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The Effect of the Sugar Content in the Manufacture of Commercial Ice Cream

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The Effect of the Sugar Content in the Manufacture of Commercial Ice Cream

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ABSTRACT.—Sugar, one of the most essential ingredients of ice cream mixture, was found to lower the freezing point of a mixture, delay freezing, increase the overrun, and improve the flavor, body and texture with each additional increment of sugar up to 12 per cent. Thereafter, the overrun was correspondingly depressed and the flavor, body and texture became inferior. The resistancy of the mixtures decreased as the sugar content was increased, the same being true when ice creams containing sugar varying from 8 to 16 per cent were exposed to a standard melting temperature of 86° Fahrenheit.

The manufacture of ice cream has reached a point where it is one of the foremost of dairy manufacturing industries. The ice cream manufactured during the year 1923 reached an approximate total of 300,000,000 gallons. Despite the magnitude of the industry, the methods employed in ice cream manufacture show little uniformity. Even in the fundamentals there is much variation. There is, for example, at least 25 per cent variation in the amount of sugar used by manufacturers of the same quality of ice cream.

This investigation was designed to aid in the standardization of present methods of manufacturing ice cream and to develop improved methods.

The work of previous investigators has been aimed chiefly at proving the value of certain commercial methods of making ice cream. The standardizing of those methods has not been attempted.

Davis of the California Station[1] in 1916, found that there was no uniform relationship between the consistency of an ice cream mixture and the per cent of swell where different thickeners were used. Decreasing the amounts of sugar in the mixture below normal, increased the percentage of swell and produced an unfavorable effect upon flavor and texture. Increasing the amount of sugar above normal caused a decrease in the percentage of swell, produced a better texture, and resulted in too sweet an ice cream.

Frandsen and Rovner[2] investigated substitutes used for conservation of sugar in ice cream making, and found that none of the substitutes

[1]Davis, L. M. Relation of Consistency and Percentage of Swell of an Ice Cream Mixture. Cal. Station Report 1916. Abstract in E. S. R. 36, p. 21

[2]Frandsen, J. H., Rovner, J. W., and Leuthly, J. Sugar Saving Substitutes in Ice Cream. Neb. Sta. Bul. 168, 1918, p. 8. Abstract in E. S. R. 39, p. 872

tested would satisfactorily replace all the cane sugar in the ice cream mixture. They worked out four formulae which save from 30 to 50 per cent of cane sugar, lower the cost of sweetening, and produce ice cream of satisfactory flavor and texture.

Ayer, Johnson and Williams of the U. S. D. A.[3] found that grain syrups could not be successfully used as substitutes because they gave a pronounced grain flavor and an acid taste when used to the extent of only 10 per cent. They also found that some grades of corn sugar imparted a yellow color and a bitter flavor.

METHODS OF INVESTIGATION

The first problem was the designing of apparatus for freezing ice cream under identical conditions so that accurate comparisons could be made. Freezers had to be so operated that three or four batches could be frozen at the same time under identical conditions. This was accomplished by arranging a battery of four freezers in the same cold brine and connecting to the same motor.

Ice Cream Freezer for Experimental Determinations.—An ice cream freezer was constructed with two adjoining compartments, namely: the compartment for the freezers proper and a compartment called the auxiliary ice box.

In the freezer compartment proper were placed four one-gallon ice cream freezers which had been stripped of the packers. All four freezers were set in an upright position and their respective fly wheels operated in a direct line. Thus it was possible to operate the four freezers from one shaft and have all freezers in motion at the same time.

In the top of each can two semicircles were cut, an inch in diameter and four inches long, for the purpose of observing the condition of the mixture while the freezers were in motion. With these two slots it was possible to observe exactly when freezing began and also to watch the mixture whip up and begin to harden. The maximum swell was easily determined in this way and the freezing could be stopped before any swell was lost.

The salt and ice used in making the brine for all of the experimental work was made in the same way as in the manufacture of ice cream commercially.

After the brine had been brought to the desired temperature the mixture to be frozen was tested for its viscosity and specific gravity at a temperature of 40° F., this temperature being a constant for all mixtures. The mixture to be used was weighed into the one-gallon ice cream cans

[3]Ayers, Johnson and Williams, U. S. D. A. Sugar Substitutes in Ice Cream Mixtures. Abstract in Ice Cream Trade Journal

and determinations were made in duplicate, triplicate, or even four determinations were made if necessary.

Apparatus and Method for Determining the Hardness of Ice Cream.—The desirability of having an accurate method for determining the hardness of ice cream has been felt for a number of years. The Virginia Station used an apparatus similar in construction but less elaborate than the one used in this investigation.

In making hardness determinations, the frame with a suitable needle and weight, if used, was suspended from the electro-magnet, and the brick of ice cream to be tested was placed in position beneath the needle, the height being regulated by an adjustable platform. The frame was then released by means of the key. The depth of penetration was ascertained by measuring with the metric rule, stretching a fine wire from rule to rule and taking the reading from each. This gave the depth of penetration direct.

The average of the six readings or penetrations was taken as the depth of penetration. Since the cross sectional area of the penetrating needle is known and the depth of penetration had been ascertained, their product indicated the volume of ice cream displaced. Comparisons were also made between different samples by means of penetration.

The amount of weight employed and the size of the needle used depend, of course, on the character of the ice cream; and the temperature at which the hardness was determined. With a proper combination of needles and weights, the needle would remain practically stationary in the ice cream after the initial plunge. To offset any chance of experimental error, the needle was brought to the same degree of temperature as the ice cream under test.

Determinations of How Close Observation Could Be Made Relative to When the Maximum Overrun Has Been Obtained With This Type of Freezer.—The ice cream, during the whipping period, could be easily seen to be gradually climbing above the spoon on the dasher, then coming to the surface of the can. It is known that a mixture swells up to a certain height and when this point is reached it will remain there but a very short time, because of the lack of further power of the mixture to hold more air, and it will then begin to fall. When the mixture fails to whip in any more air it is said to have reached the maximum overrun. This point was learned by freezing a series of forty mixtures and observing when the maximum overrun had been reached.

This series of freezings was followed by a freezing of five different mixtures in duplicate, each mixture having a different percentage of sugar varying from 8 per cent to 16 per cent.

The increase in percentage of sugar content gave a relative increase in the density of the mixture; time required to freeze; and weight of ice cream. Concurrent with the increase in sugar there was noted an increase in the weight of the finished ice cream when weighed for overrun. The total time required for freezing also increased with the sugar content showing that sugar was really the factor which retarded the freezing.

TABLE 1.—OBSERVATIONS OF MAXIMUM OVERRUN
(Fat Content Uniform at 10%)

Ingredients in mixture	8% Sugar	10% Sugar	12% Sugar	14% Sugar	16% Sugar
Sp. Gravity of mixture	1.0618	1.071	1.078	1.084	1.0925
Weight of Overrun	728	722	722	734	743
Per cent Overrun	84.20	87.35	88.57	86.50	84.25

These observations with this type of freezer gave the following results: (1) It was possible to detect differences in overrun as small as 4½ per cent. (2) Increased sugar content gave a more dense mixture or increase in weight of ice cream, which was concurrent with the increase of sugar and retarded the time required to freeze. (3) An increase of sugar up to 12 per cent gave an increase in overrun; beyond this point, the decrease proved as gradual as the increase.

The Effect of Increased Percentages of Sugar on the Hardness of Ice Cream.—The relation that sugar has to the hardness of ice cream was determined by the application of the apparatus previously described. In making the following determinations, five mixtures, each differing in the percentage of sugar were used. The variation in the temperature of the ice creams under test was not greater than 1 degree and within the limits allowed by this method.

Six penetrations were made of each brick, two in the center and two on each end of the brick. With this range of area, a uniform hardening of the brick could easily be determined. All determinations were made in duplicate, giving a total of twelve penetrations for each percentage of sugar. This work was done in a cold room, so the temperature of the ice cream would not vary and give an error in penetration.

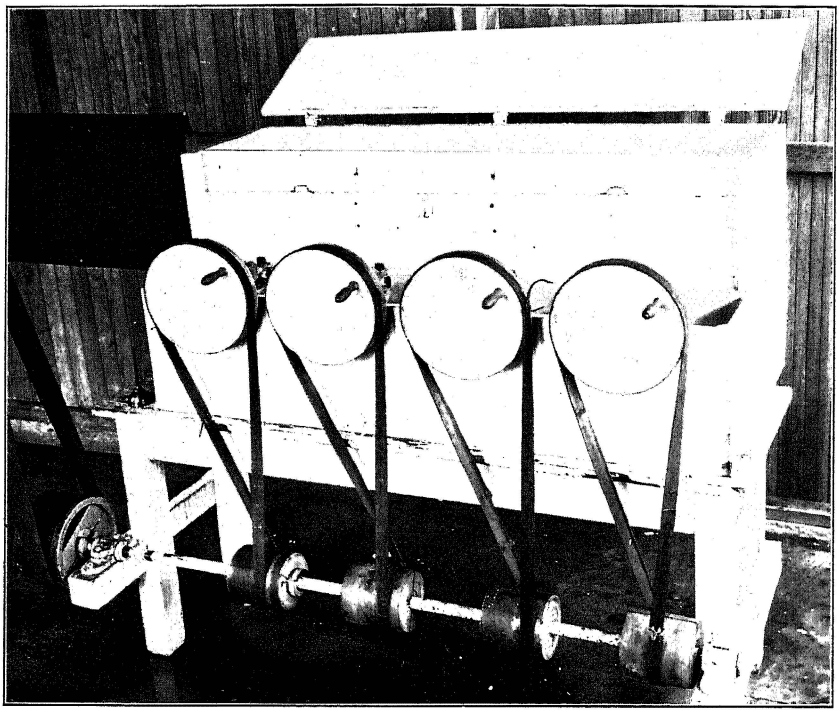

Fig. 1. Front view of freezer, showing how individual freezers were operated.

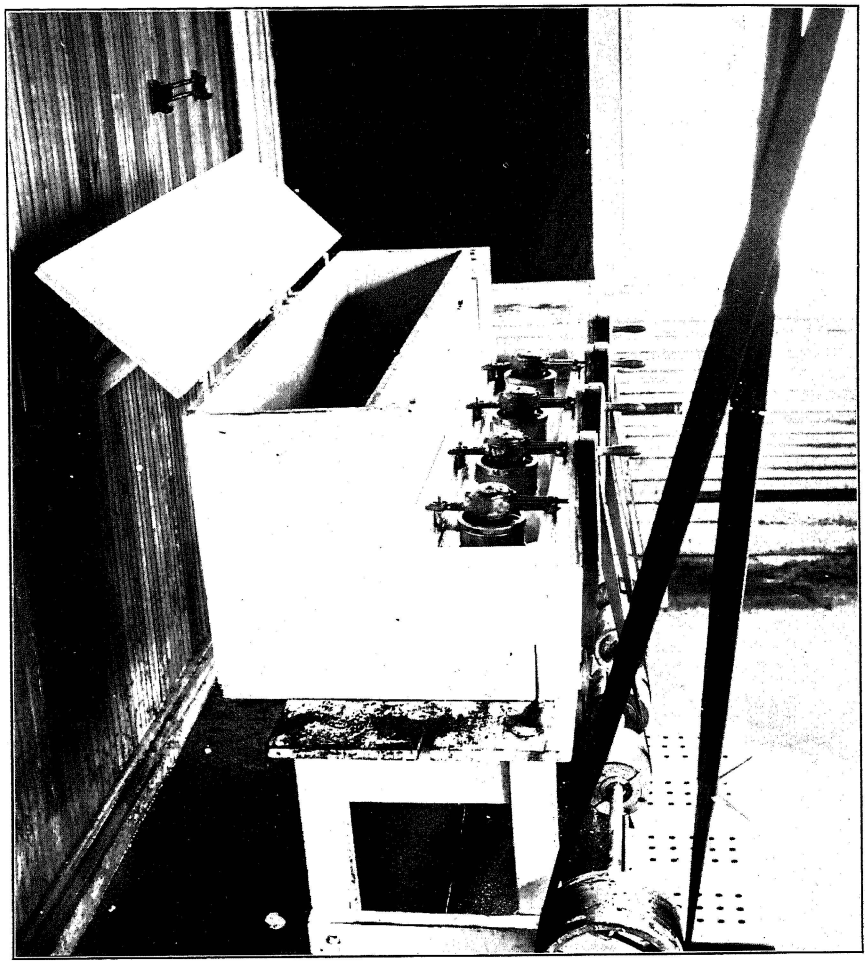

Fig. 2. End view of freezer, showing position of compartments and ice cream cans.

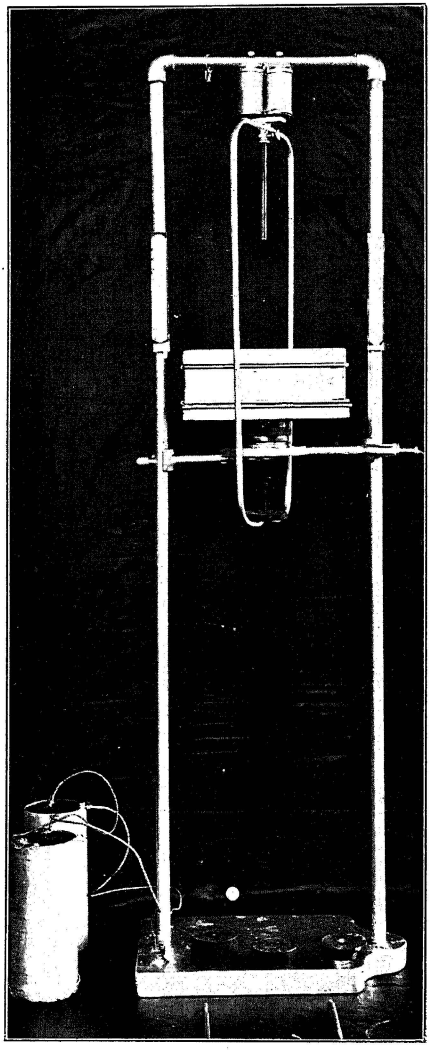

Fig. 3. Hardening apparatus; needle and brick of ice cream in position before penetration.

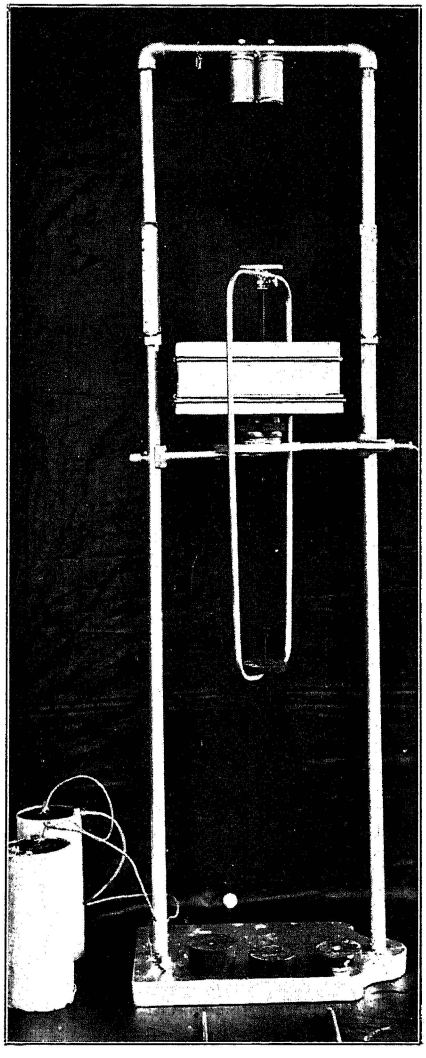

Fig. 4. Hardening apparatus; showing position of needle in penetrating brick of ice cream.

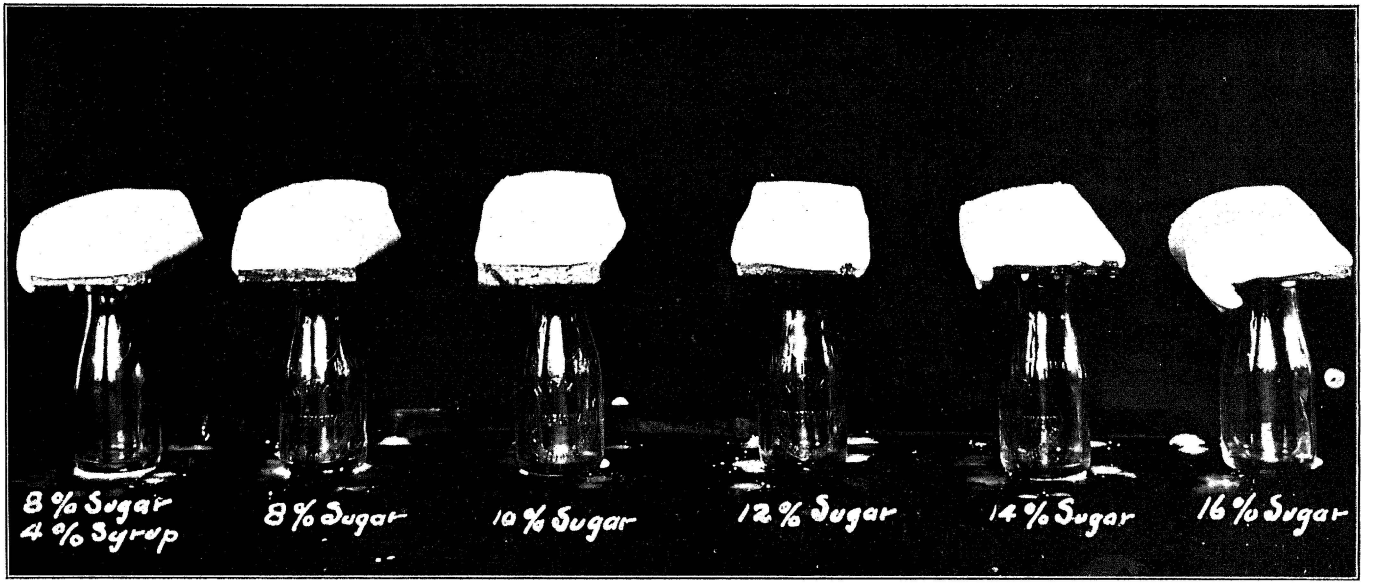

Fig. 5. Showing the six bricks of ice cream after melting for a period of four hours at a temperature of 86° F. The percentage of sugar used in each brick corresponds to the resistance to heat offered by that brick and its ability to retain its original form. Note the honeycombed appearance of bricks containing 14 and 16 per cent sugar, also the cracks in the latter.

Experiments Showing the Effect of the Percentage of Sugar on the Hardness of Ice Cream.—Table 2 illustrates the relation of the percentage of sugar in a mixture to the hardness of the finished ice cream. Little difference was found in penetrations of the needle at the end or center of any one brick. It will be noted that there was a gradual

TABLE 2.—THE EFFECT OF THE PERCENTAGE OF SUGAR ON THE HARDNESS OF ICE CREAM

(All temperatures were read in Centigrade. Penetrations are expressed in millimeters)

	8% Sugar		10% Sugar		12% Sugar		14% Sugar		16% Sugar	
Temp. of I. Cream	−9.8	−9.9	−10	−10.1	−10.2	−10.1	−9.6	−9.7	−10.1	−10.2
Penetrations										
Center	20:19	20:21	24:24	23:24	26:25	25:25	33:33	32:29	36:37	35:36
End	20:20	20:20	24:20	21:23	28:27	26:26	26:29	32:30	37:34	36:33
End	18:19	20:21	24:24	22:24	26:27	27:28	27:27	31:30	37:37	35:36
Average	19.1	20.3	22.6	22.9	26.6	26.3	29.1	30.6	36.3	35.1
Size of needle (mm.)	6.35		6.35		6.35		6.35		6.35	

increase in the depth of penetration with each additional two per cent of sugar. The depth of penetration when 16 per cent sugar was added to the mixture was nearly double that secured when 8 per cent sugar was used.

Three things are shown. (1) Ice cream made from a mixture containing 8 per cent of sugar gives the most resistant body of all mixtures. (2) The hardness of the ice cream decreased with each additional increment of sugar. The batch with 16 per cent proved only half as resistant as when 8 per cent of sugar was used. (3) With this type of apparatus the hardness of any batch of ice cream can be easily determined to within 1 centimeter.

Determination of the Time Required for Ice Cream With Different Percentages of Sugar to Melt Under Summer Conditions.—A series of mixtures ranging in sugar content from 8 to 16 per cent were frozen and the length of time that each mixture retained its original form under average summer temperatures was obtained. An average summer temperature of 86° F. to which it was considered that all ice creams may be exposed, especially upon arriving at the home of the consumer, was used in determining this factor.

A vat with a galvanized iron water jacket on the outside was used for maintaining a constant temperature. The vat was heated to 86° F. and this temperature was used as a constant in making all determinations. The rectangular forms, which were simply rectangular pieces of

wood, the size of the bricks of ice cream with a nail driven up through the center to hold the brick of ice cream in place were weighed. Each form was paraffined to retard its absorption of moisture during the standard melting period. The bricks of ice cream which had been tempered for six hours were placed on the forms, and the weight of form and brick recorded. Each brick was then transferred to the melting vat and the time noted. After one hour's time the bricks were reweighed. The melting was continued over a period of four consecutive hours, reweighing each brick at the end of each hour.

TABLE 3.—DETERMINATIONS OF LOSS IN WEIGHT BY THE MELTING OF BRICK ICE CREAM

Percentage Sugar		8%	10%	12%	14%	16%
Temperature of vat		86°	86°	86°	86°	86°
Percentage fat		10	10	10	10	10
Orig. wt. of brick		520	533	523	551	547
weight of brick after melting	1 hr.	423	439	410	446	437
	2 hrs.	315	312	227	304	282
	3 hrs.	246	237	205	222	200
	4 hrs.	198	190	160	171	147
Total Loss		342	343	363	380	400
Loss in percentage	1 hr.	18.6	17.6	21.6	19.0	18.4
	2 hrs.	39.5	41.5	47.0	44.8	48.4
	3 hrs.	52.6	55.5	60.8	59.7	63.4
	4 hrs.	61.9	64.5	69.4	69.1	73.1

The temperature of the vat did not vary more than two degrees above or below 86°. This gave a constant melting during the standard melting period. Tempering each brick eliminated any error that would enter in case the bricks were not at a uniform temperature.

The original weights of the bricks did not check to within a few grams difference, but the variation in weight was not sufficient to produce any material error, caused by greater surface exposure of some of the bricks.

Special attention should be given to the direct relation of the melting to the sugar content of each brick. The data show that there was an increased loss of 30 grams per brick with each 2 per cent increase in

sugar content. This loss is uniform for each increase of sugar content. In comparing the holding-up ability and sugar content of the brick, an inverse relation was observed. The percentage of loss increased as the percentage of sugar in each mixture increased. The percentage of loss of the brick containing 16 per cent of sugar, was 12 per cent greater than in the 8 per cent sample.

The ice cream that offered the greatest resistance to the penetration of the needles was the hardest, and held up longer under the melting temperature. This indicates that the brick of ice cream retaining the greatest weight after the standard melting time of four hours had the highest melting resistance, and for that reason is best adapted for commercial use.

At the end of the first hour of melting, the brick containing 10 per cent of sugar, had offered the greatest resistance to the heat and had held more closely to its original form. Bricks containing 12 per cent and 14 per cent of sugar respectively, had widened at the lower surface, and decreased somewhat more in size. The heat had its most marked effects during this initial period on the brick containing 16 per cent sugar, the bottom of this brick spreading out considerably and a sloughing to one side being noticeable.

After an exposure of two hours the general form of the bricks was very similar to the form after the first hour of melting. All samples were now showing the effects of the melting temperature and began taking on a honeycombed appearance, due to the loss of moisture, and the settling of the heavier ingredients of the mixture toward the lower strata of the brick.

All bricks were somewhat spread at the bottom after three hours of melting. The bricks containing the largest percentage of sugar, namely, 14 and 16 per cent, had sloughed greatly to one side and large cracks appeared on the surface showing that with these percentages of sugar the ice cream would not hold up when kept at the standard temperatures. The most stable bricks, in retaining their form, were the 8 per cent and 10 per cent, the latter retaining its form the better of the two. The honeycombing of all bricks was very noticeable at this stage.

The final period found a wide variation in comparison with the original bricks, before their exposure to standard melting temperatures. The residue on each board was very porous on the surface. The centers were very soggy, sticky and sweet, due to the continual melting and depositing of the sugar at that point.

These results justify a number of conclusions. (1) As the sugar content increased above ten per cent, the body of the ice cream weak-

ened. (2) The ice cream containing 10 per cent sugar had the best holding-up qualities. It retained more nearly its original form than any of the other mixtures observed. (3) Although the brick with 8 per cent of sugar held up practically as well as the brick containing 10 per cent sugar, the sweetness was below that required by the general trade. (4) The bricks containing 14 and 16 per cent of sugar showed a weakened body and could not hold up.

SCORING OF THE ICE CREAM

Several points not included in the other studies could not be ascertained unless a general score of each ice cream was made. This score was intended to give general or specific data relative to the flavor, body, texture, and appearance of each ice cream at the end of one and seven days respectively.

When each mixture was frozen two bricks of each were hardened and set aside, one was scored at the end of one day and the other after a period of seven days. During these periods, all bricks of ice cream were retained at a constant temperature.

When scored after one day the mixtures containing respectively 8, 10, and 12 per cent of sugar showed no decided difference in appearance or body excepting the 8 per cent had a slightly open body. The sweetness of flavor increased in proportion to sugar used.

After seven days the 8 per cent brick had the most open body and the brick containing 12 per cent of sugar the least. No deterioration in flavor had become apparent. This indicates that the 12 per cent of sugar gave a firmer body and the best textured ice cream.

When four bricks of mixtures containing 8 and 16 per cents of sugar were scored after one day the body of the 8 per cent cream was medium; texture slightly open; flavor somewhat flat; and lacked sweetness. The 16 per cent brick was firm in body; close textured; flavor a little too sweet.

After seven days the 16 per cent bricks had a more firm body, closer texture, were smoother, held up longer in the mouth and had a more desirable flavor than the 8 per cent bricks. This indicates that the additional sugar gave better body, closer texture, better flavor. Sixteen per cent of sugar did not allow the flavor to become old nor was the flavor very excessive in sweetness as might be expected with this amount of sugar.

SUMMARY

Sugar was decided upon as the first ingredient to be studied because of its importance at this time in the manufacture of commercial ice cream

and because it comprises a large portion of the cost of the mixture. Various percentages of this ingredient were used ranging from 8 to 16 per cent. This choice of range was based upon the average percentage of sugar recommended by the manufacturers of large quantities of ice cream. Working with these percentages of sugar it was found that with each additional per cent of sugar the mixture became more viscous.

It was possible to detect when the maximum overrun had been reached within an error of 2 per cent. The curved slots cut in the freezer tops made this observation possible. The overrun increases up to 12 per cent with each addition of sugar. When more sugar was added the overrun decreased with the same rapidity as it had increased, until the maximum decrease was reached. This shows that the amount of sugar that can be added to a mixture and assure an increase in overrun is limited. No further gain would be obtained should more sugar be used, as far as the ultimate overrun would be concerned.

A study was made of the hardness of each mixture after tempering for a given period. The results obtained show that sugar again was the factor which gave a variation in results. It will be seen that the resistance offered by each mixture became less with further addition of sugar to the mixture.

An attempt was made to show in what way exposure of ice cream to summer temperatures causes the cream to melt away. After exposure of the bricks of ice cream for four hours to the standard melting temperature the results obtained show that there is a direct correlation between the percentage of sugar used and the percentage loss in weight, the loss becoming greater with the addition of each 2 per cent of sugar. Ten per cent of sugar gave an increase that offered the maximum resistance to a standard summer temperature. When 14 and 16 per cent was added to the mixture the resisting power was greatly reduced, offering the least resistance of all batches.

In scoring mixtures made up of 8 to 16 per cent of sugar the score after a one-day and a seven-day period would indicate that the product containing 12 per cent sugar was superior in body, texture, and flavor, 8 per cent presenting an open texture and the 16 per cent a rather close texture and firm body. An ice cream containing 12 per cent sugar is more desirable, the 8 per cent lacking in sweetness and the 16 per cent proving somewhat excessive.

With the type of freezer used it was possible to maintain a temperature of the brine at one point with a variation not greater than one-tenth of a degree during an entire freezing. Duplicate freezings were made with a variation not greater than two-tenths of a degree higher or lower than the desired temperature.