

Frozen Fruits and their Utilization in Frozen Dairy Products

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 287

JULY, 1932

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Frozen Dairy Products

By M. J. Mack and C. R. Fellers

The frozen-pack method is used annually to preserve large quantities of fruit, much of which is later used for flavoring ice cream. Fruits used for this purpose have a very pronounced influence on the quality of the final product. Very little is known regarding the most satisfactory ways of processing fruit for utilization in frozen dairy products. The results reported here furnish some information on this subject.

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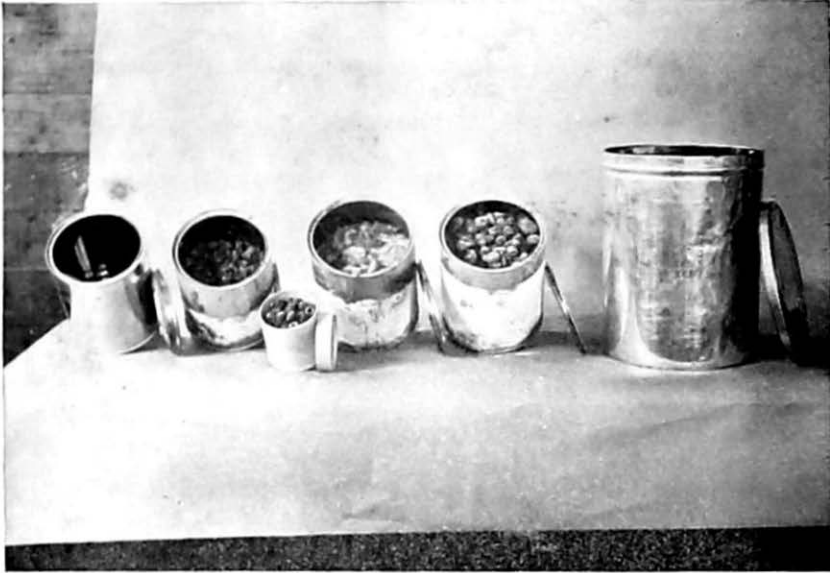


Figure 1. Containers for frozen-pack fruit. Left to right, empty 1-gallon friction top can, raspberries, sliced peaches, strawberries, 5-gallon slip cover can; in front a pint paper carton containing raspberries.

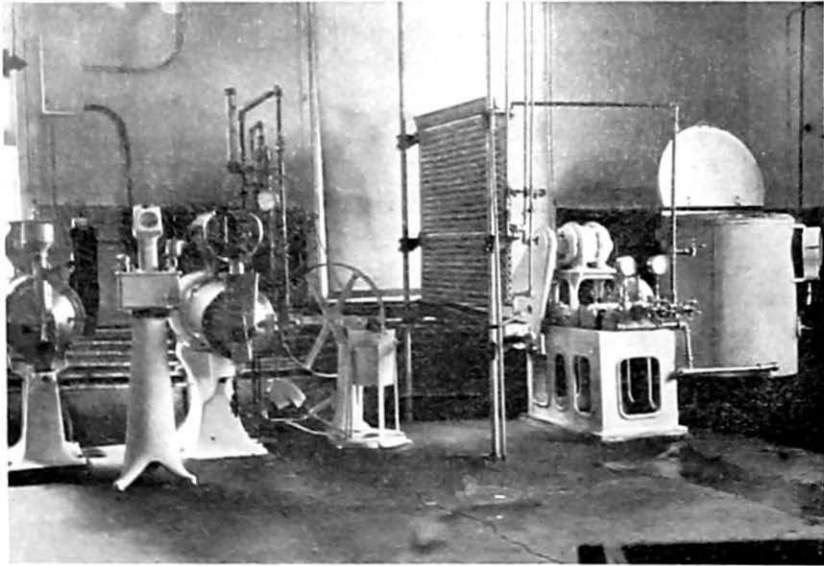


Figure 2. The equipment used for processing and freezing the ice creams made in this investigation.

FROZEN FRUITS AND THEIR UTILIZATION IN FROZEN DAIRY PRODUCTS

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and
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INTRODUCTION

In 1931 approximately 350 million gallons of ice cream besides sherbets, ices and mousses were produced in the United States. Of this immense amount 15 to 16 per cent or 55 million gallons consisted of fruit ice cream. Strawberry, raspberry, pineapple, peach, cherry, and orange were the principal fruits used, though many others were utilized to a lesser extent. Strawberry made up 8 per cent of the total—28 million gallons. Next in importance came orange-pineapple.

This shows the tremendous possibilities to the fruit industry for supplying frozen-packed fruit for ice cream and similar dairy products. The soda fountain trade, also largely dependent on ice cream, uses large quantities of frozen fruits and no doubt could absorb still more.

In view of the somewhat limited knowledge concerning the best methods of freezing and of using frozen fruits, the writers investigated some phases of the problem. The fruit thus made available was utilized in ice cream and ices to determine the effect of fruit varieties and methods of preserving on the freezing and quality of the finished products.

Plan of the Investigation

Briefly, the plan of the investigation was to prepare experimental packs of the fruits in one-gallon cans, freeze these under known conditions, store for approximately one year, thaw, examine carefully, and finally use the fruit in the manufacture of fruit ice creams, sherbets and ices.

The study thus falls naturally into two parts: (1) A study of the methods of packing, handling, freezing and storage on the quality of the frozen fruit; and (2) the utilization of these frozen fruits in frozen dairy products. In general, these parts will be treated separately because the packer of frozen fruit is interested chiefly in the method of packing, handling and storage, while the ice cream manufacturer is interested more specifically in the use of frozen fruit in dairy products.

The term "frozen-pack" is used in this bulletin in preference to the older trade designation "cold-pack" for fruits frozen with sugar. The writers agree with Diehl (6) that the former expression is more accurately descriptive of the process actually involved.

Historical

In 1927 Turnbow and Cruess (17) concluded that properly prepared frozen-packed fruits were approximately equal to the fresh for use in ice cream and water ices. They advocated the use of higher percentages of fruit in ice creams than had been customary; for example, they recommended at least four pounds of fresh strawberries to 45 pounds of basic mix for a good strawberry ice cream. They likewise considered that most frozen fruits made more satisfactory ice cream and ices than dried, canned or pulped fruits. The Marshall variety of strawberry was found to give excellent flavored ice cream. Banner was unsatisfactory.

Fabricus (7), in Iowa, found that frozen strawberries were superior to either canned fruit or strawberry extracts in the manufacture of ice cream. He recommended Gandy, Kellogg's Prize, Early Jersey, Giant, and Dunlap as desirable varieties for use in ice cream. The optimum ratio of strawberries to sugar was two to three pounds of fruit to each pound of sugar. He found full-ripe fruit gave a superior flavored ice cream. Storage at temperatures above 25° F. resulted in definite quality deterioration.

Turnbow and Raffetto (18), also Sommer (15), give general information on fruit ice creams.

Since the inception of the frozen-pack method of preserving fruits in the Pacific Northwest about 20 years ago, many papers bearing on the general subject have appeared. Most of these are found in various trade journals and contain little actual data. However, the reports by Cruess (2), Joslyn (10, 11), Diehl (6), Wiegand (19), Woodroof (20, 21), Birdseye (1), Lathrop (12), Culpepper (3), and others, sum up the available information on the subject.

The present writers have also published preliminary reports of their findings in the ice cream and fruit products' trade journals (9, 13).

PART I. FROZEN FRUIT INVESTIGATIONS

Experimental Methods

Approximately 650 one-gallon cans of fruit were frozen packed for these experiments over a three-year period. About one-half of this amount consisted of strawberries; raspberries, cherries and peaches made up the rest. The fruits were all produced in the college orchards, picked when fully ripe, and in prime condition when packed.

The methods of investigation were varied in order to compensate for the differences among the different fruits studied. However, the same general procedure was followed as closely as possible. All fruit was prepared for packing (hulled, pitted or pared as the case might be) washed in cold water and drained. It was then weighed and the desired quantity of sugar mixed uniformly through the fruit. The fruit was then transferred to one-gallon enamelled, friction-top tin cans, properly labeled, moved into a storage room and held between 0° and 5° F. This insured rapid freezing. After a few days in this room (over night is sufficient) the fruit was transferred to another cold storage room held between 10° and 15° F. The fruit was removed as needed and melted at room temperature in 15 to 20 hours. After melting, observations were taken on the following points: color of fruit and syrup; flavor of fruit and syrup; proportion of fruit to syrup; size and texture of fruit; and consistency and clarity of syrup.

The effect of the following factors on the pack was studied:

1. Variety.
2. Proportion of fruit to sugar (variation from 20-50 per cent sugar).
3. Substitution of corn sugar for cane sugar (whole or part).
4. Syrup packs.
5. Freezing without sugar.
6. Fruit; whole, sliced or crushed.
7. Vacuum packing.
8. Standing before freezing.
9. Thawing and refreezing.

The melted frozen-packed fruit was used in ice cream in order to study the effect of the factors listed above. Therefore, an important part of this investigation has been a study of the effect of methods of freezing on the properties of fruit ice creams. These are described in Part II.

Frozen Strawberries

Variety Studies

Twenty of the more important northeastern varieties were frozen in the ratio of two pounds of fruit to one pound of sugar. These studies were carried on over a three-year period, 1929, 1930 and 1931. Approximately 130 cans were packed for the variety studies. The fruit was grown on a fertile, gravelly loam soil, picked when fully mature, and frozen the same day. The fill of the container was the same in the variety studies, i. e., the weight of contents was constant at five pounds. In general, the storage period at 10° to 15° F. was for 12 months. This allowed comparisons to be made with the freshly harvested fruit of the succeeding season.

Results of examination of the 2:1 packs are summarized in Table 1. Although comparisons were also made in these varieties where the ratio of fruit to sugar were 1:1, 2½:1, 3:1 and 4:1, the results are sufficiently like the 2:1 packs so that reproduction of all these data will be omitted. Fruit solids or "fruit" in the defrosted packs was determined by weighing the portion remaining after draining for two minutes on an 8-mesh sieve of 10 inches diameter.

Besides the 20 varieties classed in Table 1, commercial packs of Klondike, Ettersberg, and Marshall were also examined. All three rated very high in appearance and flavor both after freezing and in ice cream. The ratings given the several varieties are shown in Table 1 and require no discussion. It is noteworthy to observe the rather close limits for soluble solids, 5.9 to 7.6 per cent, and titratable acidity, 0.90 to 1.43 per cent. Of course, even the same variety will vary greatly with the degree of maturity. At least two pickings during the course of two seasons were considered in determining the number of berries per pound. This method gives an excellent comparative idea of the size of the individual fruits. Flavor, appearance and other organoleptic properties of frozen fruit were judged by groups of several men with experience in the examination of fruit products. In general, the varieties which were considered best flavored when fresh, were also best both after freezing and after incorporation into fruit ice cream. The more acid varieties were usually unsatisfactory. The varieties which have a red or pink flesh, such as Howard Supreme, Senator Dunlap, or Aberdeen, gave more highly colored frozen products than the light-fleshed varieties. There was slight surface darkening in all the packs, no significant differences being noted among the several varieties. For most varieties 2.5 to 3 pounds of fruit to the pound of sugar gave a frozen product of optimum flavor. A few of the sour varieties were best when packed with sugar in the ratio of 2:1. More data bearing on the ratio of fruit to sugar are presented in Table 2. In no case did ratios of fruit to sugar, greater or less than 2:1, cause any significant change in rating of any variety of fruit. That is, there was no advantage gained in comparing the freezing qualities of varieties of fruits at ratios of fruit to sugar other than 2:1.

Effect of Varying the Ratio of Berries to Sugar

For this experiment both mixed variety, field-run strawberries and separate varieties were used. All were harvested in 1929, 1930 and 1931. The purpose of the work was to determine the most satisfactory fruit to sugar ratio in frozen packs for use in ice cream. In all, 97 one-gallon cans were packed. The fruit-sugar ratios used were 1:1, 2:1, 3:1, 4:1 and 1:0. The fruit was prepared and frozen as described in the variety tests and was examined from 11 to 16 months after packing. The data are summarized in Table 2.

TABLE 1.—CHARACTERISTICS OF FRESH AND FROZEN STRAWBERRIES, AND STRAWBERRY ICE CREAM.

Variety	Fresh Fruit					Frozen Fruit—after 1 year			
	Number per pound	Color	Flavor	Soluble solids	Acidity (citric)	Rating	Syrup concentration	Ratio of fruit : syrup	Rating in ice cream
				Per cent	Per cent		Degrees Brix		
Howard 17.....	111	Excellent	Good	0.3	0.96	Excellent	41.3	1 : 1.33	Very good
Howard Supreme.....	92	Good	Excellent	6.1	1.11	Excellent	41.5	1 : 1.46	Excellent
Sample.....	76	Poor	Poor	5.9	0.92	Poor	33	1 : 0.93	Poor
Marshall.....	69	Good	Excellent	7.5	0.90	Good but soft	38	1 : 1.1	Good
Mastadon.....	62	Fair	Good	7.4	1.2	Fair	40	1 : 0.69	Fair
Champion.....	158	Excellent	Good	6.3	1.2	Very good	40.2	1 : 1.23	Very good
King Edward.....	90	Good	Excellent	7.5	1.2	Excellent	38.5	1 : 0.69	Excellent
Bun.....	96	Poor	Excellent	7.1	1.3	Fair	34	1 : 1.09
Beacon.....	74	Poor	Fair	6.9	1.05	Good	37	1 : 1.27	Good
Boquet.....	74	Fair	Good	6.4	1.16	Poor	38.2	1 : 1.26	Excellent
Heritage.....	70	Fair	Poor	6.9	1.2	Poor	41	1 : 1.06
First Quality.....	100	Excellent	Good	6.8	1.14	Excellent	42	1 : 1.26	Very good
Bliss.....	102	Fair	Good	7.0	1.03	Fair	36	1 : 1.12	Fair
Stevens Late Champion.....	72	Fair	Good	0.5	1.43	Fair	44	1 : 0.74	Fair
Meteor.....	52	Good	Fair	5.9	1.2	Good	38	1 : 0.96	Fair
Commonwealth.....	60	Good	Very good	7.6	1.02	Very good	41	1 : 1.1	Fair
Senator Dunlap.....	90	Good	Poor	0.0	1.4	Fair	37	1 : 0.62	Poor
Progressive.....	136	Good	Good	6.3	1.96	Good	39	1 : 1.2	Fair
Aberdeen.....	90	Good	Excellent	7.0	1.16	Excellent	33	1 : 1.3	Excellent
Marvel.....	136	Poor	Fair	6.8	0.97	Fair	39.5	1 : 0.93	Poor

TABLE 2.—EFFECT OF VARYING FRUIT TO SUGAR RATIOS IN FROZEN STRAWBERRY PACKS.

Ratio of Fruit : Sugar	Fruit			Syrup					
	Color	Flavor	Size and texture	Color and clarity	Flavor	Sugar	Ratio of fruit to syrup	Rating	Rating in ice cream
						Per cent			
1 : 1*	Good	Marked by high sugar	Considerable shrinkage and disintegration	Color high but debris from broken berries	Over-sweet	50	1 : 1.72	Poor	Poor, too soft and sweet
1½ : 1*	Very good	Good	Much shrinkage, firm	High	Good	46	1 : 1.5	Fair	Fair, too sweet and soft
2 : 1*	Excellent	Excellent	Some shrinkage but no disin- tegration	Color good and clarity excellent	Excellent	38.2	1 : 1.25	Very good	Very good
2½ : 1	Good	Excellent	Moderately firm, little shrinkage	Very good	Excellent, slightly tart	35	1 : 1.03	Excellent	Excellent
3 : 1	Excellent	Natural but tart	Very little shrinkage, no disintegration	Color good, syrup clear	Tart	32.3	1 : 1	Very good	Very good
4 : 1	Natural red	Too sour	Very little shrinkage, slow to melt	Color poor, clear syrup	Sour	28.6	1 : 0.89	Fair	Poor, too sour
1 : 0	Dull brown	Flat and unnatural	Very little shrinkage, very slow to melt	Color light but clear	Very sour	7.7	1 : 0.78	Poor	Poor, un- natural acid
Dextrose 2 : 1 pack*	Dark, unnatural purplish-red	Flat and poor, un- natural	Soft and disinte- grated. Grayish red precipitate not readily solu- ble. Slow to melt	Purple, full of granular sediment	Flat and unnatural	26	1 : 1.3	Poor	Poor color, poor, soft
¼ Dextrose ¾ Sucrose 2 : 1 pack*	Slightly darkened, Deep wine red	Somewhat unnatural	Soft, shrinkage evident. Some disintegration	Color deep red. Some sediment	Unnatural	39	1 : 1.4	Fair	Poor, soft, unnatural
¾ Dextrose ¼ Sucrose 2 : 1 pack*	Unnatural, dark purplish red	Flat, ob- jection- able	Soft and broken. Fully ½ inch of purple sugar sludge. Slow to melt.	Darkened, un- natural. Muddy from crystal sludge	Flat, un- natural	38.6	1 : 1.3	Poor	Poor
¼ Dextrose ¾ Sucrose 2 : 1 pack*	Trifle deeper red than all sucrose pack	Good	Some shrinkage and disintegration	Color good but contains bro- ken berry parts	Good	38.9	1 : 1.3	Fair	Fair

* Undissolved sugar present.

Packing without sugar proved impracticable. The natural color and much of the flavor of the fruit was lost. Without a sugar syrup present, the color is destroyed, probably through oxidative changes. Sugar syrup absorbs and retains volatile compounds which are lost in a pack without sugar. The sugar probably prevents the deterioration of the volatile flavoring substances as well as absorbing them.

Attempts to substitute dextrose (corn sugar) for sucrose were unsatisfactory. Dextrose caused the fruit to darken and assume an unnatural purplish-red appearance. The seeds turned black as well as the tips of the berries. The flavor of the fruit was flat, unnatural, and objectionable. The fruit in the dextrose pack became very soft and mushy, and disintegrated to a considerable extent. These changes may be due to a greater osmotic concentration of the dextrose syrup since the molecule is only one-half as large as that of cane sugar. The greatest objection, however, to the dextrose pack was the presence of a grayish-red, granular substance which formed a crust on the surface and a sludge at the bottom of the can. This substance was not readily soluble, hence caused the fruit to melt slowly and remained as a precipitate in the syrup to a considerable extent unless it was dissolved by warming the fruit. The substance was identified as dextrose crystals (probably dextrose monohydrate) by the osazone test.

Corn syrup or dextrose (which is known by the trade name of cerelose) is bleached with sulfur dioxide in the process of manufacture. It is to this residual sulfur dioxide in the cerelose that this discoloration is attributed. The sample of cerelose used in this study contained 19 parts per million of sulfur dioxide. The purple color is formed by the interaction with tin of the anthocyanins (red pigments) of the fruit. The sulfur dioxide accelerates this corrosive action and thus indirectly impairs both flavor and color.

A 2:1 pack in which two-thirds of the sugar was dextrose was similar to the all-dextrose pack but not as outstanding in its defects. The defects were less marked where only one-half of the sugar was dextrose, yet some of the grayish-red substance cited above was evident. None was present where only one-third of the sugar was dextrose. However, the color was purplish-red and appeared somewhat unnatural. The flavor was not as desirable as that of an all-sucrose pack.

Since cane sugar was found to be the more desirable sugar, another factor to be considered was the ratio of berries to sugar. Table 2 shows that the 2:1, 2½:1 and 3:1 packs were the most desirable. The 1:1, and 1½:1 packs were too sweet and the true flavor of the fruit was masked. The higher osmotic pressure brought about considerable shrinking and disintegration of the fruit. Too much cloudy syrup was evident due to the presence of seeds and other debris from the disintegrated berries. The 4:1 pack showed practically no shrinking or disintegration and had an excellent color. However, the fruit was too sour and the syrup too thin and watery.

A choice between the 2:1 and 3:1 packs was hard to make and would probably depend upon the use for which the fruit is desired. Each of the two packs had distinct advantages. The flavor of the fruit and the consistency and flavor of the syrup were a little superior in the 2:1 pack. The advantages of the 3:1 pack were larger and firmer berries, less syrup, better color, less danger of undissolved sugar in the syrup, and less weight per gallon for transportation. Probably the 2½:1 ratio is the best for most purposes.

Few attempts have been made to investigate frozen-packing from the standpoint of temperature effects. The fruit was placed in a room at 0° F. or slightly lower for a few days to insure rapid freezing, and was later removed to a room held between 10° and 15° F. The necessity for rapid cooling to prevent fermentation has been disclosed (6). However, the fruit should not remain at this

lower temperature too long or a sugar sludge will form at the bottom of the containers. Fruit held below 0° F. for as long as two weeks had a sugar sludge at the bottom of the cans which did not disappear until the fruit had been held six months at the higher temperature of 10° to 15° F. This trouble was not noticed if the fruit was moved into the second room after two or three days and did not appear under any conditions with the 3:1 pack. Undissolved sugar was always present in the 1:1 and 1½:1 packs and was often present in small amounts in the 2:1 packs after defrosting. This excess of sugar does not aid in any way in preserving the fruit. Where the ratio of fruit to sugar exceeded 2½:1, no undissolved sugar was found in any fruit.

Effect of Freezing the Berries with Sugar Syrups

Because of the difficulties of thoroughly mixing the fruit with sugar in the frozen packs, sugar syrups were used in an effort to obviate this difficulty, save time, and possibly prevent crushing the fruit.

Several experimental packs were made in which cane sugar syrup was substituted for dry sugar. Thirty 1-gallon cans were used in the tests in 1930 with both mixed varieties and Howard 17. Since no differences were evident in the several different packs, all are considered together in Table 3. The berries were simply covered with the syrup of desired concentration, no definite weight being used.

There was a definite decrease in the surface discoloration of the syrup packs as compared with the dry sugar packs. The syrup exerted a protective action against oxidation. The optimum syrup concentrations for freezing strawberries were 40 and 50 per cent. Eighty per cent invert syrup, and 65 per cent sugar syrup were too concentrated, causing the berries to shrivel and float on the surface. The color was good, however, in the 60 and 65 per cent syrup packs. The appearance and flavor of the 40 and 50 per cent syrup frozen strawberries were considerably better than those of either higher or lower sugar concentrations.

There are definite advantages in a syrup pack. Among these are: less air discoloration, less damage to the fruit, greater convenience, and firmer textured fruit. There is no loss of undissolved sugar, and spoilage is less likely to result. Also if the syrup is chilled before using, it acts as an effective precooling agent. Where facilities for making and storing syrups are available, the use of syrup in place of dry sugar is entirely feasible. The principal objection to the use of syrup is that additional water (and weight) is thereby added to the product. The preparation of small batches of syrup is also inconvenient. Experience has shown that the amount of syrup to be added may be judged satisfactorily by simply covering the fruit.

Effect of Delay Between Packing and Freezing the Berries

In commercial practice it is often difficult to avoid delays incident to freezing the fruit. In order to determine the effect of varying storage periods before freezing, 40 one-gallon cans of Howard 17, 2:1 strawberries were packed in 1930. The berries were fully matured and of good quality. They were either frozen immediately after mixing with sugar or else allowed to stand for definite time intervals before freezing at -5° F. Two storage temperatures were used, 45° and 80° F., corresponding respectively to common cold storage and normal July temperatures. The fruit was examined both before freezing and after defrosting a year later. Representative samples were used in strawberry ice creams. The data are tabulated in Table 4.

TABLE 3.—FREEZING STRAWBERRIES WITH SUGAR SYRUPS.

Sugar syrup concentration	Ratio of fruit : syrup	Sugar in syrup	Texture of fruit	Color	Flavor	Surface discoloration	Rating in ice cream
Per cent		Per cent					
80 (invert)	1 : 1.8	43.0	Tough, much shrinkage	Poor	Poor, too sweet	Moderate in fruit above syrup	Poor
65	1 : 1.45	41.0	Very firm	Good	Poor, too sweet	Slight in fruit above syrup	Fair, sweet
60	1 : 1.2	38.6	Good, slight shrinkage	Very good	Good	None	Fair, sweet
50	1 : 0.98	37.8	Good	Very good	Excellent	None	Very good
40	1 : 0.9	33.5	Good, slightly soft	Good	Very good	None	Excellent
30	1 : 0.7	18.5	Soft	Poor	Fair, too sour	Very slight	Fair, slightly sour
Dry sugar 2½ : 1	1 : 1.1	35.0	Good	Good	Excellent	Slight	Excellent

TABLE 4.—EFFECT OF DELAYED FREEZING ON THE QUALITY OF FROZEN HOWARD 17 STRAWBERRIES (2 : 1 PACK).

Time interval between packing and freezing	Temp. of holding	Condition prior to freezing	Sugar content of syrup	Ratio of fruit : sugar after defrosting	Flavor	Color	Texture	Rating after defrosting	Rating in ice cream
Hours	°F.		Per cent						
0	...	Excellent* no syrup	36	1 : 1.3	Excellent	Good	Slightly soft	Good*	Very good
3	45	Excellent	31.5	1 : 1.5	Excellent	Excellent	Slightly soft	Excellent	Very good
6	45	Excellent slight syrup	33.5	1 : 1.7	Excellent	Excellent	Firm	Excellent	Very good
12	45	Good, considerable syrup	35.3	1 : 1.6	Excellent	Very good	Firm	Very good	Very good
24	45	Fair, much syrup	35.3	1 : 1.5	Excellent	Excellent	Tough	Good	Very good
3	80	Excellent, slight syrup	36.3	1 : 1.2	Excellent	Excellent	Firm	Excellent	Very good
6	80	Excellent, considerable syrup	34	1 : 1.3	Excellent	Good	Firm	Very good	Very good
12	80	Fair, much syrup	36.5	1 : 1.3	Good	Good	Firm	Fair	Good
24	80	Poor, slight fermentation	35	1 : 1.4	Poor, slight fermentation	Fair, discolored	Poor, slightly gassy	Poor, slight mold at surface	Fair

*Slight amount of undissolved sugar.

The table is largely self-explanatory. There was apparently no injury to the quality of the frozen pack when held 12 hours at 45° F. or 6 hours at 80° F. In fact a short holding period dissolves all the sugar, and by allowing osmotic action to proceed, thoroughly impregnates the fruit with sugar. This action seems to aid in overcoming enzymic discoloration from oxygen within the fruit. Similarly, delayed freezing draws out some of the juices from the fruit so that the appearance is similar to a syrup pack but without the disadvantage of added water.

Up to 6 hours holding at summer temperatures did not injure the quality of the fruit. However, after 12 hours, there was a lack of fresh fruit flavor and too much bleeding of the fruit; and after 24 hours, slight yeasty fermentation and surface molding had begun. Obviously it is better to hold strawberries in a pre-cooler than at room or outside temperatures because of the deteriorative influences of the latter. During the holding period the fruit appears first to give up juice to a certain point and then reabsorbs it so that finally equilibrium is reached. In the case of a 2:1 pack of strawberries this point is at a syrup concentration of about 35-36 per cent sugar.

The Effect of Vacuum Packing

With a view to overcoming surface discoloration in frozen strawberries, 27 one-gallon cans of strawberries were packed in 1930 at Gloucester, where a vacuum sealing machine for gallon cans was available. The berries were well colored, mature, yet firm in texture. Ratios of 2:1, 2½:1 and 3:1 of fruit to dry sugar and 80, 65, 50 and 40 per cent syrup packs were employed. Vacuums of 10-12 and 18-22 inches of mercury were used. Controls in the usual friction-top unsealed cans were likewise packed. The berries were frozen at 0° F. and stored at that temperature for 11 months before defrosting and examination.

Inasmuch as the results showed few essential differences from other sugar or syrup packs already recorded in Tables 1, 2 and 3, the data are not given. The outstanding observation was that the vacuum-packed fruit showed no surface discoloration. That is, the air (oxygen) in the headspace of the cans had been largely removed by vacuumization, and did not cause deleterious oxidations which injure both color and flavor of the surface layer of fruit.

The fruit packed at vacuums of 18-22 inches was somewhat better than that packed at lower vacuums, probably because of more effective oxygen removal. As stated previously in this bulletin, the 2½:1 and 3:1 dry sugar packs were considered best from the ice cream manufacturer's viewpoint; and of the syrup packs, the 40 and 50 per cent were considered superior in appearance and flavor both after defrosting and when manufactured into ice cream. The 80 and 65 per cent syrups gave unsatisfactory packs in that both were too sweet and required too large quantities to cover the fruit. The berries also floated so easily that they could not be readily packed into the cans. Vacuums in excess of 20 inches could not be secured in one-gallon (No. 10) cans because of paneling effects. That is, the sides of the can would yield to the high vacuum and become concave, thus reducing the can volume as well as vacuum. Several cans were totally ruined when attempts were made to secure vacuumization at the 25-inch level. With smaller cans, it would be feasible to use vacuums of 25 inches or even more, because they are sufficiently strong to withstand such strains.

Several glass jars of strawberries and other fruits were vacuum sealed at 25 inches and frozen with good results. In fact, glass jars of frozen fruits make a very attractive appearance. Care must be taken in packing glass jars that sufficient headspace is allowed to compensate for the expansion due to freezing. About one-half inch is sufficient for pint or quart glass jars.

Effect of Crushing or Slicing the Berries

Crushed and also sliced strawberries were frozen-packed for comparison with the whole fruit. The frozen crushed fruit was inferior in appearance because of a faded-out, unattractive color. The surface layer of fruit was also rather badly discolored. The flavor was not normal. On the other hand the sliced fruit retained well its color and flavor. No significant flavor differences could be detected in ice creams made from sliced or whole fruit. Both the sliced and crushed 2:1 strawberries gave a sugar percentage in the syrup of 36, with a fruit to sugar ratio of 1:1.05. These values are very similar to those for whole 2:1 strawberries.

Frozen Raspberries

Several varieties of raspberries were frozen packed in 1929 and 1930 by the same methods that were used for strawberries. Variety, ratio of fruit to sugar, and a few syrup packs were frozen. The raspberries were full-ripe when packed. The more important results are tabulated in Table 5. In all, 66 one-gallon cans of raspberries were packed. Sugar ratio experiments were made for Cuthbert and Herbert varieties as well as St. Regis, but the results were very similar and hence are not presented separately. Several varieties were packed with a 4:1 ratio of fruit to sugar but with less satisfactory results than when the 3:1 ratio was used. St. Regis raspberries are very seedy. Several gallons of the defrosted berries were passed through a tomato pulper and the resulting seedless pulp made into ice cream and ice. The yield of seedless pulp was 84 per cent in this trial. The dry weight of seeds in Cuthbert and Herbert varieties was found to be 8 and 7.3 per cent respectively. The removal of seeds in raspberries overcomes one of the principal objections to the use of this fruit in ice cream, jams or even as a dessert.

Of the varieties of raspberries frozen, Cuthbert, Herbert and St. Regis were most satisfactory both as frozen fruits and when used in ice cream. Though small and seedy, the St. Regis possessed a good flavor and color. The purple and black varieties as well as Ontario and Newman were of poor quality. The black raspberries shriveled badly and were very tough and seedy.

Raspberries frozen without sugar were of poor flavor and color as compared with those containing sugar. The fruit did not stand up after defrosting. Dextrose packs were poor in quality, the same defects being noted as in frozen strawberries. The use of dextrose (corn sugar) cannot be recommended in frozen fruits.

The main difference in the raspberry packs was the distinct superiority of the 3:1 over the 2:1 fruit to sugar ratio. This was true in every variety tested. Surface discoloration was always more marked on the fruit containing the least sugar. As with strawberries, the fruit shrunk less and had less color in the less concentrated sugar packs. It should be stated that all varieties of raspberries have a distinct and fairly permanent characteristic flavor and that the differences among varieties are not so great as in the case of strawberries.

Frozen Peaches

Peaches were frozen in each of the three years of the investigation. All were harvested and frozen when fully mature. They were prepared for freezing by lye-peeling in 5 per cent caustic soda solution, rinsing in clean, cold water followed by trimming and slicing into eighths. Approximately 130 one-gallon cans were frozen. Because of close similarities among varieties and ratios of fruit to sugar, only representative samples are included in Table 6.

Of the common New England-grown varieties tested, Hiley, Elberta, Hale, Crawford and Belle of Georgia gave the most promising frozen packs. These

TABLE 5.—EFFECT OF VARIETY AND SUGAR RATIOS IN FROZEN RASPBERRIES.

Variety	Ratio of fruit : sugar	Color	Flavor	Texture	Surface discoloration	Sugar content of syrup	Ratio of fruit : syrup	Rating in ice cream
						per cent		
St. Regis.....	1 : 1	Excellent	Good	Soft	Slight	56	1 : 1.6	Good
St. Regis.....	2 : 1	Very good	Very good	Moderately firm	Slight	46	1 : 1.3	Good
St. Regis.....	3 : 1	Very good	Very good	Soft	Moderate	33.6	1 : 1.2	Very good
St. Regis.....	1 : 0	Fair	Poor	Soft	Much	9	1 : 0.75	Fair
St. Regis.....	2 : 1	Poor	Poor	Soft	Very much	Poor
	(dextrose)							
Cuthbert.....	2 : 1	Excellent	Excellent	Firm	Slight	46	1 : 1.4	Excellent
Cuthbert.....	3 : 1	Very good	Excellent	Slightly soft	Moderate	34	1 : 1.2	Excellent
Herbert.....	3 : 1	Very good	Excellent	Moderately firm	Moderate	36	1 : 0.9	Excellent
Latham.....	3 : 1	Fair	Very good	Moderately firm	Slight	32	1 : 1.8	Good
Newman.....	3 : 1	Fair	Good	Soft	Moderate	33	1 : 1.3	Fair
Ontario.....	3 : 1	Poor	Good	Soft	Much	32	1 : 1.4	Fair
Columbian Purple.....	3 : 1	Poor	Good	Soft	Moderate, un-natural color	37	1 : 1.09	Poor
Plum Farmer Black.....	3 : 1	Poor	Good	Firm, seedy	None	36	1 : 1.07	Poor

TABLE 6.—EFFECT OF VARIETY AND SUGAR RATIOS IN FROZEN PEACHES.

Variety	Ratio of fruit : sugar	Color	Flavor	Texture	Surface discoloration	Sugar content of syrup per cent	Ratio of fruit : syrup	Rating in ice cream
Carman.....	2 : 1	White to yellow	Good	Firm	Very slight	44.4	1 : 0.84	Good
Carman.....	3 : 1	White to light yellow	Very good	Firm	Slight	36.5	1 : 0.72	Good
Belle of Georgia.....	2 : 1	White	Good	Medium	Moderate	45.6	1 : 0.87	Fair
Belle of Georgia.....	3 : 1	White	Good	Medium	Moderate	38.5	1 : 0.7	Fair
Greensborough.....	2 : 1	Greenish white	Poor	Very firm	Much	45.3	1 : 0.84	Poor
Greensborough.....	3 : 1	Pale, poor	Poor	Very firm	Much	38.0	1 : 0.75	Poor
Hiley.....	2 : 1	Cream white	Excellent	Slightly soft	Moderate	42.5	1 : 0.76	Very good
Hiley.....	3 : 1	Clear white	Excellent	Soft	Moderate	35.5	1 : 0.53	Very good
J. H. Hale.....	3 : 1	Deep yellow	Excellent	Medium	Slight	42.0	1 : 0.61	Very good
Crawford.....	3 : 1	Deep peach yellow	Excellent	Soft	Moderate	38.5	1 : 0.70	Very good
Champion.....	3 : 1	Pale	Good	Soft	Moderate	40.0	1 : 0.57	Good
Elberta.....	3 : 1	Deep yellow	Very good	Slightly soft	Much	35.5	1 : 0.51	Very good

TABLE 7.—CHARACTERISTICS OF FROZEN-PACK CHERRIES AND MISCELLANEOUS VARIETIES OF FRUITS.

Variety	Ratio of fruit : sugar	Color	Flavor	Texture	Surface discoloration	Sugar content of syrup	Ratio of fruit : syrup	Rating in ice cream
						Per cent		
Montmorency Cherry.....	1 : 1	Red	Excellent	Firm	Very slight	58	1 : 0.92	Good
Montmorency Cherry.....	2 : 1	Red	Slightly sour	Firm	Slight	44	1 : 0.9	Good
Montmorency Cherry.....	3 : 1	Red	Too sour	Firm	Moderate	32	1 : 0.77	Fair
Montmorency Cherry.....	2 : 1	Red	Fair	Firm	Marked	41	1 : 0.96	Fair
	(dextrose)							
Morello Cherry.....	2 : 1	Deep red	Good but sour	Firm	Very slight	43	1 : 0.93	Fair
Early Richmond Cherry.....	2 : 1	Light red	Fair, sour	Firm	Moderate	42	1 : 0.64	Fair
May Duke Cherry.....	2 : 1	Dark red	Sub-acid	Firm	Very slight	44	1 : 0.89	Good
Evergreen Blackberries.....	2 : 1	Black to brown	Sour, poor	Firm	Marked	43	1 : 1.02	Poor
Wild Blackberries.....	2 : 1	Black	Good	Slightly soft	Slight	46	1 : 0.98	Poor
Cranberries.....	1 : 1	Red	Good, very acid	Very firm	None	51	1 : 0.37	Fair, good in ice
Damson Plums.....	1 : 1	Blue	Good, acid	Firm	Slight	56	1 : 0.64	Fair in ice
Red Currants.....	2 : 1	Red	Fair, very acid	Soft	Moderate	45	1 : 0.75	Fair in ice
Rhubarb.....	1 : 1	Green to pink	Fair, very acid	Moderately firm	Slight	51	1 : 0.47	Poor
Nectarines.....	3 : 1	Deep purple	Very good	Medium	Slight	38.5	1 : 0.43	Good

same varieties were best in ice cream as well. Both white and yellow-fleshed varieties were of good quality. In general, the early-season varieties were somewhat inferior to the mid-season ones.

All the varieties lost flavor upon freezing and defrosting and lost still more when made into ice cream or sherbet. In fact but little peach flavor was evident in the pure fruit peach ice creams.

Culpepper (3) made a study of the suitability of Georgia peach varieties for ice cream manufacture. He found Belle, Carman, Yellow Hiley and Elberta were very desirable varieties for this purpose.

The frozen peaches had a uniformly attractive appearance. The yellow varieties were most attractive, but all were of very pleasing color and flavor. The optimum ratio of fruit to sugar in most varieties of mature peaches seems to be about 3:1. No particular advantage was noted in the syrup packs. The flavor of the frozen peaches was noticeably superior to that of canned peaches of the same variety.

Frozen Cherries and Miscellaneous Fruits

In order to determine the suitability of various varieties of cherries and some other New England-grown fruits for freezing, mature Montmorency, Early Richmond, Morello, and May Duke cherries, as well as Damson plums, nectarines, cranberries, blackberries, red currants, and rhubarb, were frozen in various ways as described earlier under strawberries. Some 112 one-gallon cans of these miscellaneous fruits and rhubarb were packed and frozen over a three-year period. These were examined as usual after approximately one year in freezing storage at + 10° F. Some of the data are recorded in Table 7.

The cherries used were all sour varieties except May Duke. Montmorency was outstanding in its excellence as a frozen fruit, though Morello and Duke were also very satisfactory. For sour cherries a 2:1 pack proved best from the viewpoint of appearance, flavor, and suitability for use in pies or in frozen dairy products. Sour cherries are little used in commercial ice creams at the present time. These cherries made satisfactory products but lacked flavor. The color was particularly attractive. It should be noted that in a frozen pack of cherries there is considerably more fruit than syrup, thus differing from most berry varieties.

Both wild and Evergreen blackberries yielded frozen packs of only fair quality. The flavor was good but the appearance unattractive. The same was true of red currants, Damson plums and rhubarb. However, these made frozen ices of characteristic flavor.

Nectarines, when used in ice cream, produced a flavor greatly resembling peach. The frozen product, while not particularly attractive in appearance, possessed a pleasing flavor.

Cranberries were frozen whole, sliced, and as cranberry pulp, with and without sugar. The fruit kept perfectly regardless of the method of packing. Sliced cranberries or cranberry pulp frozen with sugar in a 1:1 ratio were judged the best packs in appearance and flavor. The pulp was especially satisfactory for use in frozen ices. In ice cream, the cranberry lost its characteristic flavor.

PART II. STUDIES OF FRUIT ICE CREAMS AND ICES

Experimental

The fruit available from the studies reported in Part I was utilized in ice cream to determine the effect of methods of packing on flavor and other characteristics. Other factors investigated in the making of fruit ice creams were:

1. Comparison of fresh and frozen fruits.
2. Effect of the percentage of fruit.
3. Time of adding fruit during freezing.
4. Effect of fruit on rate of freezing and properties of the ice cream.
5. Addition of vanilla and fruit extracts.
6. Causes of off-flavor in fruit ice creams.

Since strawberry is the most popular fruit ice cream, a principal part of the study was devoted to it. Raspberry, cherry, pineapple, and peach ice creams and ices were also investigated following the same general procedure used for strawberry. The experimental work with strawberry ice cream is discussed in detail. Properties and observations peculiar to other fruit ice creams are then discussed briefly. This is followed by a discussion of fruit ices.

All fruit ice creams contained 15 per cent by weight of the fruit being studied, unless a statement is made to the contrary. Freezing data were secured by taking the temperature of the mix in the freezer and the percentage of overrun at minute intervals throughout the freezing process. The ice cream was held at hardening-room temperatures (0-5° F.) for a few days before it was judged. The judges were students and members of the college staff, mostly not specialists in dairying and therefore representing fairly well the general consuming public. A three to one preference was assumed to be significant.

The ice cream mix used averaged 14.5 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 0.35 per cent gelatin. It was pasteurized at 150-155° F., held 30 minutes, and homogenized at 3,000 pounds pressure at the pasteurization temperature. The mix was aged from 5 to 24 hours before freezing. A 40-quart brine freezer was used, with brine varying from -5 to 2° F. in temperature. All samples of ice cream for judging were drawn from the freezer at the same temperature and at an overrun of 85-90 per cent, and were hardened for a few days before examination.

Acidity readings were determined by titrating a 9-gram sample with one-tenth normal sodium hydroxide with phenolphthalein as indicator. Hydrogen ion determinations were made electrometrically, using a Leeds-Northrup potentiometer with the quinhydrone electrode at 77° F.

Strawberry Ice Cream

Desirable Varieties for Use in Ice Cream

A comparison of the common New England varieties of strawberries over three fruit crops was made. On the basis of the trials, the strawberry varieties studied may be grouped as follows in respect to their comparative value for flavoring ice cream (see also Table I):

Excellent: Howard Supreme and King Edward.

Very good: Marshall, Howard 17, First Quality.

Fairly good: Aberdeen, Boquet, Beacon, Bliss, Commonwealth, Progressive.

Somewhat lacking in flavor: Marvel, Meteor, Mastadon, Sample, Senator Dunlap, Stevens Late Champion, Bun and Heritage.

Differences were in evidence among varieties from year to year which would indicate that among the leading varieties, seasonal effects, ripeness of fruit, etc.,

are factors of major importance. New England berries are fully equal in quality to Western or Southern grown fruit, and locally grown berries were fully as desirable as the commercial packs used for flavoring ice cream, if not superior to them.

Effect of Amount and Kind of Sugar Used

In preliminary reports of this investigation (9, 13) the writers showed that cerelese could not be substituted for cane sugar if good results were to be secured. Darkening of the fruit, crystallization of the sugar, and excessive shriveling and softening of the berries resulted when cerelese was used. The use of cerelese-packed frozen fruit in strawberry ice cream injured both flavor and appearance of the product.

The effect of the quantity of cane sugar used in frozen fruit on the appearance of the pack was discussed in the first part of this report (see Table 2). When used in ice cream the 1:1 packs made a very sweet, soft ice cream while the 4:1 packs did not impart a desirable strawberry flavor. The 2:1 and 3:1 packs imparted a more desirable flavor than all others. From the large number of ice cream samples judged in this study in 1929 and 1930, the conclusion was reached that an ice cream mix containing less than 15 per cent sugar should be flavored with 2:1 packed strawberries, but the 3:1 ratio should be used where the mix contains more than 15 per cent. However, in 1931 a ratio of 2.5:1 was used to a considerable extent and was considered preferable to any other ratio when the standard mix contained approximately 15 per cent sugar.

The Effect of Using Sugar Syrup and Vacuum Packing

An undesirable factor found in the standard sugar packs was oxidation of fruit at the surface. Berries not covered by the syrup were discolored and had lost part of their flavor. In the first part of this report, the advantages of using a cane sugar syrup or vacuum packing to decrease surface discoloration were discussed. Syrups containing 30, 40, 50, 60 and 65 per cent sucrose, as well as 65 and 80 per cent invert sugar, were used in different frozen packs and in ice cream (see Table 3). The rating of the ice cream was as follows: that containing 40 and 50 per cent syrup, first and second, respectively, with little choice, if any, between the other samples. The ice cream containing fruit packed in invert syrup seemed inferior to that containing cane sugar syrup. Neither the standard sugar packs nor those containing sugar syrup were improved for flavoring ice cream by packing in sealed cans from which a part of the air had been expelled by vacuumization before freezing.

Little difference was observed between the 2:1 and 3:1 sugar packs, those containing 40 or 50 per cent sugar syrup, and the vacuum packs. These observations indicate that the ice cream maker may safely buy frozen fruit packed by any of these methods. From the standpoint of flavoring ice cream, it is evident that the quality of the fruit is of greater importance than whether it has been packed in sugar, sugar syrup, or under vacuum.

Effect of Delay Between Packing and Freezing Fruit

No differences were evident in the flavor of ice creams made from strawberries which had been held for 6-24 hours at 45° F. between the time of packing with sugar and freezing (see Table 4). This treatment affected the appearance of the fruit and the ratio of fruit to sugar in the defrosted product. However, no flavor was lost from the pack so long as the holding period did not allow fermentation. In allowing fruit to remain unfrozen for several hours, more

flavor was drawn into the syrup but the degree of flavor in the combined fruit and syrup remained unchanged.

Effect of Slicing or Crushing Berries Before Freezing

Since ice cream makers have used both crushed and sliced fruit as well as whole, it seemed advisable to determine what effect these methods of treating the fruit before freezing had on the finished pack as well as on ice cream. The appearance of the crushed berries after thawing was not desirable, and more surface discoloration was evident than with whole fruit. Although the majority of those criticising the samples of ice cream made from whole and crushed fruit could not differentiate between them, nevertheless, the more experienced judges invariably preferred those samples made from the whole fruit.

Slicing berries into thirds or quarters gave better results than crushing the fruit. The sliced fruit showed no greater surface discoloration during storage than whole fruit. Though less syrup was evident in the thawed sliced fruit samples due to the finer division of the fruit through the syrup, still, very little quality difference was found between ice cream made from whole or sliced berries. A slight preference was shown for the ice cream flavored with the sliced berries, but this difference alone was not enough to justify the extra expense involved in the preparation of the fruit.

Comparison of Fresh and Frozen Fruit

Fresh fruit is usually considered the best possible source of fruit flavor. Though fresh fruit ice creams in season always have a strong sales appeal, yet it is by no means proved that preserved fruits may not surpass the fresh in suitability.

Comparisons were made between fresh fruit which was mixed with sugar and immediately used in ice cream and fruit of the same variety and similarly prepared but held for 24 hours at 40° F. That which was held 24 hours before use in ice cream imparted considerably more fruit flavor. During the holding period the sugar syrup, through osmotic action, extracted much of the flavor from the fruit. This resulted in a finer flavored ice cream. The same action occurs in frozen fruit packed with sugar. Frozen fruit held for one year at 10-15° F. was found to be a satisfactory substitute for the fresh. When ice cream samples of both were compared, only the more discriminating judges could differentiate between those flavored with frozen fruit and with fresh fruit.

The Amount of Fruit to Use in Ice Cream

The percentage of fruit used affects not only the flavor of ice cream but the body and texture and rate of freezing as well. Therefore this factor should receive careful consideration by the manufacturer.

Strawberry ice cream was made, using from 6 to 20 per cent of fruit. The ice cream became progressively more desirable in flavor up to about 15 per cent. Above 15 per cent, very little increase in fruit flavor was detected, and a coarsening and weakening of the texture and body of the ice cream was evident. These defects actually detracted somewhat from the flavor because the product deteriorated more rapidly in storage than the ice creams containing less fruit.

The concentration of sugar and other soluble solids was also increased in proportion to the amount of fruit used. This resulted in weak-bodied ice cream, which was soft at ordinary cabinet temperatures, if more than 15 per cent of frozen fruit of the 2:1 ratio were used.

The data in Table 8 show the effect of the amount of fruit upon the freezing properties of strawberry ice cream. Increasing the fruit to about 15 per cent was

TABLE 8.—THE EFFECT OF DIFFERENT AMOUNTS OF FRUIT ON THE FREEZING PROPERTIES OF STRAWBERRY ICE CREAM.

Time in Freezer Minutes	Overrun, Per cent				
	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
2	27	28	23	24	23
3	38	38	35	36	36
4	47	49	40	47	46
5	55	56	58	57	54
6	63	66	67	65	62
7	72	74	82	70	73
8	88	89	98	96	87
Brine on, minutes.....	6.25	6.0	5.5	5.5	6.0
Drawing temperature, degrees F....	24.0	23.8	23.7	23.6	23.5
Mix, pounds.....	45	40	38.5	37.5	36.5
Fruit, 2 : 1 pack, pounds.....	0	5	6.5	7.5	8.5
Fruit, per cent.....	0	11.11	14.44	16.66	18.88

accompanied by an increase in the rate of overrun incorporation, but larger amounts of fruit resulted in a slight decrease. The rate of cooling in the freezer was increased by the addition of fruit, which is shown both by the drawing temperatures and by the length of time the brine was used (Tables 8 and 9). Fruit ice creams cooled more rapidly and whipped faster during freezing than plain ice creams. This is assumed to be due to the lowering of the viscosity of the mix by partial coagulation of casein by the fruit acids, as well as to the dilution effect.

TABLE 9.—FREEZING DATA FOR VANILLA, STRAWBERRY, RASPBERRY, AND PEACH ICE CREAM MADE FROM THE SAME BASIC MIX.

Time in Freezer Minutes	Overrun, Per cent			
	Vanilla	Strawberry	Raspberry	Peach
2	30	23	22	23
3	39	35	33	33
4	45	41	39	38
5	49	49	47	45
6	55	53	56	52
7	65	68	70	62
8	78	83	81	74
9	86	90	93	86
10	94	100	99	96
Brine on, minutes.....	6.0	5.33	5.33	6.0
Drawing temperature, degrees F.....	24.5	24.0	24.0	24.3
Mix, pounds.....	45	38.5	38.5	38.5
Fruit, 2 : 1 pack, pounds.....	0	6.5	6.5	6.5

Time to Add Fruit

In commercial practice fruit is added to the mix either at the beginning of the freezing process or after the mix has been partially frozen. A comparison of these two methods showed that the addition of the fruit at the beginning of the freezing process produced a more uniform distribution of fruit, a shorter freezing period, and a better flavor in the ice cream. When the fruit was added after the mix was partially frozen, the fruit remained near the front of the freezer and a large part of it was drawn off in the first half of the batch. Adding the fruit

at this time also raised the temperature of the mix, which resulted in slower freezing and whipping. The only advantage of adding the fruit after partial freezing of the mix was that slightly larger pieces of fruit were evident in the finished product.

The idea, now fairly prevalent, that adding fruit early in the freezing process will curdle the mix, is erroneous. Milk proteins do not normally curdle at the acidity of fruit ice creams (see Table 10). Furthermore, the rapid agitation inside the freezer at the time of mixing prevents the possibility of coagulation.

TABLE 10.—DETERMINATIONS OF pH VALUE IN FRUIT ICE CREAMS.

Flavor	Number of samples	Low pH	High pH	Average pH	Fruit added Per cent
Vanilla.....	12	5.95	6.4	6.29	0
Raspberry.....	1	5.8	13
Cherry.....	6	5.43	5.81	5.7	12
Strawberry:					
1 : 1 pack.....	9	5.69	6.02	5.85	15
2 : 1 pack.....	6	5.55	5.75	5.70	15
3 : 1 pack.....	9	5.48	5.82	5.61	15
Average.....	24	5.48	6.02	5.72	15

The Addition of Flavoring Extracts

Trials were made to determine whether part of the fruit could be replaced by the addition of strawberry extract. This was found to be impracticable. The majority of strawberry extracts studied did not impart a natural strawberry flavor. Only one extract of the eight studied could be used without actually injuring the flavor of the ice cream. This proved to be so mild in flavor that it was of no particular value.

About one-third the usual amount of vanilla extract used in the flavoring of vanilla ice cream may be added to strawberry. The vanilla flavor tends to cover off-flavors in the mix. The work indicated, however, that under most conditions the addition of strawberry or vanilla extract to strawberry ice cream was not justifiable.

Deterioration of Strawberry Ice Cream

It was observed that strawberry ice cream acquired a storage or rancid flavor in a shorter storage period than vanilla. Wright (22) showed that acidity is a factor in increasing the rate of oxidation of butter fat. Table 10 contains the average pH readings of the different fruit ice creams. The addition of the fruit increased the hydrogen ion concentration of the mix, which would thus increase the rate of oxidation of the fat. By shifting the pH of plain mix to this extent by the addition of pure lactic acid, a more rapid deterioration of the product was observed.

Tracy concludes (16) that the enzymes in the fruit itself play a part in flavor deterioration. He reported data to show that by heating the strawberries to a temperature of 175° F. for 20 minutes the enzymes were inactivated and the keeping quality of the ice cream was enhanced. This study supports the conclusions of Tracy. Dahle (4) concludes that dissolved copper salts play a part in the oxidation of butter fat in strawberry ice cream.

From the work cited above and the results secured in this study, the conclusion may be drawn that the more rapid deterioration in flavor of strawberry

ice cream is caused largely by more rapid oxidation of the butter fat which is induced in turn by the more acid nature of strawberry ice cream, the enzymes contained in the fruit, and the presence of metallic salts.

Raspberry Ice Cream

Less fruit appeared to be desirable in making raspberry ice cream than with other fruit flavors. Three reasons were evident: the seeds were objectionable when a liberal amount of fruit was used; the fruit is relatively expensive; and raspberry extracts of good quality, which could be used to replace some of the fruit, were found to be commercially available.

Much more satisfactory results were secured when either the fresh or frozen fruit was pureed to remove about 75 per cent of the seeds. From 12 to 15 per cent of the raspberry puree was necessary to properly flavor the ice cream. A product of good quality was made by reducing this amount to about 10 per cent and using it in combination with a good commercial raspberry extract.

Raspberry packs of 2:1 and 3:1 ratios proved superior to all others (see Table 5). The preference between these ratios was in favor of the 3:1 fruit in most cases. A marked difference was found between the desirability of different varieties, Cuthbert, Herbert, and St. Regis being preferred in the order named over such varieties as Newman, Latham and Ontario. The latter varieties produced an ice cream which lost its good flavor during storage more rapidly than that flavored with Cuthbert, Herbert, or St. Regis varieties. The St. Regis is a more seedy variety than either Cuthbert or Herbert.

The data in Table 9 show that raspberry ice cream cools faster in the freezer and whips faster than vanilla.

Peach Ice Cream

Peach ice cream has a popular appeal during the fresh peach season. However, a good peach flavor was found to be difficult to secure in ice cream because of the mild flavor of the fruit. Therefore, a large amount of fruit, 15 to 20 per cent, must be used. A ratio of three parts of fruit to one of sugar in frozen-packed peaches should be used. This ratio imparted the best flavor and had the added advantage that the firmness of the ice cream was not decreased as much as with the 2:1 pack. This factor is of especial importance since more fruit is necessary than for other fruit flavors.

It was found that yellow-fleshed peaches were superior to the white for flavoring ice cream and, since they are firmer, larger shreds of the fruit were evident in the ice cream. No variety of peach was studied, however, which yielded sufficient flavor. Therefore some type of flavoring extract should be added to the ice cream along with the fruit. The best product studied was a peach brandy syrup. Some manufacturers replace about one-third of the peaches with apricots and claim good results.

Canned pulped Georgia peaches (some skin was present in the fruit) were compared with fruit grown in the college orchards. The pulped fruit imparted a more desirable flavor to the ice cream. More yellow shreds of fruit were visible in the pulped product and this also improved the appearance of the ice cream.

The freezing time for peach ice cream, as is shown in Table 9, was about the same as for vanilla.

Cherry Ice Cream

The sour varieties of cherries were found to be superior to others for use in ice cream. Montmorency, Early Richmond, and May Duke cherries were

better varieties than the Morello (see Table 7). However, these cherries did not impart as satisfactory a flavor as maraschino processed cherries. By the addition of a good commercial cherry extract, or a small amount of benzaldehyde or oil of bitter almonds, to frozen fruit of the above varieties, a satisfactory substitute for the flavor of maraschino processed cherries could be secured. One to two cubic centimeters of benzaldehyde or oil of bitter almonds was sufficient for ten gallons of finished ice cream.

Cherries packed in the ratio of two pounds of fruit to one of sugar were found to be more satisfactory than packs of other ratios. A desirable amount of fruit to use in cherry ice cream was from 12 to 15 per cent. The addition of cherry extract may be practiced, as it was found that many of the extracts, if used in satisfactory amounts, were capable of improving somewhat the flavor of the cherry ice cream. The freezing time for cherry ice cream was found to be slightly less than for vanilla.

Pineapple Ice Cream

A comparison of pineapples which were packed in Hawaii and Puerto Rico was made. The fruit had been crushed and canned (heat preserved). The Hawaiian packs were found to impart a more noticeable pineapple flavor to ice cream, and possessed the added advantage of firmer flesh, a deeper color, and less syrup. The heat-preserved pineapples were found to be as satisfactory as the frozen fruit for flavoring ice cream.

From 12 to 15 per cent fruit was found to be the most desirable amount for pineapple ice cream. Pineapple ice cream was found to whip very rapidly during freezing, probably due to the partial coagulation of casein by the acid in the fruit.

General Discussion of Fruit Ice Creams

In the use of frozen or cold packed fruits, a trend is in evidence towards the 3:1 pack rather than the 2:1. Where syrup packed fruit has been used, that containing a 40 per cent sugar syrup seems more suitable than any other. This corresponds more nearly in sugar content to the 3:1 than to the 2:1 pack. This trend seems reasonable in view of the fact that the 3:1 pack contains $8\frac{1}{2}$ per cent more fruit than the 2:1. Hence more fruit flavor should be secured from the use of the 3:1 pack.

Another and perhaps more important consideration is that the 3:1 pack adds less sugar to the mix than the 2:1, and therefore an ice cream results which is firmer at the usual cabinet temperatures. This is a point of considerable importance, since the tendency in recent years has been to increase the amount of fruit, due perhaps to a corresponding decrease in the cost of the frozen fruit.

No ice cream maker should be without a hydrometer for determining the soluble solids content of fruit juices. The percentage of soluble solids in the syrup of frozen fruit is shown in Table 2 to be 38.2 for the 2:1 packs, and 32.3 for 3:1. Some frozen fruit sold on the market labelled as 3:1 was found actually to be 2:1, according to the soluble solids content of the syrup.

The freezing data which have been previously discussed indicate that fruit ice creams usually attain overrun in the freezer more rapidly than vanilla. The authors realize that this is not in agreement with the data (5) and statements (15, 14) found in previously published material on the subject. However, the data in Tables 8 and 9 are representative of that secured with two direct expansion freezers and four brine freezers, working in three different plants. The fact that slower whipping for fruit ice cream has been reported by other investigators

may be due to one or more of the following reasons: (1) the fruit used may have been at a higher temperature than the mix (particularly if frozen fruit were heated in order to hasten melting); (2) overloading the freezer may have resulted by adding the fruit to the same amount of mix that was used for vanilla ice cream; or (3) the fruit may have been added to the mix after it was partially frozen, thus raising the temperature of the entire batch and causing a loss of overrun.

Fruit ice creams should be drawn from the freezer at about 0.5° F. colder than vanilla. This is necessary in order to secure the same degree of firmness, due to the higher sugar content of the fruit ice creams, which lowers the freezing point.

Many manufacturers and consumers prefer to see large pieces of fruit scattered through fruit ice creams. The addition of the fruit at the beginning of the freezing process, as has been recommended in this bulletin, causes the fruit to be ground into small pieces, while addition of the fruit when the mix is partially frozen does not permit uniform distribution through the batch. Therefore, in order to have larger pieces of fruit visible in the ice cream, a few manufacturers follow the practice of holding out a part of the fruit pulp and adding it slowly through the fruit hopper as the ice cream is being drawn from the freezer.

The cost of flavoring fruit ice cream is not as great as one would assume when it is realized that overrun is secured on the fruit and syrup as well as the mix. Some fruits, such as frozen strawberries, canned pineapple, and bananas, do not differ greatly in cost from the ice cream mix itself. However, fruit preparations such as orange-pineapple, frozen pudding, and mint-pineapple are relatively more expensive.

Fruit Ices

Fruit ices were made from a base of 33 pounds of water, 9 pounds cane sugar, 3 pounds cerelese, and enough gelatin to cause a slight thickening in 24 hours of aging. This was found to be 0.5 per cent for the gelatin used in this experiment. To this was added 8 to 10 pounds of fruit and enough of a 50 per cent solution of citric or tartaric acid to produce an acidity of 0.7 per cent. The ices were frozen to a firm condition in the freezer and were drawn at an overrun of 30-35 per cent. Sherbets were made in the same way by substituting whole milk for the water.

Pureed raspberries, pulped peaches, strawberries, plums, and pineapple proved very satisfactory for ices. Frozen, pulped cranberries with sugar (2:1) as well as pulped, cooked cranberries also proved satisfactory. Ices were made from pulped currants which had been frozen with the 2:1 ratio, rhubarb pulp packed 1:1, blueberry and blackberry pulps packed 2:1, all of which possessed the characteristic flavor.

A study was made to determine the optimum acidity that an ice should possess. Variations in acidity from 0.5 to 1 per cent (expressed as lactic acid) were employed. The majority of judges preferred an acidity of about 0.7 per cent, the others being about equally divided between 0.6 and 0.8 per cent.

Acidity was determined by titrating a 9-gram sample of the ice (seeds and pulp excluded) with one-tenth normal sodium hydroxide, using phenolphthalein as the indicator. The weighed sample was diluted with 9 cubic centimeters of distilled water previous to titration in order to have a more workable sample. The readings were expressed in terms of lactic acid, using the formula:

$$\frac{\text{c.c. of 0.1 N NaOH used} \times 0.009 \times 100}{\text{wt. of sample in grams}} = \% \text{ lactic acid}$$

Although many ices are colored pink, no difficulty was encountered in determining the end point because the solution became practically colorless before the

end point was reached. This method of titrating ices or sherbets for acidity is therefore recommended because the equipment is always available in an ice cream plant.

SUMMARY

Investigations on methods of freezing and utilization of frozen New England fruits were carried on during three crop seasons. All the fruits studied were grown in the college orchards, frozen, defrosted, examined, and later utilized in frozen dairy products. In all, over 650 one-gallon cans of these fruits were frozen.

1. Fruit varieties vary greatly in their suitability for freezing and for use in ice cream. Of the 20 varieties of strawberries, the most desirable frozen packs were Howard Supreme, King Edward, Marshall, Howard 17, First Quality, Aberdeen, Boquet, Beacon and Bliss. The red-fleshed varieties of strawberries gave higher colored frozen packs. The most satisfactory raspberry varieties were Cuthbert, Herbert and St. Regis; peaches, Hiley, Elberta, Hale and Crawford; cherries, Montmorency. In general, yellow-fleshed varieties of peaches were more attractive than white when frozen.
2. While plums, red currants, nectarines, cranberries, blackberries, blueberries, black and purple raspberries, and rhubarb were successfully preserved by freezing, these fruits cannot be considered entirely satisfactory. Though not suited for use in ice cream, fairly satisfactory ices can be made from them. Cranberry ice is particularly good.
3. For one-gallon cans of fruit a freezing temperature of 0 to -10° F. with subsequent storage at 10 to 15° F. proved entirely satisfactory. A moderately constant storage temperature is essential for maintaining the quality of the pack. Defrosting and refreezing are definitely injurious to both appearance and flavor of frozen fruits.
4. The soluble solids content of 20 varieties of strawberries varied from 5.9 to 7.6; acidity (citric) from 0.9 to 1.43 per cent; ratio of fruit to syrup in the 2:1 frozen pack from 1:0.62 to 1:1.46; and Brix readings from 33 to 44 per cent.
5. The sugar concentration (Brix reading) of the syrup of defrosted fruits serves as an index of the original fruit to sugar ratio. (See Table 2).
6. Discoloration in frozen fruits is normally limited to the surface layer. Although this injures somewhat the appearance of the fruit, little injury to flavor results. Peaches were particularly subject to surface discoloration. Syrup packing reduced this defect considerably; vacuum sealing practically eliminated it.
7. In every case the addition of sugar to fruit before freezing greatly improved the flavor, color and general appearance of the pack. Fruit to sugar ratios of 2:1, 2.5:1, and 3:1 were most satisfactory for frozen strawberries and raspberries. When the ice cream mix contained 15 per cent sugar or less, the 2:1 or 2.5:1 packs should be used; while the 3:1 ratio was preferred when the sugar in the mix exceeded 15 per cent. Cherries should be frozen with sugar in the ratio of 2:1, and peaches with a 3:1 ratio.

8. Cerelose (corn sugar) was unsatisfactory in frozen fruit because it injured the flavor and texture and caused discoloration of the fruit.
9. Freezing fruit in syrup containing 40 or 50 per cent cane sugar proved a desirable method of storing fruit for later use in ice cream.
10. Vacuum packing prevented oxidation of the fruit at the surface, but otherwise was the equivalent of syrup or dry sugar packs.
11. Delayed freezing caused some shrinking of the fruit but did not injure the quality of the pack, providing the delay was not sufficient to allow fermentation. Pre-cooling of the fruit or syrup before freezing greatly hastened the freezing process.
12. Slicing or crushing strawberries before freezing was of no particular benefit when the fruit was used in ice cream.
13. The optimum amount of fruit of any desirable pack to use in ice cream was about 15 per cent by weight for strawberries, cherries or pineapple, 10 to 12 per cent for raspberries, and 15 to 20 per cent for peaches.
14. The time necessary to attain the desired consistency and yield in freezing ice cream varied with the flavor; the time required for peach was about the same as for vanilla, but for strawberry, pineapple, cherry and raspberry it was less.
15. The fruit should be added to the freezer immediately after the freezing operation is started if uniform fruit distribution and rapid overrun incorporation are to be realized.
16. Supplementing fruit with fruit extracts in flavoring ice cream was of no value with strawberry because most strawberry extracts had an artificial unnatural flavor. However, many raspberry, cherry, and peach extracts, when used in the correct amounts, did improve the flavor of the ice cream.
17. Strawberry ice cream deteriorated more rapidly in flavor than vanilla, due in part to more rapid oxidation of the butterfat, which is induced by the fruit acids and enzymes. Heating the fruit to 165° F. for 20 minutes inactivated the enzymes and improved the keeping quality of the ice cream.
18. A basic formula is given for fruit ices. The acidity of fruit ices should be constant, 0.7 per cent being suggested as the most desirable acidity.

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