30 and 0.40 per cent. All three colloids improved the gloss and shape retention of the berries. The flavor was unchanged.

Hoover and Dennison (1955), using 0.3 per cent low methoxyl pectin based on berry weight, found a highly significant increase in drained weight. A significant color improvement also was noted. Sidwell and Cain (1955) reported that the drained weight of raspberries was increased significantly by low methoxyl pectin with or without calcium salts. Solidity and sheen were improved by the treatments. There was not always a correlation between drained weight and solid appearance. Berries treated with 0.20 per cent low methoxyl pectin, with a calcium lactate dip, and with 0.25 per cent low methoxyl pectin plus a calcium chloride dip showed gelling.

A pectin treatment of 0.15 per cent low methoxyl pectin, based on berry weight, in 60 per cent sirup decreased the juice drained from strawberries by 10 per cent in a study cited by Murphy et al. (1954). These workers reported no other particular effects. Kertesz (1951) stated that sugar and dry pectin prevented "bleeding" cherries.

The effect of the addition of calcium to raspberries before freezing was investigated by Sidwell and Cain (1950) and Kertesz (1951). These workers found that this treatment improved the shape of the frozen berries. Kertesz (1951) attributed the firming action of calcium to its reaction with plant pectins present. Erikson and Boyden (1947) found that the texture of canned strawberries was slightly firmed by the addition of calcium salts, and that ascorbic acid was apparently protected. These workers adjudged that the extent to which the reaction of plant pectin and calcium occurred depended on the ratio of pectin to protopectin (the greater the amount of pectin the more disintegration), and the degree of ripeness, which determined the amount of pectin present in the fruit. Kaloyereas (1947b) reported that calcium chloride added to strawberries improved the firmness, and had a slight effect on the color, flavor and aroma of the berries.

<u>Freezing Rate</u>. In reports by Woodroof (1930) and Wiegand (1931), it was shown that a short freezing time improved the quality of the berries. Woodroof (1938) found that intimate contact with the refrigerant seemed to be more important than low temperature, per se. Freezing rapidly, at temperatures ranging from -65^{o} F. to -85^{o} F., decreased the drip and gave a firmer product

after thawing, Kaloyereas (1947). Kethley et al. (1950) stated that quick, low temperature freezing, in which the berry remained in the zone of crystallization a short period of time, lessened the breakdown of structure in the berries. Lutz et al. (1932) found no difference between slowly and rapidly frozen berries after eight months storage at 16° F. to 18° F. Guerrant (1957) stated, in his study dealing with color and ascorbic acid content only, that -20° F. storage was best for strawberries. In the anonymous article (1951) about the Danish freezing process, quick freezing was said to be beneficial because surfaces froze instantly, forming a cold shell which prevented escape of flavor, aroma and juice.

Methods for Evaluating the Quality of Frozen Strawberries

Palatability Tests. Descriptive terms and numerical ratings of the characteristics of fruits were suggested for scoring the palatability of fruits by Dawson and Harris (1951). Fruits were rated on scales with one to five or one to seven ranges. It was suggested also that strawberries be ground for scoring flavor.

Drip and Drained Weight. The drip was found to correspond in a practical way to the changes occurring during freezing in work by Kaloyereas (1947a,b). He devised several methods for determining drip of strawberries. He had good results by compressing the berries with mercury and also by thawing in ether. He pointed out that the method of draining over mesh into a graduated cylinder was not good because no equilibrium was reached. Joslyn and Marsh (1933) reported that it was difficult to drain juice from the thawed product, but the data so obtained were consistent. Barton (1951), Wegener et al. (1951a,b), Hoover and Dennison (1955) and Aref et al. (1956) used the drip method with a No. 8 wire mesh screen to determine the drip and drained weight of thawed berries.

Color Tests. In color comparisons, MacKinney and Chichester (1954) pointed out that deviations from standard color were interpolated by the eye with surprising accuracy in the spinning disc additive colorimeter. Lighting was standard and colors were of moderate saturation, they added.

Ascorbic Acid Content. Rapid determination of the ascorbic acid in fruits and vegetables was done by Loeffler and Ponting (1942) by disintegrating the sample in dilute metaphosphoric acid in a high speed cutter and measuring the decolorizing effect of the extracted ascorbic acid on indophenol dye with a photoelectric colorimeter. The ascorbic acid was distributed throughout the filtrate, so a small amount could be used for the final analysis. With the one per cent metaphosphoric acid, the pH was low enough to prevent loss of the vitamin in blending and high enough to prevent too rapid decolorizing of the dye. Tressler and Evers (1957) asserted that the basic method of Loeffler and Ponting can be used with any photoelectric colorimeter with which mixing and reading can be done rapidly. However, the "ascorbic acid factor" for the instrument must be redetermined with different instruments.

EXPERIMENTAL PROCEDURE

Statistical Design of the Experiment

Blakemore and Premier strawberries were obtained over a period of three weeks from the Kansas State College horticulture department farms. A Youden Square design with six treatments and six replications was used for each variety. Five of the six treatments were included in each replication. The treatments and the order in which they were applied to the Blakemore and Premier berries, are given in Tables 1 and 2, respectively.

Table 1. Statistical design for Blakemore strawberries.

Replications					
I	II	III	IV	V	VI
B4[1]	B6	B1	B3	B2	B5
B5	B3	B4	B2	B1	B6
B2	B4	B5	B6	B3	B1
B3	B2	B6	B1	B5	B4
B6	B1	B3	B5	B4	B2

[1] Treatments:

B1. Cane sugar, 25%.
B2. Cane sugar, 25%; and low methoxyl pectin, 0.2%. (M.C.P. "low sugar" pectin, Mutual Citrus Products Company, Anaheim, California.)
B3. Cane sugar, 25%; low methoxyl pectin, 0.2%; and calcium chloride, 0.038%. (USP Fine granulated, white. $CaCl_2 \cdot 2H_2O$.)
B4. Corn sugar, 41%. (Granular Frodex. American Maize-Products Company, New York, New York.)
B5. Corn sugar, 41%; and low methoxyl pectin, 0.2%.
B6. Corn sugar, 41%; low methoxyl pectin, 0.2%; and calcium chloride, 0.038%.

Table 2. Statistical design for Premier strawberries.

Replications					
I	II	III	IV	V	VI
P6[1]	P5	P3	P1	P4	P2
P4	P1	P5	P6	P2	P3
P5	P2	P1	P3	P6	P4
P1	P3	P2	P4	P5	P6
P2	P4	P6	P5	P3	P1

[1] Treatments:

P1. Cane sugar, 25%.
P2. Cane sugar, 25%; and low methoxyl pectin, 0.5%.
P3. Cane sugar, 25%; low methoxyl pectin, 0.2%; and calcium chloride, 0.038%.
P4. Cane sugar, 25%; and Sorbo, 5%. (Sorbo, 70% D-sorbitol solution. Chemical department, Atlas Powder Company, Wilmington, Delaware.)
P5. Cane sugar, 12.5%; and Sorbo, 5%.
P6. Cane sugar, 12.5%; and Sorbo, 10%.

Preparation and Freezing of Samples

One or two quarts of the berries were washed in pans of cold tap water, and quickly drained in wire colanders. They were capped immediately and sliced in half with stainless steel paring knives. Samples of 100 g each were then weighed into polyethylene freezer bags, on a Toledo scale, and the treatments to be tested were applied.

All percentages were based on the weight of the berries. The low methoxyl pectin and calcium chloride were weighed in eight sample lots on an analytical balance and blended with the sugar for eight samples by sifting three times in a Foley five-cup sifter. The Sorbo was weighed directly into the bags of berries on a torsion balance. The large crystals of corn sugar were blended to a powder in a Waring Blendor just before use.

The bags were closed and tied with plastic covered wire. Before freezing, a sirup was allowed to form in the bags from the dry ingredients and the natural juice of the berries. Duplicate bags were then packed in each cardboard freezer box and placed on the coils of a home freezer. After one day, the boxes were removed from the coils and stored on the freezer shelves at approximately -20° F. Samples to be tested while fresh were stored in the refrigerator until used.

Evaluation of Strawberries

Tests were made on the treated berries while fresh, after one day of frozen storage and after four months of frozen storage. The results of the tests are shown in Tables 16 through 28 in the Appendix.

Thawing of Frozen Samples. The samples tested after freezing were removed from the freezer and allowed to thaw at room temperature in the plastic bags, to a point where the berries could be separated but some ice crystals still remained. Duplicate 100-g samples of each treatment were thawed. One was used for palatability tests and one for determination of drip, drained weight, ascorbic acid content, and color comparison.

Palatability. Fresh samples and thawed frozen samples were scored by a tasting panel of seven experienced persons, using Form I (Appendix). The berries were turned out into flat white bowls which were coded with numbers so that the treatments were unknown to the tasters. The samples were observed in the bowls and then small samples were removed to white coded plates for individual tasting. Color scoring was done by daylight to assure as true a color impression of the berries as possible.

"Drip" and Drained Weight. The "drip" was determined by placing the thawed sample in a four-inch diameter polyethylene funnel and allowing it to drain into a 100-ml graduate cylinder for three minutes from the time of the first drop. A Kodak timer was used. The amount of "drip" in milliliters, was read from the cylinder, and the berries were turned from the funnel onto the pan of an Ohaus triple beam balance and weighed, to obtain the drained weight. Then the berries and juice were transferred quantitatively to the container used for ascorbic acid determination.

Ascorbic Acid. The ascorbic acid content of the fresh and thawed frozen berries was determined by the Loeffler-Ponting colorimetric method, as modified by workers at Kansas State College and described by Peaslee (1956) for use with the Klett-Summerson photoelectric colorimeter (Appendix).

Color. Approximately 0.5 ml of the filtrate used for ascorbic acid determination were dropped on a white blotter. The spot of color was masked with a double thickness of filter paper (#1 Whatman) and matched with the color plates in the Dictionary of Color by Maerz and Paul (1950). Two 3/8-inch squares were cut side by side from a double thickness of filter paper; one square to mask the color on the blotter and one to mask the color in the book. The color matched from the Dictionary of Color was recorded using the letter-number code of the dictionary. The first digit of the code indicated the particular plate of color blocks. The second digit indicated hue, and the capital letter indicated value, B being more grey than A as the sequence went.

RESULTS AND DISCUSSION

Quality of Fresh Strawberries

The quality of the fresh strawberries was evaluated by palatability tests and ascorbic acid content. The mean scores of the fresh berries for each palatability factor, as shown in Table 3, ranged from 5.10 to 6.50, or from good to very good, but not excellent in the judgment of the panel.

Table 3. Mean palatability scores and ascorbic acid content of each variety of fresh strawberries.

Factors	Variety: Blakemore	Variety: Premier
Aroma	6.50	6.39
Color	6.43	5.82
Shape	6.47	5.35
Flavor	5.90	6.05
Texture	6.20	5.10
Seediness	5.77	5.36
Per cent acceptability	98.6	97.6
Ascorbic acid (mg/100g)	56.94	69.71

Ascorbic acid content for the two varieties of berries when fresh averaged 56.94 and 69.71 mg/100 g sample (Table 3). These values lie within the range of the ascorbic acid content of berries acceptable for eating, according to Scott and Schrader (1947). They reported the desirable range to be 53.0 to 85.3 mg/100 g sample.

Table 4. Analysis of variance and significance for palatability factors, per cent acceptability and ascorbic acid content of strawberries.

Factors	Sources of variation: Variety-treatment combinations	Storage	Combination x storage
D/F	11	2	22
Palatability factors			
Aroma	***	***	ns
Color	***	***	ns
Shape	***	***	ns
Flavor	***	***	ns
Texture	***	***	ns
Seediness	***	***	ns
Per cent acceptability	**	ns	ns
Ascorbic acid content	***	***	ns

** - Differences significant at the 1 per cent level
*** - Significant at the 0.1 per cent level
ns - Non-significant

Effect of Freezing and Frozen Storage

In the analysis of palatability scores, per cent acceptability, and ascorbic acid content, the data for both varieties were combined in order to show the effects of freezing and frozen storage. Certain overall effects were created in which variety and treatments showed no interaction (Table 4). All berries after one day of frozen storage showed significant lowering of palatability scores, but no significant change in ascorbic acid content (Table 5). Actually, the mean ascorbic acid content increased approximately one mg after one day of storage.

Table 5. Mean palatability scores, ascorbic acid content, and significance of strawberries for each storage period for both varieties. (n = 72)

Frozen storage periods	Mean scores of palatability factors: Aroma	Color	Shape	Flavor	Texture	Seediness	Ascorbic acid content mg/100 g
0 (fresh)	6.45	6.11	5.90	5.98	5.63	5.56	63.55
	*	*	*	*	*	*	ns
1 day	6.27	5.94	5.41	5.42	4.73	5.15	64.54
	*	*	near*	*	*	*	*
4 mo.	5.92	5.60	5.23	5.05	4.60	4.84	56.13

* - Differences significant at the 5 per cent level
ns - Non-significant
near* - Significant at about the 6 or 7 per cent level

A possible explanation of this phenomenon is that some of the dehydro ascorbic acid present in the fresh berries might have been reduced to ascorbic acid during the freezing process. Then the increased amount of ascorbic acid showed up in the analysis after one day of storage.

Four months additional storage brought another significant decrease in the scores for all palatability factors, excepting shape, which was near significance (Table 5). Also, ascorbic acid content decreased significantly after this period of storage (Table 5). Per cent acceptability, however, did not vary significantly with the storage periods, shown by the analysis of variance in Table 4.

Considering these effects of freezing and storage, it seemed that freezing in itself had a deleterious effect on eating quality but apparently not on nutritive value of the berries. Continued frozen storage caused a downward trend in which nutritive value also deteriorated. In this study, the treatments seemed to show no significant effect on the deterioration of ascorbic acid.

Variety Differences

In order to show the effects of variety differences, the data for all storage periods were combined. The mean palatability scores for Blakemore and Premier strawberries are shown in Table 6. In nearly all cases, Blakemore scores were higher than those for the Premier. The scores for texture and shape showed the greatest differences, whereas per cent acceptability did not show any particular distinction between the two varieties (Table 6).

Table 6. Mean scores for each palatability factor, per cent acceptability and ascorbic acid content for each strawberry variety and all storage periods. (n = 36)

Factors	Mean scores	
	Blakemore	Premier
Aroma	6.19	6.21
Color	6.09	5.69
Shape	6.09	4.98
Flavor	5.36	5.58
Texture	5.44	4.56
Seediness	5.36	5.02
Per cent acceptability	97.54	97.90
Ascorbic acid (mg/100g)	55.17	67.29

The variety differences were apparent in the array of mean scores regardless of the treatments applied (Table 8).

Table 7. Mean ascorbic acid content of strawberries for each treatment and frozen storage period. (n = 6)

Treatments	Frozen storage periods: 0 (fresh)	1 day	4 months	Average
	mg/100 g			
B1	54.14	58.94	48.47	53.85
B2	57.46	57.98	45.84	53.76
B3	58.09	59.16	50.19	55.81
B4	56.41	57.21	51.10	ns 54.91
B5	58.04	59.43	51.02	56.16
B6	57.97	60.11	51.45	56.51
				*
P1	70.72	70.90	60.92	67.51
P2	70.55	69.47	60.63	66.88
P3	69.74	67.92	63.37	ns 67.01
P4	68.99	69.53	61.49	66.67
P5	68.67	70.34	64.16	67.72
P6	69.57	71.42	62.87	67.96

† The means at the ends of the brackets, and within them, do not differ significantly.

Significant differences at the five per cent level were detected between ascorbic acid content of the two varieties. Premier strawberries (P) were significantly higher than Blakemore (B) in ascorbic acid content as shown in Table 7. This was the only criterion in which Premier showed any superiority. As presented in Table 8, Blakemore berries (B) had significantly higher texture and shape scores than the Premiers (P). Also, color and seediness scores for Blakemore berries were higher, although there was no significant dividing line between the two varieties.

In each variety, two treatments were exactly alike; B1 was the same as P1 and B3 the same as P3. In the pairs of treatments named, the varieties showed significant differences in color, shape, texture and seediness when the pairs of treatments were subjected to the lsd test (Table 8).

Table 8. Mean scores and significance for each palatability factor, each treatment of strawberries and all storage periods. (n = 18)

Treatments	Mean scores for palatability factors					
	Aroma	Color	Shape	Flavor	Texture	Seediness
B1	6.47	6.27	6.04	5.86	5.55	5.46
B2	6.45	6.06	6.05	5.78	5.47	5.40
B3	6.27	6.12	6.05	5.67	5.49	5.45
B4	ns 6.02	*5.97	*6.06	ns4.79	5.45	5.29
B5	5.79	6.11	6.13	5.07	* 5.31	* 5.26
B6	6.13	6.01	6.19	4.99	5.34	5.27
P1	ns 6.37	* 5.78*	* 5.07ns	5.86	* * 4.63	* 5.17
P2	6.11	5.69	4.98	5.28	4.49	4.93
P3	6.11	5.69	5.00	5.59	4.57	5.01
P4	6.23	5.71	5.14	5.66	4.61	4.93
P5	6.22	5.65	4.82	5.47	4.54	5.06
P6	6.23	5.63	4.88	5.63	4.53	4.99
lsd* =	0.28	0.36	0.46	0.32	0.31	0.29

ns The means at the ends of the brackets do not differ significantly.

* The means at the ends of the brackets are significantly different at the 5 per cent level.

Effects of Treatments

The various treatments were restricted to either one or the other variety in all cases excepting the two pairs (B1 and P1, and B3 and P3) used to show variety differences. The data for all storage periods were combined in the arrays of palatability scores in Table 9 to show differences attributed to treatment. The palatability factors omitted from Table 9, and the ascorbic acid content showed no differences ascribed to treatment.

Low Methoxyl Pectin With and Without Calcium Chloride. Among the Blakemore berries, the treatments with low methoxyl pectin (B2 and B5) and low methoxyl pectin plus calcium chloride (B3 and B6) seemed to have no appreciable effect on the scores for the palatability factors or on the per cent acceptability. In Table 9, it can be seen that the scores for these treatments are scattered throughout the array. However, among the Premier berries, treatments with an increased level of low methoxyl pectin (P2) and low methoxyl pectin plus calcium chloride (P3) had lower average aroma scores than the treatment with sugar alone (P1). In per cent acceptability, the treatments with sugar alone (P1), with added five per cent level of Sorbo (P4), and with ten per cent level Sorbo plus 12.5 per cent sugar (P6) were all significantly higher than treatment P2. The method of application may have been responsible for the ineffectiveness of these additives. The same levels used with a sirup solution rather than dry sugar had noticeable effects in other investigations reported in the literature.

Table 9. Arrays of mean scores for aroma and flavor, and per cent acceptability for each treatment of the strawberries for all storage periods. (n = 18)

	Aroma				Flavor				Acceptability		
	Treatment	Mean scores			Treatment	Mean scores			Treatment	Per cent	
	B1	6.47			B1	5.86			B2	100.00	
	B2	6.45	ns		P1	5.86			B1	100.00	
	P1	6.37			B2	5.78			P1	100.00	ns
	B3	6.27			B3	5.67			B3	99.27	
	P4	6.23			P4	5.66			P4	99.07	
	P6	6.23		*	P6	5.63			P6	99.07	
near*	P5	6.22			P3	5.59			P5	98.13	
	B6	6.13	ns		P5	5.47	*		P3	97.00	*
	P2	6.11			P2	5.28			B4	96.20	
	P3	6.11			B5	5.07		*	B6	96.00	
	B4	6.02			B6	4.99		ns	P2	94.13	
	B5	5.79	*near		B4	4.79			B5	93.78	
	lsd* = 0.28				lsd* = 0.32				lsd* = 4.47		

near* The means at the ends of the brackets are almost significantly different at the 5 per cent level, whereas those within the brackets are not significantly different.

ns The means at the ends of the brackets, and within them, do not differ significantly.

* The means at the ends of the brackets are significantly different at the 5 per cent level, whereas those within the brackets are not significantly different.

Corn Sugar. In aroma, flavor and per cent acceptability, the berries treated with corn sugar (B4, B5 and B6) scored lower than those treated with cane sugar (B1, B2 and B3). The differences in flavor scores were significant at the five per cent level. No significant differences in color, shape, texture or seediness were found due to the substitution of corn sugar for sucrose.

Sorbo. Strawberries treated with five per cent Sorbo and 12.5 per cent sugar (P5) received the lowest scores of all berries treated with Sorbo (P4, P5 and P6); the berries treated with ten per cent Sorbo and 12.5 per cent sugar (P6) scored the next lowest. The berries treated with 25 per cent sugar (P1) had higher flavor scores than those treated with Sorbo, but the difference was not clear cut. It would appear that the reduction of sugar in treatments P5 and P6 caused the lower scores since the berries treated with Sorbo and the usual amount of sugar (P4) had produced berries with the highest flavor score of the three. The Sorbo apparently did not have the same sweetening effect as sugar. In acceptability, the berries treated with sugar alone (P1), with 25 per cent sugar and five per cent Sorbo (P4) and with 12.5 per cent sugar and 10 per cent Sorbo (P6) were scored significantly higher in flavor than those treated with sugar and 0.5 per cent low methoxyl pectin (P2). Sorbo had no effect beyond reasonable sampling differences on the aroma, shape, color, texture and seediness of the berries.

Relationships Between Certain Measurements Used

Drip and Drained Weight. In the analysis of variance, the drip and drained weight showed non-significance with all variations (Table 10).

Table 10. Analysis of variance for drip and drained weight of strawberries.

	Sources of variation		
Factors	Variety-treatment combinations	Storage	Combination x storage
D/F	11	1	11
Drip	ns	ns	ns
Drained weight	ns	ns	ns

Analysis of the correlations between texture and drip, and texture and drained weight was insensitive because the number of replications was small. No significant correlation value was found for these, although the values approached significance for the texture and drip in treatments B3, B5, P2, P4, P5, and P6, and for the texture and drained weight in treatments B5, P2, P5, and P6 (Table 11). The fact that the value approached significance six times with the texture and drip and only four times with the texture and drained weight might indicate that the drip was a better measurement for texture evaluation. Texture scores and drained weight showed positive correlation tendencies and texture scores and drip tended to show negative correlation, as might be expected.

Per Cent Acceptability and Per Cent Retention. In the correlation of per cent acceptability and per cent retention of ascorbic acid, difficulty was again encountered because of the small number of replications. In this case, the correlation coefficient obtained generally was non-significant (Table 12).

Table 11. Linear correlation coefficients for texture and drip, and texture and drained weight, for each treatment of strawberries for all storage periods. (n = 18)

Treatments	Correlation coefficients: Texture and drip	Correlation coefficients: Texture and drained weight
B1	0.048 ns	-0.202 ns
B2	0.028 ns	-0.038 ns
B3	0.419 [1]	-0.195 ns
B4	-0.166 ns	-0.011 ns
B5	-0.663 [1]	0.536 [1]
B6	0.123 ns	-0.205 ns
P1	-0.100 ns	0.053 ns
P2	-0.483 [1]	0.411 [1]
P3	-0.085 ns	0.066 ns
P4	0.248 [1]	-0.004 ns
P5	-0.578 [1]	0.597 [1]
P6	-0.325 [1]	0.481 [1]

[1] Significant at about the 6 or 7 per cent level

The per cent acceptability did not show differences in the variety as the other criteria did. However, significant treatment differences were detected in the acceptability percentages.

Color Matching. The color values given in Table 28 (Appendix, p. 55) refer to the color plates with which the filtrates of the samples were matched. The first digit was number one in all cases, indicating the plate of color blocks ranging in shades of red to orange. The second digit showing hue, was either eight or nine in this study; the nine being more orange than eight. The capital letters indicating value, ranged from B to E, E being greyed more than B.

Table 12. Correlation and significance of per cent acceptability and per cent retention of ascorbic acid for each treatment of strawberries. (n = 18)

Treatments	Correlation coefficient for per cent acceptability and per cent retention
B1	0 ns
B2	0 ns
B3	0 ns
B4	-0.324 ns
B5	-0.039 ns
B6	-0.056 ns
P1	0 ns
P2	-0.376 ns
P3	-0.124 ns
P4	0 ns
P5	0.002 ns
P6	0 ns

The percentage of times that a number or letter was present in a given treatment, variety or storage period gave some indication of the color changes. In the Premier berries, 69 per cent were hue number eight and 31 per cent were hue number nine, whereas in Blakemore, 90 per cent were hue number eight and 10 per cent hue number nine (Table 13). This showed that the Premier was in general, a slightly more orange-colored berry than the Blakemore.

Table 13. Percentages of numbers indicating the color hue for each variety of strawberries. (n = 216)

Varieties	Hue number 8	Hue number 9
	Per cent	
Blakemore	69	31
Premier	90	10

The percentages of color values were similar for the two varieties (Tables 14 and 15). With the fresh and one day frozen storage period for Blakemore, the majority of the values were C and D, while after four months, D alone had the majority (Table 14). This suggested a slight darkening of the color value in Blakemore, agreeing with findings of Guerrant (1957). The percentages of darker values, such as E, decreased with increased storage in the Premier berries, while the lighter value, such as C and B, increased (Table 15). Therefore, it seemed that the Premier berries may have faded during storage, in agreement with Barton (1951).

Table 14. Percentages of color value letters for each storage period of Blakemore strawberries. (n = 72)

Storage periods	Color value letters B	C	D	E
	Per cent			
0 (fresh)	0	39	44	17
1 day	13	39	26	22
4 months	0	13	74	13

Table 15. Percentages of color value letters for each storage period of Premier strawberries. (n = 72)

	Color value letters			
	B	C	D	E
Storage periods	Per cent			
0 (fresh)	0	16	42	42
1 day	4	24	36	36
4 months	10	32	48	10

In both varieties, the greatest color change was noticeable at the four-month storage period (Tables 14 and 15). Color, palatability and ascorbic acid content all tended to deteriorate with four-month storage.

Suggested Treatments for Future Investigations

Since the results of this study showed no treatment that produced decisive improvement in strawberry quality, other treatments should be considered for future investigations. These might include addition of increased levels of the low methoxyl pectin and calcium chloride, use of sirups rather than dry sugar, use of other colloidal materials such as Irish moss and kelp extractives, and freezing at extremely low temperatures with carbon dioxide or liquid air.

SUMMARY

The purposes of this study were to determine the effect of freezing and frozen storage on strawberries; to compare the relative adaptability to freezing of two varieties of Kansas strawberries, Blakemore and Premier; and to determine the effect of treatment with certain additives on the improvement of the quality of the frozen berries.

The quality was measured by palatability tests and by determining drip and drained weight, ascorbic acid content and color changes. A minor objective of the study was to evaluate the measurements used by studying the correlations of texture scoring with the drip and drained weight, and the per cent retention of ascorbic acid with per cent acceptability.

The additives used for treatments were (1) cane sugar, (2) cane sugar plus low methoxyl pectin, (3) cane sugar plus low methoxyl pectin and calcium chloride, (4) cane sugar plus an increased level of low methoxyl pectin, (5) corn sugar, (6) corn sugar plus low methoxyl pectin, (7) corn sugar plus low methoxyl pectin and calcium chloride, (8) cane sugar plus Sorbo, a 70 per cent solution of sorbitol, (9) a half portion of cane sugar plus Sorbo, and (10) a half portion of cane sugar plus an increased amount of Sorbo. The two varieties each received two identical treatments (1 and 3) so as to detect variety differences. The differences showed up regardless of treatment, however. The corn sugar treatments were applied to the Blakemore berries. The Sorbo treatments and the increased level of low methoxyl pectin

were applied to the Premier berries.

Six replications of the two varieties were obtained over a period of three weeks from the Kansas State College horticulture department farms. On the day of freezing, they were washed, capped, sliced in half and weighed in 100-g lots into polyethylene bags. Then the treatments were applied, the bags packed in cardboard boxes and the packages of berries frozen on the coils of an upright home freezer. After freezing, the packages were removed from the coils and stored on the shelves of the freezer at approximately -20° F.

Testing was done on the berries with no freezing, after one day, and four months of frozen storage. On the day of testing, the berries were thawed, and then evaluated by the several methods. Palatability scoring was done by an experienced tasting panel, whereas texture was tested also by the determination of the amount of drip and the drained weight. The ascorbic acid content was determined by a modification of the Loeffler-Ponting method and color changes were noted by comparing the sample color with printed color plates. All data were tabulated and subjected to statistical analyses appropriate to a Youden Square design.

Interpretation of the analyses revealed that freezing reduced palatability but not the ascorbic acid content. Frozen storage of four-month duration further reduced palatability and also reduced ascorbic acid content. There were significant differences between the varieties. Blakemore was superior to Premier in palatability, but the Premier had higher ascorbic acid content than Blakemore. The treatments with low methoxyl pectin alone, and in combination with calcium chloride, lowered the Premier palatability scores but apparently not the Blakemore. The treatments substituting corn sugar had lower palatability scores than those using cane sugar. Sorbo treatments showed somewhat reduced palatability scores, compared to the treatment with sugar alone. The drip and drained weight determinations did not correlate significantly with texture scoring, nor did ascorbic acid retention correlate with per cent acceptability. The color comparisons showed trends that agreed with findings of some other investigations reported in the literature.

Possibly, Blakemore could be recommended as a variety more adapted to freezing than Premier, although ascorbic acid content might influence the recommendation. Since the results showed no treatment that produced decisive improvement in strawberry quality, other treatments should be considered for future investigations. These might include addition of increased levels of the low methoxyl pectin and calcium chloride, use of sirups rather than dry sugar, use of other colloidal materials such as Irish moss and kelp extractives, and freezing at extremely low temperatures with carbon dioxide or liquid air.

ACKNOWLEDGMENT

The author wishes to express her appreciation to Miss Gwendolyn L. Tinklin, Associate Professor in the Department of Foods and Nutrition, for her advice during the experimental phases, and guidance and aid in the preparation of the manuscript; to Dr. Dorothy L. Harrison, Head of the Department of Foods and Nutrition for her constructive criticism; to Dr. Grayce E. Goertz, Associate Professor in the Department of Foods and Nutrition, for her constructive criticism; to Dr. H. C. Fryer, Director of the Statistical Laboratory, for his assistance in the statistical analysis of the data; to Mr. William L. Beale, Instructor in the Department of Horticulture for his assistance in the experimental phase of the study; and to the tasting panel of the Department of Foods and Nutrition for their evaluation of the palatability of the products.

LITERATURE CITED

Anonymous.
Unique Danish freezing process used for tomatoes, melons, bananas. Refrig. Engg. 59:1209, 1238. 1951.

Anonymous.
Use of sorbitol in medicine. Nutrition Rev. 14:236-238. 1956.

Aref, M., A. P. Sidwell, and E. M. Litwiller.
The effects of various sweetening agents on frozen strawberries for preserve manufacture. Food Technol. 10:293-297. 1956.

Baker, George L.
Pectin as aid in freezing fruits. Food Indus. 13:55-57. 1941.

Barton, Richard R.
Improving the quality of frozen Premier strawberries. Proc. Amer. Soc. Hort. Sci. 58:95-98. 1951.

Caul, Jean F., and Loren B. Sjöström.
Effects of replacing sucrose in blackberry and raspberry packs. Quick Frozen Foods 13:59-61. May, 1951.

Dawson, Elsie H., and Betty L. Harris, compilers.
Sensory methods for measuring differences in food quality. Review of literature and proceedings of conference. Bureau of Human Nutrition and Home Economics. United States Department of Agriculture. Agriculture Information Bulletin No. 34. August, 1951.

Ellis, Fred W., and John C. Krantz, Jr.
Sugar alcohols; metabolism and toxicity studies with mannitol and sorbitol in man and animals. Jour. Biol. Chem. 141:147-154. 1941.

Erikson, S. E., and R. E. Boyden.
Effect of calcium chloride on firmness of some canned products and on their content of ascorbic acid. Kentucky Agr. Expt. Sta. Bull. 511. December, 1947.

Fieger, E. A., C. W. DuBois, and S. Kaloyereas.
Freezing experiments on strawberries. Fruit Prod. Jour. 25: 297-301. 1946.

Food Protection Committee of the Food and Nutrition Board.
The use of chemical additives in food processing, a report. Washington, D. C. National Academy of Sciences - National Research Council. Publication 398. February, 1956.

Gilbert, Phillip E.
Better frozen fruits with new corn syrup solids. Food Engg. 28:125-127. August, 1956.

Guerrant, N. B.
Changes in light reflectance and ascorbic acid content of foods during frozen storage. Jour. of Agr. and Food Chem. 5: 207-212. 1957.

Hoover, Maurice W., and R. A. Dennison.
Some treatments influencing the quality of Florida frozen strawberries. Proc. Amer. Soc. Hort. Sci. 65:188-194. 1955.

Joslyn, M. A., and G. L. Marsh.
Changes occurring during freezing storage and thawing of fruits and vegetables. University of California Agr. Expt. Sta. Bull. 551. 1933.

Kaloyereas, Socrates A.
Drip as a constant for quality control of frozen foods. Food Research 12:419-428. 1947a.

Kaloyereas, Socrates A.
Strawberry studies. A new method for determining firmness. Fruit Prod. Jour. 27:6-7. 1947b.

Kertesz, Z. I.
The pectic substances. New York: Interscience Publishers. 1951.

Kethley, T. W., W. B. Cown, and F. Bellinger.
Tests show optimum time for strawberry freezing. Food Engg. 22:56-58. 1950.

Lee, Frank A., and George L. Slate.
Chemical composition and freezing adaptability of raspberries. New York State Agr. Expt. Sta. Bull. 761. 1954.

Loeffler, H. J.
Retention of ascorbic acid in strawberries during processing, frozen storage, and manufacture of Velva Fruit. Food Research 11:69-83. 1946.

Loeffler, H. J., and J. D. Ponting.
Ascorbic acid. Rapid determination in fresh, frozen or dehydrated fruits and vegetables. Indus. and Engg. Chem. Analyt. Ed. 14:846-848. 1942.

Lutz, J. M., Joseph S. Caldwell, and H. H. Moon.
Frozen pack: studies on fruits frozen in small containers. Ice and Refrig. 83:111-113. 1932.

Maerz, A., and M. Rea Paul.
A dictionary of color. New York: McGraw-Hill Book Company. 1950.

MacKinney, G., and C. O. Chichester.
The color problem in foods. In advances in food research 5: 302-347. Edited by E. M. Mrak and G. F. Stewart. New York: Academic Press, 1954.

Murphy, Elizabeth F., Russell M. Bailey, and Mildred R. Covell.
Observations on methods to determine food palatability and comparative freezing quality of certain new strawberry varieties. Food Technol. 8:113-116. 1954.

Olcott, H. S.
Measurement of color and color differences in relation to quality. In symposium on color in foods. Advisory Board of Quartermaster Research and Development Committee on Foods. National Academy of Sciences - National Research Council. Washington, D. C. p. 163. November, 1954.

Peaslee, Mary Griebel.
Effects of certain calcium treatments on the quality of frozen green beans. M. S. Thesis. Unpublished. Kansas State College. 1956.

Robinson, W. B., F. A. Lee, G. L. Slate, and C. S. Pederson.
Chemical composition and freezing adaptability of strawberries. New York State Agr. Expt. Sta. Bull. 726. August, 1947.

Schrader, A. Lee, and D. H. Scott.
Quality comparisons of strawberry varieties as affected by processing with the freezing method. Proc. Amer. Soc. Hort. Sci. 50:246-250. 1947.

Scott, L. E., and A. Lee Schrader.
Ascorbic acid content of strawberry varieties before and after processing by freezing. Proc. Amer. Soc. Hort. Sci. 50:251-253. 1947.

Sidwell, Arthur P., and Robert F. Cain.
The effects of low methoxyl pectin and calcium salts on the drained weight and calcium content of processed raspberries. Food Technol. 9:438-441. 1955.

Tressler, Donald K., and Clifford F. Evers.
The freezing preservation of fruits, fruit juices and vegetables. New York: Avi Publishing Company, 1936.

Tressler, Donald K., and Clifford F. Evers.
The freezing preservation of foods. Volume 1. Westport, Conn.: Avi Publishing Company, 1957.

Wegener, J. B., B. H. Baer, and P. D. Rodgers.
Addition of colloids improves quality of strawberries. Quick Frozen Foods 14:50-51. August, 1951a.

Wegener, John B., Beverly H. Baer, and P. D. Rodgers.
Improving quality of frozen strawberries with added colloids. Food Technol. 5:76-78. 1951b.

Wiegand, Ernest,H.
The "Frozen-Pack" method of preserving berries. Oregon State Agr. Expt. Sta. Bull. 278. May, 1931.

Woodroof, J. G.
Preserving fruits by freezing I. Peaches. Georgia Expt. Sta. Bull. 163. August, 1930.

Woodroof, J. G.
Preservation by freezing. Some effects on quality of fruits and vegetables. Georgia Expt. Sta. Bull. 168. December, 1931.

Woodroof, J. G.
Freezing methods evaluated. Food Indus. 10:618-621. 1938.

APPENDIX

Form I

Score Card

STRAWBERRIES

Name ________________

Date ________________

Sample Number	1	2	3	4	5
1. Aroma: fresh, fruitlike, characteristic strawberry					
2. Appearance: Color: Bright, not too pale nor too dark					
Shape: Berries separate and distinguishable; not broken down					
3. Flavor: Fresh; not bitter, flat, nor "off"					
4. Texture: Firm yet tender, not mushy					
5. Seediness: Not noticeable					
Would you consider this an acceptable product to serve at a meal?					

Scale:
- 7 - excellent
- 6 - very good
- 5 - good
- 4 - fairly good
- 3 - fair
- 2 - poor
- 1 - very poor
- 0 - inedible

Comment:

Preparation of Solutions Used for Ascorbic Acid Testing

All solutions used were at room temperature, approximately 24° C.

Metaphosphoric Acid. A solution of ten per cent metaphosphoric acid was prepared by dissolving 100 g of metaphosphoric acid pellets in less than 1000 ml of distilled water, and then making up to volume in a 1000-ml volumetric flask. The ten per cent acid was stored in the refrigerator to prevent deterioration. One per cent metaphosphoric acid was prepared fresh from the stock solution of ten per cent acid each time the analysis was made. One hundred milliliters of the ten per cent acid was added to 900 ml distilled water and mixed in a stoppered graduate cylinder.

Dye. A solution of 2,6-dimethylbenzenone-indophenol dye was prepared by dissolving 20 ml of the crystalline dye in less than 1000 ml boiling distilled water, cooling to room temperature and making up to volume in a 1000-ml volumetric flask. The dye solution was stored in the refrigerator to prevent deterioration.

Ascorbic Acid. The ascorbic acid solutions used in dye standardization were made up in dilutions of three, four and five μg of the crystalline ascorbic acid (Cebione-Merck, U. S. P.) to 100 ml of one per cent metaphosphoric acid. First, a solution of ascorbic acid was prepared by weighing 25 mg of the crystalline ascorbic acid on an analytical balance and dissolving it in one per cent metaphosphoric acid in a 250-ml volumetric flask, and making up to volume. Then, three, four and five milliliter portions of that solution were transferred with a Mohr-type pipette into 100-ml volumetric flasks and made up to volume with one per cent metaphosphoric acid.

Standardization of Dye

The dye was standardized with known solutions of ascorbic acid. First the Klett-Summerson colorimeter was calibrated to zero by introducing a Klett tube containing ten ml of distilled water and turning the zero adjustment knob. This step of the procedure was necessary to correct for turbidity of the water and the test tube. Then five ml of dye were pipetted with an automatic Friedricks-type pipette into all other matching Klett tubes.

Blank Reading. Into one tube of dye, five ml of the one per cent metaphosphoric acid was introduced with a five-ml volumetric pipette and the tube and contents quickly mixed by inverting and shaking. Within a specified 15 seconds from the beginning of the addition of the solution to the dye, a reading was obtained in the colorimeter. A Cenco interval timer was used to mark the 15-second interval. All colorimeter readings were double checked. The reading gave a measure of the amount of decolorization of the dye caused by the added acid and was called the blank reading. On each day of testing, a blank reading was obtained to check on deterioration of the dye. If the reading had changed, the dye was restandardized.

Ascorbic Acid Factor. A reading was obtained for each of the dilutions of ascorbic acid in much the same manner as for the blank reading, except that the dilutions rather than the metaphosphoric acid solution were pipetted into the dye. This was necessary to establish the range in which the dye was most sensitive to the acid.

By subtracting the reading for each of the ascorbic acid dilutions from the blank reading, a corrected reading for each unknown was obtained. The ascorbic acid factor used in calculating the ascorbic acid of the unknown solution was determined by use of the formula:

$$\frac{\text{concentration of ascorbic acid}}{\text{corrected reading for unknown}}$$

Ascorbic Acid Determinations

Extraction. To prepare a filtrate to be analyzed by the colorimetric method, each 100-g sample of strawberries with all its juice was washed, with a polyethylene wash bottle, into approximately 400 ml of one per cent metaphosphoric acid in a Waring Blendor jar, and then blended at high speed for five minutes. A few drops of n-butyl stearate were added to prevent excessive foaming. The blended mixture was transferred quantitatively into a 1000-ml volumetric flask and made up to volume with one per cent metaphosphoric acid. The mixture was thoroughly mixed and then a portion filtered through fluted filter paper (#1 Whatman) into a 125-ml Erlenmeyer flask.

Analysis of the Filtrate. The filtrate was first diluted by pipetting three, four or five ml into a 50-ml volumetric flask and making up to volume with one per cent metaphosphoric acid. The amount used varied depending upon the ascorbic acid content of the berries. The strength of the dilution needed to be such that when five ml of the dilution were added to a tube of the dye, the reading in the colorimeter was within the range of the readings of the known ascorbic acid solutions used in the dye standardization process.

Before taking readings it was necessary to adjust the colorimeter to zero to correct for turbidity of the dilution and its natural color. This was done by pipetting five ml of the dilution into a Klett tube containing five ml of distilled water, and adjusting the colorimeter to zero. Readings then were made for the dilution and the dye. A value for the ascorbic acid content, in mg per 100-g sample of strawberries, was determined by obtaining the corrected reading for the unknown as in the dye standardization and then using the formula:

$$\frac{\text{corrected reading} \times \text{ascorbic acid factor} \times \text{dilution}}{\text{five-ml aliquot}}$$

Table 16. Treatment B1. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors							Drip (ml)	Dr.wt. (g)	Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable			(mg/100g)	% Retention
	6.1	6.7	6.3	5.7	6.3	5.9	100	-	-	54.90	-
	6.7	6.7	6.7	6.6	6.8	6.3	100	-	-	57.64	-
Fresh	6.4	6.6	6.7	6.0	6.0	5.8	100	-	-	55.02	-
	6.6	6.3	6.2	6.3	6.0	5.6	100	-	-	52.07	-
	6.8	6.8	6.6	6.6	6.4	5.8	100	-	-	51.09	-
Av.	6.5	6.6	6.5	6.2	6.3	5.9	100	-	-	54.14	-
	6.3	6.4	5.8	6.1	5.1	5.3	100	30	85	67.10	122
	6.6	6.3	6.1	5.7	5.3	5.3	100	34	84	69.43	120
1 day	6.8	6.1	6.0	5.8	5.4	5.1	100	50	69	53.06	96
	6.6	6.1	5.7	5.7	5.3	5.8	100	33	84	59.93	115
	6.8	6.1	6.0	6.4	5.5	5.4	100	32	74	45.20	88
Av.	6.6	6.2	5.9	5.9	5.3	5.4	100	36	79	58.94	108
	6.4	6.4	6.3	5.4	5.0	5.7	100	30	90	52.31	95
	6.3	6.5	6.5	5.5	5.8	5.2	100	33	83	65.17	113
4 mo.	6.2	5.6	5.2	5.4	4.4	5.2	100	35	83	41.62	76
	6.2	5.5	5.3	5.5	5.2	4.7	100	41	73	39.96	77
	6.2	6.0	5.2	5.2	4.8	4.8	100	38	76	43.29	85
Av.	6.3	6.0	5.7	5.4	5.0	5.1	100	35	81	48.47	89
Grand Av.	6.47	6.27	6.04	5.86	5.55	5.46	100.00	-	-	53.85	-

Table 17. Treatment B2. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

	Palatability factors									Ascorbic acid	
Storage periods	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable	Drip (ml)	Dr.wt. (g)	(mg/100g)	% Retention
	6.6	6.1	6.7	6.1	6.7	6.0	100	-	-	59.78	-
	6.4	6.7	6.4	5.7	6.2	5.7	100	-	-	63.44	-
Fresh	7.0	6.4	6.3	6.1	5.8	6.0	100	-	-	57.97	-
	6.8	6.2	6.2	6.7	6.2	5.7	100	-	-	55.02	-
	6.7	6.8	6.7	6.3	6.1	5.8	100	-	-	51.09	-
Av.	6.7	6.4	6.5	6.2	6.2	5.8	100	-	-	57.46	-
	6.2	5.2	5.8	5.6	5.0	4.9	100	28	91	70.76	118
	6.4	6.4	6.3	6.0	5.4	5.1	100	24	89	65.88	104
1 day	6.7	6.4	5.8	5.6	5.0	5.5	100	35	79	59.93	103
	6.7	6.4	6.0	5.7	5.4	5.8	100	34	82	43.23	78
	6.8	6.1	6.0	6.0	5.5	4.9	100	39	79	50.11	98
Av.	6.6	6.1	6.0	5.8	5.3	5.2	100	32	84	57.98	100
	6.1	4.0	5.9	5.6	5.3	5.0	100	34	84	46.30	77
	6.4	6.0	6.3	5.6	4.9	5.7	100	32	88	48.02	76
4 mo.	6.0	6.0	5.2	5.0	4.6	5.2	100	30	85	48.28	83
	5.7	6.0	5.7	5.5	5.0	4.7	100	39	74	42.46	77
	6.2	6.2	5.5	5.2	5.0	5.0	100	44	75	44.12	86
Av.	6.1	5.6	5.7	5.4	5.0	5.1	100	36	81	45.84	80
Grand Av.	6.45	6.06	6.05	5.78	5.47	5.40	100.00	-	-	53.76	-

Table 18. Treatment B3. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors							Drip (ml)	Dr.wt. (g)	Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable			(mg/100g)	% Retention
	6.7	6.1	6.6	6.4	6.6	6.1	100	-	-	71.98	-
	6.7	6.6	6.3	5.8	6.2	6.0	100	-	-	57.34	-
Fresh	6.1	6.7	6.7	5.8	6.7	5.3	89	-	-	55.02	-
	6.7	6.7	6.6	6.0	6.1	6.1	100	-	-	56.98	-
	5.9	6.2	6.0	6.1	6.0	5.8	100	-	-	49.12	-
Av.	6.4	6.5	6.4	6.0	6.3	5.9	98	-	-	58.09	-
	6.3	5.4	5.6	5.4	4.6	4.8	100	28	90	68.32	95
	6.1	6.1	5.8	6.0	5.4	5.7	100	29	89	59.78	104
1 day	6.1	6.0	6.1	5.3	4.8	5.1	100	34	81	57.64	105
	6.7	6.6	6.1	6.1	5.2	5.6	100	40	75	59.93	105
	6.6	6.4	5.8	5.1	5.7	6.0	100	39	79	50.11	102
Av.	6.4	6.1	5.9	5.6	5.1	5.4	100	34	83	59.16	102
	6.1	4.4	6.0	5.9	5.3	4.7	100	29	91	56.60	79
	6.6	6.4	6.6	5.3	5.0	5.0	100	24	88	49.16	86
4 mo.	6.2	6.5	6.2	5.8	5.3	5.5	100	35	86	59.45	108
	5.8	6.0	5.4	5.2	4.6	5.4	100	21	93	43.29	76
	5.5	5.7	5.0	4.8	4.8	4.7	100	40	74	42.46	86
Av.	6.0	5.8	5.8	5.4	5.0	5.1	100	30	86	50.19	87
Grand Av.	6.27	6.12	6.05	5.67	5.49	5.45	99.27	-	-	55.81	-

Table 19. Treatment B4. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors									Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable	Drip (ml)	Dr.wt. (g)	(mg/100g)	% Retention
Fresh	6.6	6.3	7.0	5.4	6.4	5.7	86	-	-	50.33	-
	6.3	6.2	6.3	5.2	6.1	5.8	100	-	-	68.32	-
	6.0	6.7	6.6	5.4	6.7	5.8	100	-	-	64.19	-
	6.1	6.0	6.0	5.3	5.9	5.3	100	-	-	49.12	-
	6.7	6.4	6.3	5.6	6.1	5.8	100	-	-	50.11	-
Av.	6.3	6.3	6.4	5.4	6.2	5.7	97	-	-	56.41	-
1 day	5.4	5.9	6.5	4.2	4.9	5.0	86	33	*	54.90	109
	6.6	6.0	6.0	5.1	5.3	5.3	100	31	95	58.56	86
	5.6	5.7	6.0	4.4	4.6	5.1	100	40	87	73.36	114
	6.6	6.1	5.6	4.6	5.4	5.7	100	52	71	50.11	102
	6.6	6.2	5.8	5.1	5.5	5.2	88	32	80	49.12	98
Av.	6.2	6.0	6.0	4.7	5.1	5.3	95	38	83	57.21	102
4 mo.	5.9	5.7	6.7	4.3	5.1	4.7	83	34	90	50.59	100
	5.9	6.1	6.1	4.6	4.9	5.3	100	38	90	49.74	73
	5.3	6.0	6.2	4.0	5.3	5.2	100	36	86	68.60	107
	5.5	4.8	4.8	4.0	4.8	4.5	100	50	79	42.46	86
	5.2	5.5	5.0	4.7	4.7	5.0	100	38	74	44.12	88
Av.	5.6	5.6	5.8	4.3	5.0	4.9	97	39	84	51.10	91
Grand Av.	6.02	5.97	6.06	4.79	5.45	5.29	96.20	-	-	54.91	-

* Missing data

Table 20. Treatment B5. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors							Drip (ml)	Dr.wt. (g)	Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable			(mg/100g)	% Retention
	6.6	6.4	6.8	5.8	6.3	5.6	100	-	-	59.48	-
	6.0	6.2	6.4	5.7	6.2	5.8	100	-	-	61.57	-
Fresh	6.7	6.7	6.3	6.3	6.0	5.7	100	-	-	53.06	-
	*	*	*	*	*	*	*	-	-	*	-
	*	*	*	*	*	*	*	-	-	*	-
Av.	6.4	6.4	6.5	5.9	6.2	5.7	100	-	-	58.04	-
	5.5	6.1	6.4	5.0	5.0	4.9	100	30	-	60.39	102
	5.7	6.3	6.0	4.6	4.8	5.3	86	39	87	59.93	97
1 day	5.7	6.6	5.5	4.5	4.6	5.1	75	51	78	57.97	109
	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*
Av.	5.6	6.3	6.0	4.7	4.8	5.1	87	40	82	59.43	103
	5.4	5.3	6.6	4.3	5.3	4.6	83	31	89	44.59	75
	5.5	5.8	6.2	5.2	5.2	5.3	100	41	85	65.17	106
4 mo.	5.0	5.6	5.0	4.2	4.4	5.0	100	43	84	43.29	82
	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*
Av.	5.3	5.6	5.9	4.6	5.0	5.0	94	38	86	51.02	88
Grand Av.	5.79	6.11	6.13	5.07	5.31	5.26	93.78	-	-	56.16	-

* Missing data

Table 21. Treatment B6. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors									Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable	Drip (ml)	Dr.wt. (g)	(mg/100g)	% Retention
	6.6	6.3	6.7	5.6	6.3	5.4	100	-	-	58.56	-
	6.7	6.0	6.4	5.2	6.1	6.0	86	-	-	61.30	-
Fresh	6.1	6.4	6.4	5.9	6.0	5.2	100	-	-	66.81	-
	6.7	6.1	6.6	5.7	5.6	5.7	100	-	-	56.00	-
	6.8	6.7	6.4	6.0	5.7	5.8	100	-	-	47.16	-
Av.	6.6	6.3	6.5	5.7	5.9	5.6	97	-	-	57.97	-
	5.5	5.2	6.5	4.2	4.9	4.5	83	42	82	61.30	105
	6.6	6.1	6.0	5.1	4.6	5.3	100	32	94	68.32	111
1 day	5.8	6.0	5.8	4.8	4.7	5.0	100	32	89	58.95	88
	6.4	6.4	5.9	5.0	5.0	5.8	88	50	75	56.00	100
	6.2	6.0	6.1	5.2	5.6	5.2	100	36	84	56.00	119
Av.	6.1	5.9	6.1	4.9	5.0	5.2	94	38	85	60.11	105
	5.3	5.4	6.6	4.6	5.4	4.9	83	39	88	51.45	88
	6.6	6.3	6.7	4.6	5.1	4.9	100	31	92	57.17	93
4 mo.	5.7	6.3	6.3	4.3	5.3	5.2	100	*	*	62.88	94
	5.2	5.8	5.4	4.0	4.8	5.4	100	40	85	47.45	85
	5.7	5.2	5.0	4.7	5.0	4.8	100	39	79	38.30	81
Av.	5.7	5.8	6.0	4.4	5.1	5.0	97	37	86	51.45	88
Grand Av.	6.13	6.01	6.19	4.99	5.34	5.27	96.00	-	-	56.51	-

* Missing data

Table 22. Treatment P1. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors							Drip (ml)	Dr. wt. (g)	Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable			(mg/100g)	% Retention
	6.6	6.1	5.7	6.4	5.6	5.7	100	-	-	71.98	-
	6.2	6.2	5.5	6.2	5.2	5.5	100	-	-	65.88	-
Fresh	6.6	5.2	4.8	5.9	5.1	5.6	100	-	-	76.86	-
	6.6	5.7	5.2	6.4	4.7	5.2	100	-	-	73.36	-
	6.7	6.0	5.9	6.4	5.0	5.3	100	-	-	65.50	-
Av.	6.5	5.8	5.4	6.3	5.1	5.5	100	-	-	70.72	-
	6.7	6.3	6.2	6.2	5.0	5.5	100	32	83	75.64	105
	6.1	5.8	4.6	6.0	4.5	5.5	100	45	69	64.66	98
1 day	6.1	5.4	4.5	6.0	4.0	4.5	100	43	74	76.64	99
	6.6	5.8	3.8	5.8	4.0	5.4	100	46	68	73.36	100
	6.1	5.2	5.1	5.6	4.4	5.0	100	32	84	64.19	98
Av.	6.3	5.7	4.8	5.9	4.4	5.2	100	40	76	70.90	100
	5.7	5.8	5.3	4.7	4.0	4.7	100	22	95	67.46	94
	6.5	5.7	4.3	5.5	4.5	4.7	100	36	80	53.16	81
4 mo.	6.4	6.3	4.7	5.7	4.6	5.3	100	39	77	66.31	86
	6.7	5.6	5.1	6.3	4.4	5.3	100	30	84	66.60	91
	6.0	5.6	5.4	4.8	4.4	4.4	100	29	81	51.06	78
Av.	6.3	5.8	5.0	5.4	4.4	4.9	100	31	83	60.92	86
Grand Av.	6.37	5.78	5.07	5.86	4.63	5.17	100.00	-	-	67.51	-

Table 23. Treatment P2. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors							Drip (ml)	Dr.wt. (g)	Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable			(mg/100g)	% Retention
	5.4	6.6	6.3	6.1	5.3	5.6	100	-	-	74.42	-
	6.5	6.0	5.0	5.5	4.9	5.8	86	-	-	75.64	-
Fresh	6.6	5.9	5.0	5.1	5.2	5.1	83	-	-	75.64	-
	6.6	5.3	5.3	6.1	5.1	5.4	100	-	-	65.50	-
	6.3	5.6	4.8	5.9	4.8	4.8	100	-	-	61.57	-
Av.	6.3	5.9	5.3	5.7	5.1	5.3	94	-	-	70.55	-
	6.7	6.3	5.8	5.8	4.7	5.2	100	24	84	73.20	98
	6.1	5.5	4.5	5.8	4.4	5.2	100	42	71	57.34	76
1 mo.	5.5	5.2	4.4	4.2	3.6	4.2	71	40	75	72.70	96
	6.2	6.2	5.8	5.5	4.8	5.0	100	35	83	74.67	114
	6.2	5.5	5.0	4.5	4.0	4.8	86	20	92	69.43	113
Av.	6.1	5.7	5.1	5.2	4.3	4.9	91	32	81	69.47	99
	5.5	5.5	5.0	5.5	4.2	4.3	100	32	85	64.03	86
	6.3	5.0	3.8	5.0	3.3	4.7	100	43	77	50.59	67
4 mo.	5.9	5.9	4.7	4.4	4.1	5.0	100	26	85	69.74	92
	5.4	4.9	3.7	4.0	3.7	4.1	86	30	84	67.71	103
	6.4	6.0	5.6	5.8	5.2	4.8	100	21	92	51.06	83
Av.	5.9	5.5	4.6	4.9	4.1	4.6	97	30	85	60.63	86
Grand Av.	6.11	5.69	4.98	5.28	4.49	4.93	94.13	-	-	66.88	-

Table 24. Treatment P3. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors: Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable	Drip (ml)	Dr.wt. (g)	Ascorbic acid (mg/100g)	Ascorbic acid % Retention
Fresh	6.2	5.9	5.4	5.5	5.0	5.4	86	-	-	65.88	-
	6.2	5.9	5.4	5.8	4.9	5.4	100	-	-	73.20	-
	6.6	5.9	5.4	6.3	5.1	5.2	100	-	-	70.74	-
	6.3	5.3	5.9	6.3	5.9	5.4	100	-	-	72.05	-
	6.4	6.0	5.4	5.9	5.1	5.1	100	-	-	66.81	-
Av.	6.3	5.8	5.5	6.0	5.2	5.3	97	-	-	69.74	-
1 day	6.0	5.4	4.6	4.8	4.4	5.4	83	52	64	67.10	102
	6.2	5.8	4.4	5.8	4.0	4.8	86	33	82	64.19	88
	6.3	6.1	4.1	5.7	4.3	5.6	100	30	80	70.74	100
	6.2	6.3	6.2	6.2	5.0	5.5	100	37	83	74.67	104
	6.1	5.5	4.9	5.0	3.9	4.4	100	22	95	62.88	94
Av.	6.2	5.8	4.8	5.5	4.3	5.1	94	35	81	67.92	98
4 mo.	6.0	5.5	4.0	5.2	3.5	4.5	100	45	75	61.74	94
	6.1	5.9	5.1	5.4	4.6	5.1	100	31	84	69.74	95
	6.0	5.3	4.7	5.0	4.6	4.9	100	36	81	64.38	91
	5.4	5.0	4.1	5.1	3.9	3.9	100	44	73	64.38	89
	5.6	5.6	5.4	5.8	4.4	4.6	100	36	80	56.61	85
Av.	5.8	5.5	4.7	5.3	4.2	4.6	100	38	79	63.37	91
Grand Av.	6.11	5.69	5.00	5.59	4.57	5.01	97.00	-	-	67.01	-

Table 25. Treatment P4. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors									Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable	Drip (ml)	Dr.wt. (g)	(mg/100g)	% Retention
	6.4	6.3	6.0	6.1	5.1	5.4	100	-	-	68.32	-
	6.1	5.8	5.1	6.1	5.0	5.6	86	-	-	68.32	-
Fresh	6.4	5.7	5.1	6.4	5.3	5.1	100	-	-	75.98	-
	6.7	5.3	5.0	6.4	5.1	5.7	100	-	-	66.81	-
	6.4	6.0	5.9	6.4	5.1	4.8	100	-	-	65.50	-
Av.	6.4	5.8	5.4	6.3	5.1	5.3	97	-	-	68.99	-
	6.7	6.5	6.3	5.8	5.0	4.8	100	40	79	75.64	111
	6.4	5.5	4.6	5.4	4.4	4.9	100	49	72	59.78	88
1 day	6.0	6.1	4.3	5.6	4.3	5.0	100	35	79	74.67	98
	6.7	6.2	5.8	5.5	5.0	5.3	100	38	81	69.43	104
	6.4	5.2	4.8	5.5	4.1	4.8	100	37	84	68.12	104
Av.	6.4	5.9	5.2	5.6	4.6	5.0	100	40	79	69.53	101
	5.7	5.8	5.5	5.0	4.2	4.7	100	34	81	67.46	99
	6.0	5.2	4.3	5.3	4.0	4.5	100	37	75	55.74	82
4 mo.	5.9	5.4	5.1	5.1	4.4	4.6	100	45	77	68.82	90
	6.0	4.9	3.9	5.3	3.6	4.1	100	37	81	65.49	98
	5.6	5.6	5.4	5.0	4.6	4.6	100	39	82	49.95	76
Av.	5.8	5.4	4.8	5.1	4.2	4.5	100	38	79	61.49	89
Grand Av.	6.23	5.71	5.14	5.66	4.61	4.93	99.07	-	-	66.67	-

Table 26. Treatment P5. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors: Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable	Drip (ml)	Dr.wt. (g)	Ascorbic acid (mg/100g)	Ascorbic acid % Retention
	6.0	6.3	5.7	6.1	5.6	5.6	100	-	-	73.20	-
	6.5	5.9	5.1	5.9	4.6	5.2	86	-	-	62.22	-
Fresh	6.5	5.4	4.6	5.4	4.5	5.9	100	-	-	75.64	-
	6.3	5.7	5.0	6.1	5.1	5.2	100	-	-	64.19	-
	6.9	5.4	5.3	6.0	5.3	5.3	100	-	-	68.12	-
Av.	6.4	5.7	5.1	5.9	5.0	5.4	97	-	-	68.67	-
	6.7	6.3	5.3	6.0	5.0	5.5	100	30	83	70.76	97
	6.6	5.8	4.4	5.6	4.4	5.2	100	26	81	71.98	116
1 day	5.6	5.2	4.2	5.1	4.0	4.5	86	35	78	68.78	91
	5.8	6.1	4.1	5.3	3.8	5.0	100	40	65	66.81	104
	6.2	6.2	6.0	5.2	4.7	5.5	100	25	84	73.36	108
Av.	6.2	5.9	4.8	5.4	4.4	5.1	97	31	78	70.34	103
	5.3	5.5	4.5	5.2	4.2	4.3	100	29	84	66.31	90
	6.5	5.3	4.3	5.0	4.3	4.7	100	24	83	51.45	83
4 mo.	6.3	5.7	4.6	5.4	4.4	5.0	100	26	86	73.17	97
	6.1	5.4	4.9	5.1	4.3	4.7	100	37	77	64.38	100
	6.0	4.6	4.3	4.6	3.9	4.3	100	33	81	65.49	96
Av.	6.0	5.3	4.5	5.1	4.2	4.6	100	30	82	64.16	93
Grand Av.	6.22	5.65	4.82	5.47	4.54	5.06	98.13	-	-	67.72	-

Table 27. Treatment P6. Scores of strawberries for each storage period, for each palatability factor, drip, drained weight, ascorbic acid content and per cent retention of ascorbic acid.

Storage periods	Palatability factors							Drip	Dr.wt.	Ascorbic acid	
	Aroma	Color	Shape	Flavor	Texture	Seediness	% Acceptable	(ml)	(g)	(mg/100g)	% Retention
	6.3	6.4	6.3	6.6	5.7	5.7	100	-	-	76.86	-
	6.2	5.6	4.8	5.5	5.0	4.9	100	-	-	73.20	-
Fresh	6.3	5.7	5.3	6.4	4.7	5.4	100	-	-	69.43	-
	6.6	5.4	5.4	6.3	5.0	5.4	100	-	-	66.81	-
	6.4	6.0	5.3	6.1	5.1	5.1	100	-	-	61.57	-
Av.	6.4	5.8	5.4	6.2	5.1	5.3	100	-	-	69.57	-
	6.3	6.3	5.7	5.5	4.7	5.3	100	34	84	78.08	102
	6.1	4.9	3.8	5.6	3.8	4.5	86	36	75	70.74	97
1 day	6.4	6.1	3.8	6.0	4.1	5.1	100	46	69	73.36	106
	6.8	6.0	5.3	5.8	4.3	5.2	100	38	81	66.81	100
	6.0	5.2	4.6	5.1	4.4	4.5	100	31	87	68.12	111
Av.	6.3	5.7	4.6	5.6	4.3	4.9	97	37	79	71.42	103
	6.2	5.5	5.2	5.3	4.2	4.7	100	30	84	61.74	80
	6.0	5.3	4.3	5.1	4.3	5.3	100	43	75	60.60	83
4 mo.	6.1	5.3	4.6	5.7	4.6	5.0	100	32	82	69.93	101
	5.7	4.9	4.0	4.6	3.6	3.9	100	38	79	65.49	98
	6.0	5.8	4.8	4.8	4.4	4.8	100	36	81	56.61	92
Av.	6.0	5.4	4.6	5.1	4.2	4.7	100	36	80	62.87	91
Grand Av.	6.23	5.63	4.88	5.63	4.53	4.99	99.07	-	-	67.96	-

Table 28. Color plate, hue and value codes for each treatment and storage period.

Storage period	Treatments											
	B1	B2	B3	B4	B5	B6	P1	P2	P3	P4	P5	P6
	-	-	-	-	-	-	-	-	-	-	-	-
	18E	18C	18C	18D	-	18D	18E	19C	18E	18D	19D	-
Fresh	19C	-	18C	18D	18D	19C	18D	19C	18D	-	19B	18D
	18D	18D	18C	-	18E	18C	18E	-	19E	19D	19C	18E
	18C	18D	18C	18D	-	-	-	18E	19D	18E	18D	18E
	18E	18D	-	18E	-	18D	18C	18E	18E	18D	-	18D
	-	-	-	-	-	-	-	-	-	-	-	-
	18E	18D	18D	18D	-	19B	18D	18E	18E	19B	19C	-
1 day	19B	-	18C	19C	19B	18C	18C	18C	18D	-	18E	18D
	18C	19C	18C	-	18D	18C	19C	-	18D	19C	18E	19D
	18D	18C	18D	18C	-	-	-	18E	19D	19C	18D	18E
	18E	18E	-	18E	-	18E	18E	18D	18D	18E	-	18E
	-	18B	18C	18B	18B	18C	18D	18D	-	18C	18D	18C
	18D	18D	18D	18D	-	18D	18D	18D	18D	18D	18C	-
4 mo.	18E	-	18C	18D	18D	18C	18D	19B	18D	-	18C	19B
	18D	18D	18D	-	18D	18D	18D	-	19B	19C	19C	18E
	18E	18D	18C	18D	-	-	-	19C	18D	19C	19C	19D
	18D	18E	-	18D	-	18D	18E	18D	18E	18E	-	18D

First digit - color plate number from Maerz and Paul, Dictionary of Color
Second digit - number indicating hue
Capital letter - letter indicating value

THE EFFECTS OF CERTAIN TREATMENTS ON THE QUALITY
OF FRESH AND HOME FROZEN KANSAS STRAWBERRIES

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1956

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1958

Strawberries, after freezing and thawing, often develop off odors and flavors; and become soft, mushy, and broken down in structure. Thus, the thawed product is inferior to the fresh. Therefore, this investigation was undertaken to: (1) ascertain the effects of freezing and frozen storage on two common varieties of Kansas strawberries, Blakemore and Premier; (2) determine the effects of the application of low methoxyl pectin, with and without calcium chloride, on both varieties; (3) make a comparison of the effects of adding cane sugar and corn sugar to the Blakemore variety and (4) determine the results of the application of Sorbo to Premier berries.

Six replications of strawberries were prepared for freezing by a standard procedure, treated as specified, packaged, frozen and stored in an upright home freezer at approximately -20° F. Testing was done while the berries were fresh, and after one day and four months of frozen storage.

Palatability scoring was done by an experienced tasting panel, and the amounts of drip and drained weight were determined. Color changes were noted by comparing the color of each sample with printed color plates, and ascorbic acid content was determined by a modification of the Loeffler-Ponting method. All data were tabulated and subjected to statistical analyses appropriate to a Youden Square design.

Interpretation of the statistical analyses revealed that freezing, itself, reduced palatability but not the ascorbic acid content of the strawberries. Frozen storage of four-month duration further reduced palatability and also reduced ascorbic acid content. There were some significant differences between the varieties. Blakemore was superior to Premier in palatability, but the Premier had higher ascorbic acid content than Blakemore. The treatments with low methoxyl pectin alone, and with calcium chloride lowered the Premier palatability scores but apparently not those for the Blakemore berries. The berries treated with corn sugar had lower palatability scores than those using cane sugar. Sorbo treatments caused somewhat reduced palatability scores, compared to the treatment with sugar alone. The drip and drained weight data did not correlate significantly with texture scores, nor did the per cent retention of ascorbic acid correlate with per cent acceptability. The color comparisons showed trends that agreed with findings of some other investigations reported in the literature.

Possibly, Blakemore could be recommended as a variety more adapted to freezing than Premier, although ascorbic acid content might influence the recommendation. Since the results showed no treatment that produced decisive improvement in strawberry quality, other treatments should be considered for future investigations. These might include addition of increased levels of the low methoxyl pectin and calcium chloride, use of sirups rather than dry sugar, use of colloidal materials such as Irish moss and kelp extractives, and freezing at extremely low temperatures with carbon dioxide or liquid air.