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The Freezing Properties, Stabilty, and Physical Qualities of Chocolate Ice Cream

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The Freezing Properties, Stability, and Physical Qualities of Chocolate Ice Cream

W. H. E. Reid and W. E. Painter*

Abstract.—Sugar decidedly influences the whipping ability of a chocolate ice cream mixture, prolongs the freezing time, induces a lower temperature of the ice cream, and creates a physical condition resulting in a lower overrun. Proper balancing of the sugar content of a chocolate mixture causes it to freeze equally fast and attain the same overrun as the vanilla mixture. Excess sugar submerges the true chocolate flavor and causes the ice cream to have a sticky and soggy body, close texture, and impaired stability. Egg powder, when added to a chocolate ice cream mixture, improves its whipping ability, reduces its viscosity, partially submerges the chocolate flavor, removes some of the stickiness caused by a high sugar content, and gives the ice cream a smooth body and a finer texture. Aging a chocolate ice cream mixture improves its whipping ability and reduces the time required to freeze. Reduction of the chocolate flavoring material to three-fourths or one-half of the normal amount added to a base mixture improves the flavor of the ice cream and produces a mixture that freezes equally as fast as a vanilla mixture. There seems to be a point of balance at which chocolate flavoring material and the sugar content produce the most desirable, true chocolate flavor. Chocolate flavoring acts as a stabilizer. Viscosity of ice cream mixtures seemed to increase in direct relation to their sugar content and hours aged. Egg powder increases the viscosity; however, an excess decreases the viscosity. Cocoa and chocolate liquor increase the viscosity of ice cream mixtures. Different increments of sugar, egg powder, cocoa and chocolate liquor do not appreciably affect the surface tension of ice cream mixtures.

INTRODUCTION

Chocolate ice cream ranks second only to vanilla in popularity and many ice cream manufacturers award it first place in the volume of sales during the winter months. The flavor of chocolate ice cream has received considerable attention, yet the whipping properties have been little studied except in a more or less incidental way when investigating the flavor. Little is known as to what occurs chemically or physically when chocolate flavoring material is added to a vanilla mixture and subsequently frozen.

The need for this investigation was further indicated by the replies received in response to a questionnaire directed to 142 ice cream manufacturers who were asked if they were having difficulty in whipping chocolate ice cream to the same overrun as vanilla. A summary of the replies received showed that: 87 per cent of the ice cream manufacturers had difficulty in obtaining an overrun equal to vanilla ice cream; the difference in overrun of chocolate and vanilla ice cream varied from zero to 15 per cent; one-half of the ice cream manufacturers added the chocolate flavoring material to the mixture before pasteurization; none of the ice cream manufacturers reduced the sugar content of the mixture to compensate for the sugar added with the chocolate paste or syrup; only two of the ice cream manufacturers were familiar with the analysis of

*The data presented in this bulletin were taken from a thesis submitted by the junior author in fulfilment of the thesis requirement for the degree of Master of Arts in the Graduate School of the University of Missouri, 1931.

their chocolate paste or syrup; 60 per cent of the ice cream manufacturers did not venture an opinion relative to what factors might prolong the freezing time and decrease the overrun; 40 per cent of the manufacturers were of the opinion that sugar, or a similar product, depressed the whipping ability of chocolate ice cream.

The theory on which this investigation was based was that the removal of sugar, cocoa, or other materials commonly added as or with chocolate flavoring could be eliminated or reduced as a means of keeping the chocolate mixture as near as possible to the composition of the vanilla mixture. A second theory was that of adding dehydrated egg yolk to the mixture as a means of overcoming the difficulties that could not be corrected by otherwise modifying the composition of the mixture. Any process or method which would improve the whipping properties of the chocolate mixture without otherwise injuring its desirable properties would be a substantial improvement.

The purpose of this investigation was threefold: first, to find the composition of a mixture that would whip as readily as vanilla; second, to improve the flavor and stability of the ice cream so that it would compare favorably with vanilla ice cream; and third, to develop improved methods of processing and freezing a modified chocolate ice cream mixture.

REVIEW OF LITERATURE

Caulfield (1930) found that the change in the composition of an ice cream mixture caused by the addition of commercial, prepared chocolate syrups was the principal cause of difficult freezing. A good grade of cocoa or chocolate liquor was more desirable than a combination of both or of any of the syrups used.

Tracy, Ruehe, and Tuckey (1930) found that each of the main constituents of cocoa—fat, non-fat and sugar—impaired the whipping qualities of chocolate mixtures. They recommend a sugar content of 17 per cent for chocolate ice cream when 14 per cent sugar is used in vanilla ice cream.

Dahle (1927) believes that the extra sugar and the additional amount of material in the freezer caused some of the whipping difficulties. He believed that using extra sugar was the most satisfactory way of controlling the flavor.

Fabricius (1930) says a careful selection of cocoa will result in a much improved chocolate ice cream. Cocoa is a cheaper and more desirable chocolate flavoring than chocolate liquor or prepared chocolate flavoring syrups. Adding the flavoring material before homogenization was found to have no effect on flavor.

PROCEDURE

Throughout the entire investigation the experimental conditions were such as are commonly found in commercial plants of both large and small volume. The ice cream mixtures involved were prepared, processed, and frozen in the Ice Cream Laboratory of the University of Missouri and in three commercial plants.

The basic mixture used throughout the investigation, unless otherwise designated, was one selected as an average of those used in many plants, the composition of which was as follows:

Butterfat	12 per cent
Solids (serum)	11 per cent
Sugar	15 per cent
Gelatine	0.5 per cent
Total solids	38.5 per cent

The method of processing the basic mixture, unless otherwise designated, was as follows:

1. Pasteurized by heating to 150 degrees Fahrenheit (65.5 degrees Centigrade) with a holding period of 30 minutes.
2. Viscolized at pasteurization temperature by applying a pressure of 2500 pounds.
3. Cooled immediately to 40 degrees Fahrenheit (4.4 degrees Centigrade).
4. Aged 24 hours at 40 degrees Fahrenheit (4.4 degrees Centigrade).

Samples for viscosity and surface tension determinations were obtained immediately after cooling the mixture.

A control batch was removed from every series of prepared mixture and frozen under the same conditions and at the same time as the chocolate mixture. The freezer was always cooled and conditioned by freezing one or more batches of mixture before the control batch was frozen.

The mixtures were frozen, as indicated, in brine, direct expansion, or instant freezers.

Temperature and overrun readings were obtained every minute or as otherwise designated during the freezing and whipping period of each mixture. The temperature readings were taken with a Centigrade thermometer reading in 0.01 of one degree.

Samples for scoring and other determinations were removed when an overrun of 100 per cent had been reached, and the whipping continued until a maximum overrun had been reached.

Cocoa as the source of flavoring material was added at the rate of 3 per cent or three pounds per 100 pounds of mixture, unless otherwise stated. When chocolate liquor was used it was added to the mixture upon the flavor basis of cocoa, which was 76 per cent and chocolate liquor as 46 per cent.

The physical and chemical properties or factors which might be affected by the different combinations of chocolate ice cream flavoring materials are as follows:

1. Freezing ability
2. Whipping ability
3. Total time to freeze
4. Temperature
5. Overrun
6. Flavor, body, texture, and color
7. Dipping qualities
8. Stability.
9. Surface tension.
10. Viscosity.

The time required to freeze each batch was divided into three phases: (1) the time before the refrigerant was turned off, (2) the time required to obtain 100 per cent overrun, and (3) the time required to attain the maximum overrun.

The overrun was obtained by application of a standard overrun tester reading direct in both percentage and pounds per gallon.

The dipping qualities were measured by tempering the ice creams for a period of eight hours in an electric refrigerated cabinet at 8 degrees Fahrenheit (−13.3 degrees Centigrade) and dipped by one individual who had considerable experience in dipping ice cream. The cone dishes were made with a No. 20 disher which was dipped in cold water with definite frequency. In order to establish whether or not this was a fair method, individual weightings were made of one series of the ice creams and it was determined that the averages were similar. The quarts and pints were dipped, with a regularly used ice cream spoon, into sealrights.

The flavor, body, texture, and color of the samples of ice cream from each batch were observed by four or more competent judges. The body and texture are two characteristics or qualities of the ice creams of primary interest as far as the whipping properties of the mixture are concerned.

The samples to be used in determining the stability of each ice cream were taken in individual quart forms, hardened for 24 hours, and then tempered for eight hours at 8 degrees Fahrenheit (−13.3 degrees Centigrade). They were then placed in an electric control cabinet at 86 degrees Fahrenheit (30 degrees Centigrade) for a period of three hours. The original weight of each brick of ice cream was obtained and each brick was reweighed after the first, second, and third hour of exposure. A photograph was made of the original bricks of ice cream and immediately following an exposure of one, two, and three hours, respectively.

Surface tension and viscosity tests were made at the end of 4, 24, 48, and 72 hours from individual samples of each mixture. No samples were used more than one period. The temperature at which tests were made was 68 degrees Fahrenheit (20 degrees Centigrade). The surface tension apparatus used was a DuNouy. A MacMichael viscosimeter was used in determining the viscosity of all samples.

EXPERIMENTAL DATA

The Effect of Varying the Sugar Content and of Aging on the Freezing Properties of Chocolate Ice Cream Mixtures.—The study was divided into three phases, first, the addition of sugar and flavoring material prior to or subsequent to pasteurization of the mixture; second, the freezing of mixtures varying in sugar content and aging period, using a brine batch freezer, and Vogt instant freezer; and third, the variation of aging periods of mixtures frozen in a direct expansion and a brine batch freezer.

Table 1 gives the results of adding the chocolate flavoring material to the mixture, before pasteurization as indicated in batches 2 and 3, and at the freezer in batches 4 and 5. The data show that in the ice creams to which the chocolate flavoring was added, the overrun was decreased. The decrease in the overrun was marked in batches 3 and 5, which contained additional sugar. Batch 5 had a lower overrun than batch 3, which seems to show that adding chocolate flavor at the freezer also reduces the overrun. The difference in the overrun between batches 1, 2, and 4, and batches 3 and 5 is believed to be due to the increased sugar content. Tables 2 and 3 show that aging of the chocolate mixture greatly reduces the time required to freeze and to whip. Ten or more batches of each mixture were frozen. The reason for this difference in the freezing ability of aged and unaged chocolate mixtures is unknown. Aging was not studied on a Vogt instant freezer because that particular machine seems to be capable of freezing aged and unaged mixtures equally fast.

TABLE 1.—THE EFFECT OF VARYING THE SUGAR CONTENT ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Time to Freeze Five Gallons of Ice Cream Minutes	Time to Freeze and Whip One and One-third Quarts of Ice Cream Seconds	Overrun Per Cent	Temperature of Ice Cream When Drawn Degrees F.
1	15	0	3.0	11.9	130.5	23.5
2	14	3	3.0	11.9	127.4	23.5
3	17	3	3.1	12.2	116.8	23.7
4	14	3	3.0	11.9	129.3	23.3
5	17	3	3.2	12.6	110.3	23.5

TABLE 2.—THE EFFECT OF VARYING THE SUGAR CONTENT AND AGING ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A BRINE BATCH FREEZER

Batch Number	Sugar Per Cent	Age Hours	Freezing Time Minutes	Time Whipped Minutes	Time to Obtain 100 Per Cent Overrun Minutes	Temperature of Ice Cream at 100 Per Cent Overrun Degrees F.	Maximum Overrun Per Cent	Time to Obtain Maximum Overrun Minutes
1	15	4	4½	3½	8	26	112	9
1	15	24	3½	2½	6	26	140	9
2	15	4	4½	7½	12	25	106	15
2	15	24	3	3	6	26	115	18
3	17	4	5½	7½	13	25	108	14
3	17	24	4½	2½	7	25	116	10
4	20	4	5	10	15	26	101	16
4	20	24	3½	4½	8	24	110	9

TABLE 3.—THE EFFECT OF AGING ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Age Hours	Freezing Time Minutes	Time Whipped Minutes	Time to Obtain 100 Per Cent Overrun Minutes	Temperature of Ice Cream at 100 Per Cent Overrun Degrees F.
1	4	8	7	15	26
2	4	9	4	13	26
3	4	8	5½	13½	26
4	24	6	1	7	25
5	24	7	1	8	26
6	24	6	2	8	26

These two particular phases of the investigation seemed to indicate that sugar was the principal factor causing a decrease in overrun, a longer freezing time, and a lower freezing temperature.

The Effect of Varying the Sugar and Egg Powder Content on the Freezing Properties of Chocolate Ice Cream When Frozen in a Direct Expansion Batch Freezer.—The first four batches shown in Table 4 were used as controls. The data again show that sugar had a detrimental effect on the whipping ability, time to freeze, overrun, and the temperature of the ice cream. A longer time was required to freeze and whip, while a lower overrun and temperature resulted from the higher sugar contents. The data further shows that the larger increments of egg powder improved the whipping properties of the mixture and decreased the total time to freeze. The body of the chocolate ice cream had an appearance of being drier and firmer when egg powder was added.

Batches 8 to 13, inclusive, contained higher sugar percentages, which seemed to impair their improved qualities acquired by the addition of egg powder, but not to the extent of causing the egg powder to entirely lose its ability to create greater ease in freezing.

TABLE 4.—THE EFFECT OF VARYING THE SUGAR AND EGG POWDER CONTENT ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Sugar Per Cent	Egg Powder Per Cent	Freezing Time Minutes	Time Whipped Minutes	Time to Obtain 100 Per Cent Overrun Minutes	Temperature of Ice Cream at 100 Per Cent Overrun Degrees F.
1	15	0.00	6	4.0	10.0	24.5
2	15	0.00	6	4.0	10.0	24.5
3	18	0.00	7	3.5	10.5	23.5
4	22	0.00	8	6.0	14.0*	23.5
5	15	0.25	8	2.0	10.0	24.5
6	15	0.50	7	2.0	9.0	24.5
7	15	0.75	6	3.0	9.0	24.5
8	18	0.25	7	4.0	11.0	24.0
9	18	0.50	8	4.0	12.0	24.0
10	18	0.75	6	3.0	9.0	23.5
11	22	0.25	7	2.0	9.0	23.0
12	22	0.50	8	3.0	11.0	23.5
13	22	0.75	7	2.0	9.0	22.0

*Overrun obtainable only 91 per cent due to low temperature of mixture before whipping.

The Effect of Varying the Sugar Content and Chocolate Flavoring Material on the Freezing Properties of a Chocolate Ice Cream Mixture When Frozen in a Direct Expansion Batch Freezer or a Vogt Instant Freezer.—The higher sugar content was detrimental to the freezing ability of the different mixtures, tables 5, 6, 7, and 8, although the basic mixture contained 0.5 per cent egg powder, which assisted in partially overcoming the freezing difficulties.

Decreasing the amount of chocolate flavoring material may slightly improve the freezing properties of chocolate ice creams. This improvement may be due to the fact that the chocolate mixtures containing the smaller amounts of chocolate flavoring material more nearly approached the composition and physical properties of the base mixture.

TABLE 5.—THE EFFECT OF VARYING THE SUGAR AND COCOA CONTENT ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Time to Freeze Five Gallons of Ice Cream Minutes	Time to Freeze and Whip One and One-third Quarts of Ice Cream Seconds	Overrun* Per Cent	Temperature of Ice Cream When Drawn Degrees F.
1	15	0.00	3.1	11.9	121	23.5
2	15	3.00	3.2	12.6	121	23.5
3	15	2.25	3.1	11.9	120	23.5
4	15	1.50	3.1	11.9	120	23.5
5	18	3.00	3.4	13.4	114	23.0
6	22	3.00	3.5	13.9	101	23.0

*Average of three readings per five gallon can of ice cream taken every 60 seconds.

TABLE 6.—THE EFFECT OF VARYING THE SUGAR AND CHOCOLATE LIQUOR CONTENT ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Freezing Time Minutes	Time Whipped Minutes	Time to Obtain 100 Per Cent Overrun Minutes	Temperature of Ice Cream at 100 Per Cent Overrun Degrees F.
1	14	0.0	6	4	10	25
2	14	4.9	6	5	11*	25
3	14	3.6	5	3	8	25
4	14	2.4	5	4	9	25
5	17	4.9	4	3	7	25
6	20	4.9	5½	4½	10	24

*95 per cent at 11 minutes.

TABLE 7.—THE EFFECT OF VARYING THE SUGAR AND COMBINATION OF COCOA AND CHOCOLATE LIQUOR ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Chocolate Liquor Per Cent	Time to Freeze Five Gallons of Ice Cream Minutes	Time to Freeze and Whip One and One-third Quarts of Ice Cream Seconds	Overrun Per Cent	Temperature of Ice Cream When Drawn Degrees F.
1	14	0.00	0.0	3.1	12.2	126	24
2	14	1.50	2.4	3.0	11.9	128	24
3	14	1.12	1.8	3.1	12.2	124	24
4	14	0.75	1.2	3.2	12.6	127	25
5	17	1.50	2.4	3.4	13.4	127	24
6	20	1.50	2.4	3.5	13.9	124	24

TABLE 8.—THE EFFECT OF VARYING THE SUGAR, COCOA, AND CHOCOLATE LIQUOR CONTENT ON THE FREEZING PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A BRINE BATCH FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Chocolate Liquor Per Cent	Freezing Time Minutes	Time Whipped Minutes	Time to Obtain 100 Per Cent Overrun Minutes	Temperature of Ice Cream at 100 Per Cent Overrun Degrees F.
1	14	3.00		6	1	7	25
2	14	2.25		5	1	6	25
3	14	1.50		6	1	7	24
4	17	3.00		5	1	6	24
5	20	3.00		7	½	7½	24
6	14		4.9	7	1	8	24
7	14		3.6	7	1	8	25
8	14		2.4	6	1	7	24
9	17		4.9	9	0	9	24
10	20		4.9	9	0	9	24
11	14	1.50	2.4	6	½	6½	25
12	14	1.12	1.8	6	½	6½	25
13	14	0.75	1.2	6	½	6½	25
14	17	1.50	2.4	7	½	7½	24
15	20	1.50	2.4	7	1	8	24

The Effects of Varying the Sugar and Chocolate Flavor Content on the Physical Properties of Chocolate Ice Cream When Frozen in a Vogt Instant, A Direct Expansion Batch, or a Brine Batch Freezer.—The data in Tables 9 to 15 inclusive show the results of lowering the normal flavoring value of chocolate ice cream when compared with the basic mixture. Batch 2 of each series contained a normal amount of chocolate flavor, batch 3 of each series contained three-fourths normal amount of chocolate flavor, and batch 4 of each series contained one-half normal amount of chocolate flavor. Batches 5 and 6 in each series contained normal amount of chocolate flavor and a varied amount of sugar.

Increased sugar content above the normal amount partially or almost entirely submerged the chocolate flavor of all chocolate ice creams shown in Tables 9, 10, and 11.

TABLE 9.—THE EFFECT OF VARYING THE SUGAR AND COCOA CONTENT ON THE PHYSICAL PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Flavor	Body	Texture	Color
1	15	0.00	Pleasant Vanilla	Smooth Resistant	Close	Desirable
2	15	3.00	Pronounced Chocolate	Smooth Resistant	Close	Desirable Brown
3	15	2.25	Not Bitter Desirable Chocolate	Smooth Resistant	Close	Medium Brown
4	15	1.50	Delicate Chocolate Chocolate	Smooth Resistant	Close	Delicate Brown Brown
5	18	3.00	Chocolate Partially Submerged	Smooth Resistant	Close Pasty	Medium Brown Shiny
6	22	3.00	Chocolate Excessive Sweetness	Smooth Resistant	Close Pasty Sticky	Medium Brown

TABLE 10.—THE EFFECT OF VARYING THE SUGAR AND CHOCOLATE LIQUOR CONTENT ON THE PHYSICAL PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Flavor	Body	Texture	Color
1	14	0.0	Pleasant Vanilla	Smooth Resistant	Close	Desirable
2	14	4.9	Pronounced Chocolate	Smooth Resistant	Close	Medium Brown
3	14	3.6	Desirable Chocolate	Smooth Resistant	Close	Medium Brown
4	14	2.4	Delicate Chocolate	Smooth Resistant	Close	Light Brown
5	17	4.9	Sweet Chocolate	Smooth Resistant	Close Pasty	Medium Brown
6	20	4.9	Chocolate Excessive Sweetness	Smooth Resistant	Close Pasty Sticky	Medium Brown Shiny

TABLE 11.—THE EFFECT OF VARYING THE SUGAR AND COMBINATION OF COCOA AND CHOCOLATE LIQUOR CONTENT ON THE PHYSICAL PROPERTIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Chocolate Liquor Per Cent	Flavor	Body	Texture	Color
1	14	0.00	0.0	Desirable Vanilla	Smooth Resistant	Close	Desirable
2	14	1.50	2.4	Pronounced Chocolate	Smooth Resistant	Close	Dark Brown
3	14	1.12	1.8	Desirable Chocolate	Smooth Resistant	Close	Medium Brown
4	14	0.75	1.2	Delicate Chocolate	Smooth Resistant	Close	Light Brown
5	17	1.50	2.4	Distinct Chocolate	Smooth Resistant	Close	Dark Brown
6	20	1.50	2.4	Fair Chocolate Sweet	Smooth Resistant	Close Sticky	Dark Brown

The body and texture of the different chocolate ice creams were very similar. Decreasing the amount of cocoa gave a marked difference in color of the chocolate ice creams.

The flavor varied from a very pronounced chocolate in the batch containing a normal amount of chocolate to a pleasant, delicate flavor in the batch containing one-half of the normal amount of chocolate. The high sugar content submerged the normal chocolate flavor in batches 5 and 6. It was the opinion of the judges that the flavor of the chocolate ice creams could be improved by retaining the sugar content of chocolate ice cream at the same per cent as in the base or vanilla mixture and by varying the chocolate flavoring material so as to comply with the consumer's demand. If a higher or intensified chocolate color was requested by the consumer it would be better to add chocolate color to the mixture before freezing. However, through organized effort the public could be educated to appreciate and acquire a liking for a light colored chocolate ice cream. It could be associated with some higher priced candies which have a light chocolate color.

Not only could an improved and more uniform chocolate ice cream be made by decreasing the chocolate and sugar content of chocolate ice creams but a larger volume would be consumed. A larger financial saving would also be effected by the manufacturers, resulting from the reduced amounts of materials that go into the chocolate mixture.

Since the cocoa and liquor were from the same source and of the same blend it was comparatively easy to determine the grand total and these data are shown in Table 15. These data indicate that a slight preference was given the ice creams containing a normal cocoa and 17 per cent sugar. This preference may have been caused by the sweetness of the present

TABLE 12.—MANUFACTURER AND CONSUMER PREFERENCE FOR FLAVOR AND COLOR OF CHOCOLATE ICE CREAMS CONTAINING VARIABLE AMOUNTS OF SUGAR AND COCOA

	Flavor Preference in Per Cent					Color Preference in Per Cent				
Batch Number	1	2	3	4	5	1	2	3	4	5
Sugar, Per Cent	14	14	14	17	20	14	14	14	17	20
Cocoa, Per Cent	3.00	2.12	1.50	3.00	3.00	3.00	2.12	1.50	3.00	3.00
Manufacturers*										
A. Missouri	23.10	38.40	23.10	7.70	7.70					
B. Colorado	14.30	8.58	34.32	42.80	0.00					
C. Oklahoma	10.00	25.00	20.00	45.00	0.00	15.00	10.00	15.00	60.00	0.00
D. Missouri	11.38	11.61	22.54	16.74	37.71	21.37	26.50	23.18	23.37	5.56
Consumers*										
A. Women married	0.00	25.00	31.25	25.00	18.75	0.00	0.00	37.50	43.75	18.75
B. Women students	14.64	13.22	13.95	19.00	39.19	53.00	4.00	5.12	19.37	18.50

*Number participating, manufacturers 128, consumers 58.

TABLE 13.—MANUFACTURER AND CONSUMER PREFERENCE FOR FLAVOR AND COLOR OF ICE CREAMS CONTAINING VARIABLE AMOUNTS OF SUGAR AND CHOCOLATE LIQUOR

	Flavor Preference in Per Cent					Color Preference in Per Cent				
Batch Number	1	2	3	4	5	1	2	3	4	5
Sugar, Per Cent	14	14	14	17	20	14	14	14	17	20
Chocolate Liquor, Per Cent	4.9	3.6	2.4	4.9	4.9	4.9	3.6	2.4	4.9	4.9
Manufacturers*										
A. Missouri	38.40	7.70	15.40	15.40	23.10					
B. Colorado	0.00	40.04	28.60	31.36	0.00					
C. Oklahoma	15.00	5.00	25.00	55.00	0.00	15.00	10.00	15.00	60.00	0.00
D. Missouri	21.65	12.57	16.73	26.56	22.53	20.93	15.93	15.00	19.06	29.06
Consumers*										
A. Women married	0.00	18.75	6.25	43.75	31.25	0.00	18.75	12.50	56.25	12.50
B. Women students	13.95	35.35	24.72	8.90	11.52	30.00	11.37	9.12	44.37	5.62

*Number participating, manufacturers 128, consumers 58.

TABLE 14.—MANUFACTURER AND CONSUMER PREFERENCE FOR FLAVOR AND COLOR OF ICE CREAM CONTAINING VARIABLE AMOUNTS OF SUGAR, COCOA, AND CHOCOLATE LIQUOR

	Flavor Preference in Per Cent					Color Preference in Per Cent				
Batch Number	1	2	3	4	5	1	2	3	4	5
Sugar, Per Cent	14	14	14	17	20	14	14	14	17	20
Cocoa, Per Cent	1.50	1.12	0.75	1.50	1.50	1.50	1.12	0.75	1.50	1.50
Chocolate Liquor, Per Cent	2.4	1.8	1.2	2.4	2.4	2.4	1.8	1.2	2.4	2.4
Manufacturers*										
A. Missouri	15.30	23.10	46.20	0.00	15.40					
B. Colorado	28.60	17.16	45.66	8.58	0.00					
C. Oklahoma	25.00	30.00	25.00	20.00	0.00	25.00	10.00	5.00	60.00	0.00
D. Missouri	14.50	11.16	13.39	21.20	39.72	24.50	16.93	22.60	16.25	19.81
Consumers*										
A. Women married	0.00	12.50	18.75	68.75	0.00	6.25	0.00	12.50	62.50	18.75
B. Women students	17.07	13.22	17.07	25.45	27.17	10.00	9.12	8.00	31.00	41.87

*Number participating, manufacturers 128, consumers 58.

TABLE 15.—GRAND TOTAL OF PLACING OF TABLES 12, 13, AND 14.

FLAVOR

Batch Number	Sugar	Cocoa	Chocolate Liquor	Cocoa and Chocolate Liquor	Grand Total
1	14	12.23	14.51	16.74	14.49
2	14	20.30	19.45	17.85	19.20
3	14	24.19	19.45	27.67	23.77
4	17	26.04	30.19	23.99	26.74
5	20	17.22	16.40	13.71	15.77

COLOR

Batch Number	Sugar	Cocoa	Chocolate Liquor	Cocoa and Chocolate Liquor	Grand Total
1	14	22.14	16.48	16.43	18.35
2	14	10.03	14.01	9.01	11.01
3	14	20.21	12.80	12.00	15.00
4	17	36.22	44.92	42.43	41.19
5	20	11.20	11.79	20.10	14.33

CHOICE OF FLAVORING MATERIAL

Number of Individual	Cocoa	Chocolate Liquor	Cocoa and Liquor
58	36	7	15

day chocolate ice cream with which most manufacturers and consumers are familiar.

Color placings favored the darker product, which can be explained on the basis of the present day chocolate ice cream, which has a color more nearly like the chocolate liquor and which seemed to be the most generally expressed preference as to what the color of chocolate ice cream should be.

Relative to the choice of flavoring materials, there was a decided preference for the cocoa, as shown in Table 15. The combination of cocoa and chocolate liquor received second choice.

The Effect of Variable Amounts of Sugar, Egg Powder, and Chocolate Flavoring Materials on the Dipping Qualities of Chocolate Ice Creams When Frozen in Different Types of Freezers.—The results of two different freezers are shown in Tables 16 and 17. The data gives the variables and the average of 220 dishes obtained from five gallons of ice cream. Each dish was weighed as it was removed from the disher.

There was a slight difference between the average weight of individual dishes of the high and low overrun, but again it seemed that the

TABLE 16.—THE EFFECT OF VARYING THE SUGAR AND THE CHOCOLATE LIQUOR CONTENT ON THE WEIGHT OF INDIVIDUAL DISHES* OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Overrun Per Cent	Average Weight Ounces	Highest Weight Above Average Ounces	Lowest Weight Below Average Ounces	Difference Between High and Low Weight Ounces
1	14	0.0	100	1.4	1.8	1.1	0.7
2	14	4.9	99	1.4	1.7	1.2	0.5
3	14	3.6	100	1.4	1.6	1.2	0.4
4	14	2.4	100	1.4	1.7	1.3	0.4
5	17	4.9	100	1.6	1.9	1.2	0.7
6	20	4.9	100	1.6	1.9	1.4	0.5

*Number 20 disher used.

TABLE 17.—THE EFFECT OF VARYING THE SUGAR, CHOCOLATE LIQUOR, AND COCOA CONTENT ON THE WEIGHT OF INDIVIDUAL DISHES* OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Chocolate Liquor Per Cent	Overrun Per Cent	Average Weight Ounces	Highest Weight Above Average Ounces	Lowest Weight Below Average Ounces	Difference Between High and Low Weight Ounces
1	14	0.00	0.0	126	1.4	1.6	1.1	0.5
2	14	1.50	2.4	128	1.5	1.6	1.0	0.6
3	14	1.12	1.8	124	1.3	1.4	1.1	0.3
4	14	0.75	1.2	127	1.3	1.4	1.1	0.3
5	17	1.50	2.4	127	1.4	1.6	1.1	0.5
6	20	1.50	2.4	124	1.4	1.7	1.1	0.6

*Number 20 disher used.

Vogt instant freezer furnished an ice cream with a better body even with a high overrun.

Batches 2 to 4, inclusive, of Table 18 show that high percentages of sugar cause greater shrinkage and that cocoa seems to serve as a stabilizer and to reduce the shrinkage. This may be due to the greater amount of solids present or the stabilizing effect of cocoa. Batches 5 to 7, inclusive, show that dehydrated egg yolk does not have much effect on the shrinkage, although in dipping these ice creams there was a definite tendency for the ice cream to crawl and follow the spoon. Batches 8 to 13, inclusive, seem to show that dehydrated egg yolk tends to reduce the shrinkage in ice cream of high sugar content. As the sugar was increased, the tendency of the ice cream to crawl and follow the spoon changed to stickiness.

TABLE 18.—THE EFFECT OF VARYING THE SUGAR AND EGG POWDER CONTENT ON THE DIPPING QUALITIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Sugar Per Cent	Egg Powder Per Cent	Overrun Per Cent	Net Weight of Five Gallons of Ice Cream Pounds	Number Cones Dipped Per Five Gallons of Ice Cream	Average Weight of Ice Cream		Shrinkage Per Cent
						Quarts Ounces	Pints Ounces	
1	15	0.00	102	22	230	23.0	11.25	23.0
2	15	0.00	103	23	235	23.0	11.00	19.5
3	18	0.00	106	23	225	24.0	11.12	26.0
4	22	0.00	91	22	230	25.0	12.25	29.0
5	15	0.25	101	22	220	21.0	11.25	15.5
6	15	0.50	100	22	230	23.5	11.37	24.0
7	15	0.75	100	22	230	21.5	11.37	17.5
8	18	0.25	95	23	230	23.5	11.37	22.0
9	18	0.50	92	23	225	23.5	12.31	22.0
10	18	0.75	105	23	230	24.5	12.62	25.0
11	22	0.25	100	23	230	24.0	12.25	23.5
12	22	0.50	100	24	230	24.5	12.75	22.0
13	22	0.75	99	24	230	24.5	12.75	22.0

Tables 19, 20, and 21 show the results of varying the sugar and chocolate flavoring material. With the exception of Table 21, these data show that when batch 2 is compared to the base mixture, batch 1, to which the chocolate flavoring material was added, without additional sugar, the shrinkage was reduced.

TABLE 19.—THE EFFECT OF VARYING THE SUGAR AND COCOA CONTENT ON THE DIPPING QUALITIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Overrun Per Cent	Net Weight of Five Gallons of Ice Cream Pounds	Number Cones Dipped Per Five Gallons of Ice Cream	Average Weight of Ice Cream		Shrinkage Per Cent
						Quarts Ounces	Pints Ounces	
1	15	0.00	121	19.60	225	22.0	11.0	29.0
2	15	3.00	121	19.60	231	19.5	10.0	20.0
3	15	2.25	120	19.70	230	19.5	11.5	19.5
4	15	1.50	120	19.70	222	20.0	10.0	21.5
5	18	3.00	114	20.25	225	21.5	10.5	24.5
6	22	3.00	101	23.25	222	22.0	11.5	15.5

TABLE 20.—THE EFFECT OF VARYING THE SUGAR AND CHOCOLATE LIQUOR CONTENT ON THE DIPPING QUALITIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Overrun Per Cent	Net Weight of Five Gallons of Ice Cream Pounds	Number Cones Dipped Per Five Gallons of Ice Cream	Average Weight of Ice Cream		Shrinkage Per Cent
						Quarts Ounces	Pints Ounces	
1	14	0.0	100	23.5	235	22.5	11.0	19.0
2	14	4.9	99	24.0	235	23.0	11.1	16.5
3	14	3.6	100	24.0	230	22.5	11.6	15.0
4	14	2.4	100	23.5	235	22.5	11.5	19.0
5	17	4.9	105	23.9	240	22.3	11.8	15.0
6	20	4.9	100	24.5	240	23.0	12.1	15.0

TABLE 21.—THE EFFECT OF VARYING THE SUGAR AND COMBINATION OF COCOA AND CHOCOLATE LIQUOR CONTENT ON THE DIPPING QUALITIES OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Chocolate Liquor Per Cent	Overrun Per Cent	Net Weight of Five Gallons of Ice Cream	Number Cones Dipped Per Five Gallons of Ice Cream	Average Weight of Ice Cream		Shrinkage Per Cent
							Quarts Ounces	Pints Ounces	
1	14	0.00	0.0	126	19.0	215	18.8	11.5	19.5
2	14	1.50	2.4	128	19.0	215	18.8	11.0	19.5
3	14	1.12	1.8	124	20.1	215	20.0	11.2	20.0
4	14	0.75	1.2	127	20.0	220	20.3	12.0	23.0
5	17	1.50	2.4	127	19.0	225	18.9	11.3	19.6
6	20	1.50	2.4	124	20.5	230	21.0	11.7	22.5

The Effect of Variable Amounts of Cocoa, Chocolate Liquor and a Combination of Cocoa and Chocolate Liquor on the Stability of Chocolate Ice Creams.—This study included a series of mixtures in which the sugar, cocoa, chocolate liquor, and a combination of the two, were varied.

The first three batches upon which the stability determinations were made, show, in general, the series containing variable amounts of sugar and cocoa. Table 22, Plate I, shows a greater loss than either chocolate liquor, Table 23, Plate II, or the combination of chocolate flavor shown in Table 24, Plate III. The differences can be explained by the fact that there was more cocoa fat, which has a higher melting point than butter fat, in the last two batches. The first series had a greater total percentage loss and can be accounted for by its high sugar content.

In all batches, the cocoa, Table 22, Plate I, the chocolate liquor, Table 23, Plate II, and the combination of cocoa and chocolate liquor,

TABLE 22.—THE EFFECT OF VARYING THE SUGAR AND COCOA CONTENT ON THE STABILITY OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Loss in Per Cent at End of		
			1 Hour	2 Hours	3 Hours
1	15	0.00	20.82	59.47	87.98
2	15	3.00	12.30	46.91	76.91
3	15	2.25	14.45	53.27	80.22
4	15	1.50	13.51	48.48	82.38
5	18	3.00	22.38	61.00	90.10
6	22	3.00	26.59	67.72	93.07

TABLE 23.—THE EFFECT OF VARYING THE SUGAR AND CHOCOLATE LIQUOR CONTENT ON THE STABILITY OF CHOCOLATE ICE CREAM WHEN FROZEN IN A DIRECT EXPANSION BATCH FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Loss in Per Cent at End of		
			1 Hour	2 Hours	3 Hours
1	14	0.00	8.11	43.69	74.60
2	14	4.9	0.33	21.71	53.52
3	14	3.6	0.47	26.11	59.37
4	14	2.4	0.00	30.55	67.48
5	17	4.9	0.00	28.84	56.24
6	20	4.9	0.00	30.52	67.74

TABLE 24.—THE EFFECT OF VARYING THE SUGAR AND COMBINATION OF COCOA AND CHOCOLATE LIQUOR CONTENT ON THE STABILITY OF CHOCOLATE ICE CREAM WHEN FROZEN IN A VOGT INSTANT FREEZER

Batch Number	Sugar Per Cent	Cocoa Per Cent	Chocolate Liquor Per Cent	Loss in Per Cent at End of		
				1 Hour	2 Hours	3 Hours
1	14	0.00	0.0	13.34	54.92	73.48
2	14	1.50	2.4	00.19	13.57	50.38
3	14	1.12	1.8	00.38	32.36	60.87
4	14	0.75	1.2	04.84	39.18	72.31
5	17	1.50	2.4	05.58	37.98	63.92
6	20	1.50	2.4	05.64	46.02	72.12

Table 24, Plate III, acted as stabilizers when added to a vanilla mixture of the same sugar content. The addition of three pounds of cocoa, or its equivalent of some other chocolate flavoring material, each of which contains about 94 per cent solids, furnished considerable stabilizing properties.

The difference in the stability of chocolate liquor, Table 23, Plate II, and the combination of cocoa and chocolate liquor, Table 24, Plate III, was not entirely due to the presence of cocoa fat or additional solids. There was a difference of about 20 per cent in the overrun of the different ice creams, which would have had considerable effect had not the two series been frozen in two different freezers. The series having the higher overrun showed a smaller loss than would be expected because of the fact that it was frozen in a Vogt instant freezer, which seems to give to the ice cream a body with greater resistance or stability.

The batches to which was added three per cent of cocoa or its equivalent in flavor of chocolate liquor, or a combination of both had greater stability than the vanilla or control ice cream. This seems to indicate that there were other stabilizing factors involved which

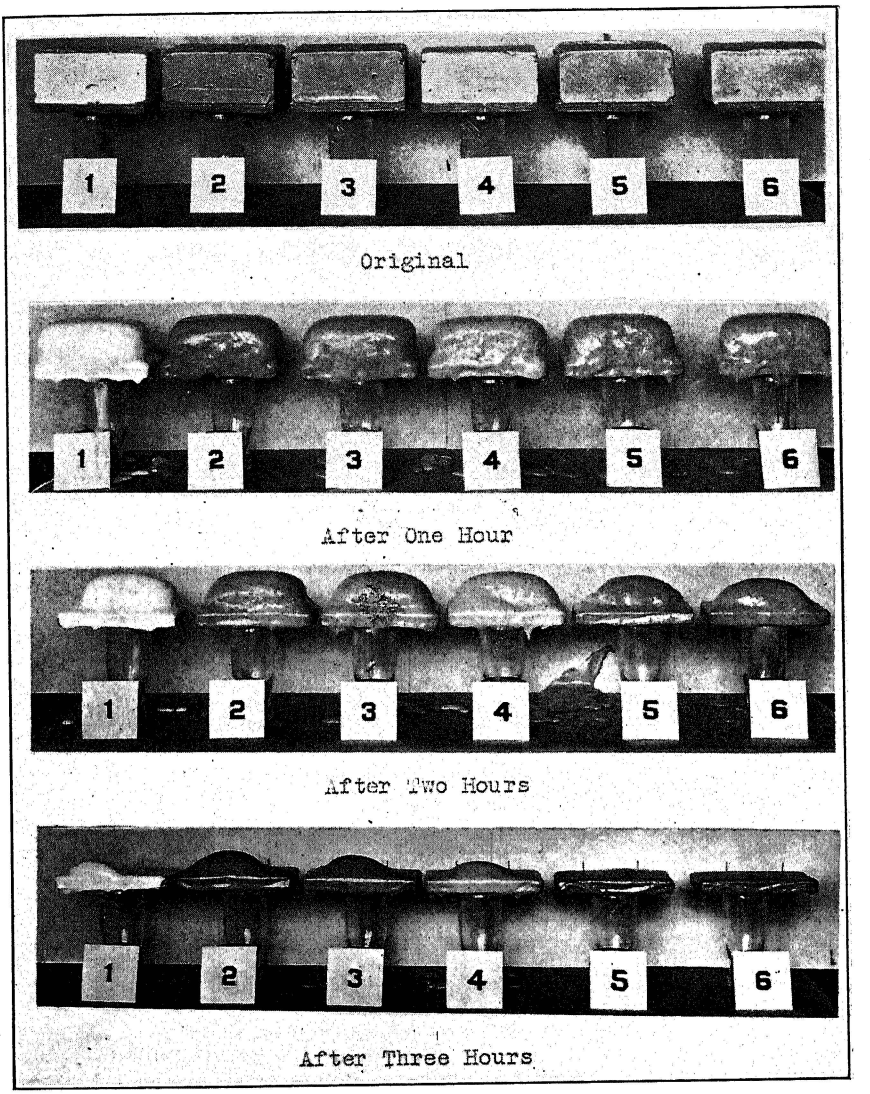

Plate I. The effect of varying the sugar and cocoa content on the stability of chocolate ice cream when frozen in a Vogt Instant Freezer.

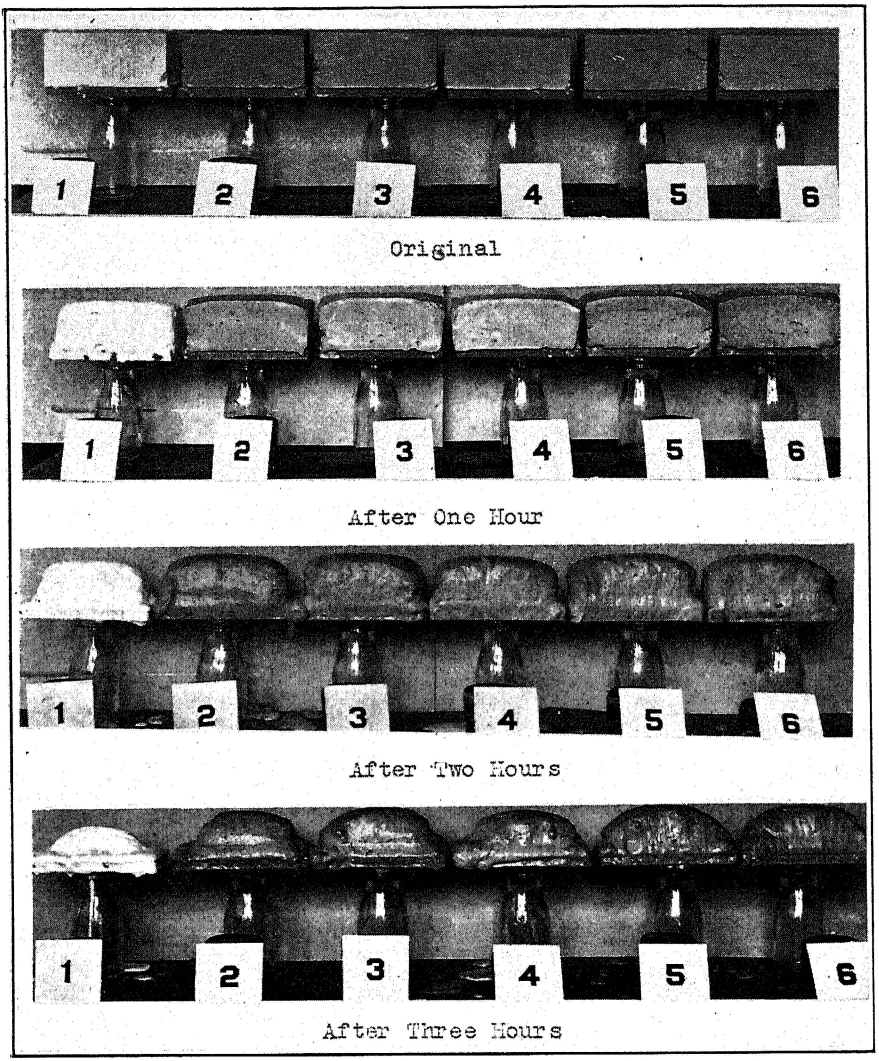

Plate II. The effect of varying the sugar and chocolate liquor content on the stability of chocolate ice cream when frozen in a Direct Expansion Batch Freezer.

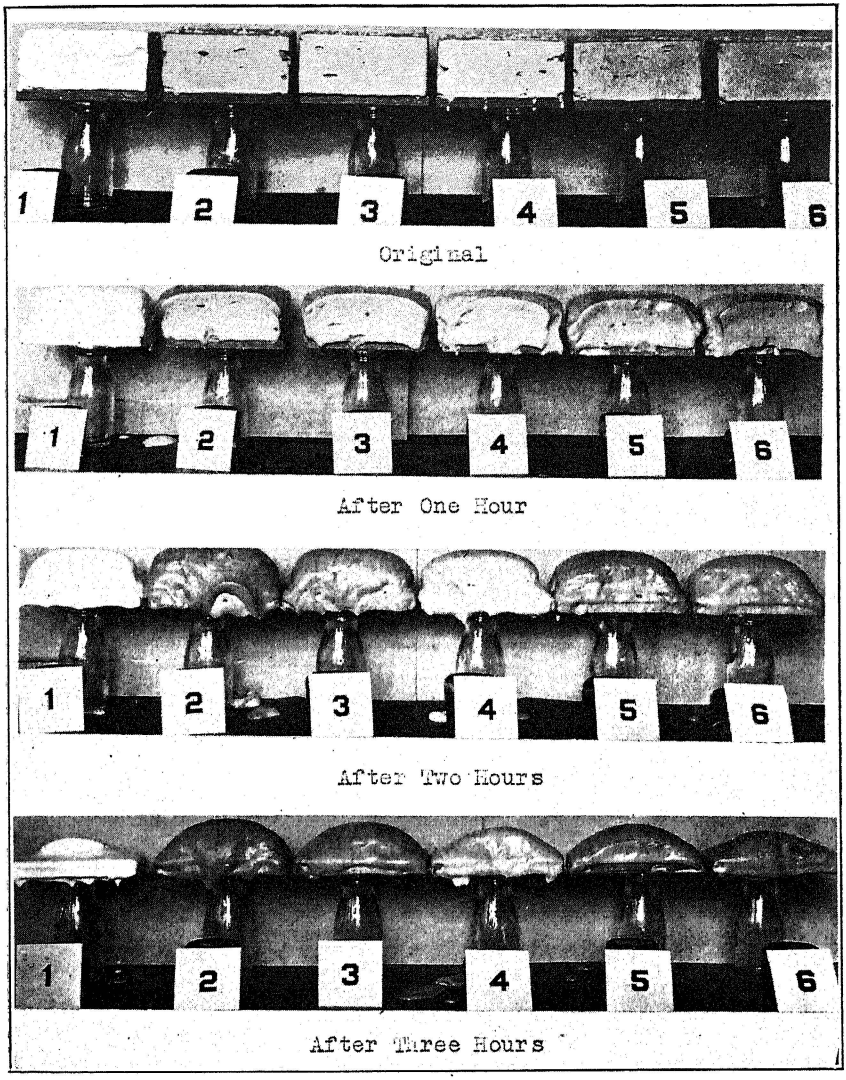

Plate III. The effect of varying the sugar and combination of cocoa and chocolate liquor content on the stability of chocolate ice cream when frozen in a Vogt Instant Freezer.

might have water absorbing properties. In order to determine the water absorbing property of cocoa, a pound of the product was added to a known volume of water, which thickened into a paste. It was determined that one pound of cocoa would readily absorb two quarts, or about four pounds of water. At this rate, three pounds of cocoa would absorb 12 pounds of water. The chocolate paste would then have a higher viscosity than is desired in an ice cream mixture. An ice cream containing 40 per cent total solids, prior to the addition of cocoa, would have a water content of 60 per cent. All of this water is not free water and when three pounds of cocoa is added to the mixture it must have an opportunity to absorb 12 or more pounds of water.

Comparing batches 1 (vanilla), 4 and 6 of the three different series, Tables 22, 23, and 24, it can be said that the vanilla ice cream and the ice cream containing the lowest amount of cocoa, or chocolate liquor, or combination of cocoa and chocolate liquor, and the ice cream having the highest sugar with the normal amount of chocolate, are very similar as far as total loss is concerned. The data also show that there is a direct relation between an increase or decrease of the cocoa content and the loss sustained.

It seems that sugar impairs the stabilizing properties of an ice cream with a high sugar content and normal amount of cocoa gives a loss which is greater than the basic mixture. In all batches there was, however, a sharp decrease in the total loss when a normal amount of chocolate flavoring material was added to the basic mixture.

The Effect of Variable Amounts of Sugar, Cocoa, Chocolate Liquor and a Combination of Cocoa and Chocolate Liquor on the Viscosity and Surface Tension of Different Ice Cream Mixtures.—The viscosity of the different control mixtures was increased in direct relation to the increase in the sugar content, and the hours aged, Table 25. When .25 per cent of egg powder was added, the viscosity was increased, however,

TABLE 25.—THE EFFECT OF VARYING THE SUGAR AND EGG POWDER CONTENT ON THE VISCOSITY OF A CHOCOLATE ICE CREAM MIXTURE*

Batch Number	Sugar Per Cent	Egg Powder Per Cent	Age of Mixture			
			4 Hours	24 Hours	48 Hours	72 Hours
1	15	0.00	10.8	16.2	21.6	43.2
2	15	0.00	59.4	75.6	81.0	108.0
3	18	0.00	75.6	108.0	135.0	108.0
4	22	0.00	194.4	226.8	211.4	324.0
5	15	0.25	75.6	108.0	108.0	135.0
6	15	0.50	54.0	75.6	81.0	102.6
7	15	0.75	51.3	66.4	72.9	102.6
8	18	0.25	91.8	108.0	124.2	167.4
9	18	0.50	59.4	75.6	86.4	118.8
10	18	0.75	48.6	64.8	75.6	102.6
11	22	0.25	86.4	102.6	129.6	183.6
12	22	0.50	72.9	86.4	102.6	129.6
13	22	0.75	70.2	81.0	86.4	129.6

*Viscosity expressed in centipoises.

with each increased increment the viscosity decreased. The viscosity of all mixtures containing egg powder increased with aging. The addition of cocoa to the control mixture increased the viscosity in direct relation to the different increments of cocoa used, Table 26. When 3 per cent of cocoa was added to the mixture containing 18 per cent of sugar, the viscosity was decreased. The viscosity of each batch increased with aging. A similar increase in viscosity was acquired when increased increments of chocolate liquor and a combination of cocoa and chocolate liquor were added to different batches, Tables 27 and 28.

TABLE 26.—THE EFFECT OF VARYING THE SUGAR AND COCOA CONTENT ON THE VISCOSITY OF A CHOCOLATE ICE CREAM MIXTURE

Batch Number	Sugar Per Cent	Cocoa Per Cent	Age of Mixture		
			4 Hours	24 Hours	48 Hours
1	15	0.00	178.2	259.2	270.0
2	15	3.00	324.0	405.0	421.2
3	15	2.25	280.8	378.0	394.2
4	15	1.50	205.2	324.0	351.0
5	18	3.00	162.0	216.0	226.8
6	22	3.00	194.4	230.2	248.4

TABLE 27.—THE EFFECT OF VARYING THE SUGAR AND CHOCOLATE LIQUOR CONTENT ON THE VISCOSITY OF A CHOCOLATE ICE CREAM MIXTURE

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Age of Mixture			
			4 Hours	24 Hours	48 Hours	72 Hours
1	14	0.0	70.3	81.0	97.2	102.6
2	14	4.9	324.0	351.0	361.8	156.4
3	14	3.6	270.0	291.6	297.0	291.6
4	14	2.4	237.6	253.8	264.6	259.2
5	17	4.9	194.4	189.0	205.2	209.6
6	20	4.9	124.2	140.4	152.2	162.0

TABLE 28.—THE EFFECT OF VARYING THE SUGAR AND COMBINATION OF COCOA AND CHOCOLATE LIQUOR ON THE VISCOSITY OF A CHOCOLATE ICE CREAM MIXTURE

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Cocoa Per Cent	Age of Mixture		
				4 Hours	24 Hours	48 Hours
1	14	0.0	0.00	97.2	118.8	135.0
2	14	2.4	1.50	243.0	259.2	253.8
3	14	1.8	1.12	156.6	162.0	178.2
4	14	1.2	0.75	129.6	140.4	156.6
5	17	2.4	1.50	162.0	178.2	183.6
6	20	2.4	1.50	189.0	199.8	199.8

That the effect of variable amounts of sugar and egg powder on the surface tension in different batches of ice cream mixture was almost negligible is shown in Table 29. Each increased increment of egg powder slightly decreased the surface tension in each series containing different increments of sugar. There was a decrease in the surface tension of each mixture when aged seventy two hours.

TABLE 29.—THE EFFECT OF VARYING THE SUGAR AND EGG POWDER CONTENT ON THE SURFACE TENSION OF A CHOCOLATE ICE CREAM MIXTURE*

Batch Number	Sugar Per Cent	Egg Powder Per Cent	Age of Mixture			
			4 Hours	24 Hours	48 Hours	72 Hours
1	15	0.00	48.3	46.9	46.9	47.6
2	15	0.00	51.8	50.4	49.7	49.0
3	18	0.00	51.8	49.7	49.0	48.3
4	22	0.00	51.8	51.1	50.4	49.7
5	15	0.25	49.7	49.0	49.7	49.0
6	15	0.50	48.3	48.3	49.0	48.3
7	15	0.75	48.3	46.7	47.6	47.6
8	18	0.25	50.4	48.3	47.6	48.3
9	18	0.50	49.0	48.3	48.3	49.0
10	18	0.75	48.3	46.9	45.4	47.6
11	22	0.25	49.7	49.0	49.0	49.0
12	22	0.50	49.7	48.3	47.6	48.3
13	22	0.75	49.0	46.9	46.2	47.6

*Surface tension expressed in dynes.

The surface tension of the mixtures containing variable amounts of sugar in combination with different increments of cocoa, chocolate liquor and a combination of cocoa and chocolate liquor was not appreciably affected, as shown in Tables 30, 31 and 32. When the maximum amount of sugar was added, the surface tension of that particular mixture was decreased slightly irrespective of the cocoa and chocolate liquor content. Aging of the mixtures had no effect upon their surface tension.

TABLE 30.—THE EFFECT OF VARYING THE SUGAR AND COCOA CONTENT ON THE SURFACE TENSION OF A CHOCOLATE ICE CREAM MIXTURE

Batch Number	Sugar Per Cent	Cocoa Per Cent	Age of Mixture		
			4 Hours	24 Hours	48 Hours
1	15	0.00	49.7	49.0	50.4
2	15	3.00	49.0	48.3	48.3
3	15	2.25	48.3	48.3	49.7
4	15	1.50	49.0	49.7	49.7
5	18	3.00	49.7	49.0	49.7
6	22	3.00	47.6	48.3	48.3

TABLE 31.—THE EFFECT OF VARYING THE SUGAR AND CHOCOLATE LIQUOR CONTENT ON THE SURFACE TENSION OF A CHOCOLATE ICE CREAM MIXTURE

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Age of Mixture			
			4 Hours	24 Hours	48 Hours	72 Hours
1	14	0.0	49.7	49.0	49.7	49.7
2	14	4.9	48.3	49.0	48.3	47.6
3	14	3.6	49.0	49.7	50.4	49.7
4	14	2.4	49.0	48.3	49.0	49.7
5	17	4.9	49.0	49.0	49.7	49.7
6	20	4.9	49.0	49.0	50.4	49.7

TABLE 32.—THE EFFECT OF VARYING THE SUGAR AND COMBINATION OF COCOA AND CHOCOLATE LIQUOR CONTENT ON THE SURFACE TENSION OF A CHOCOLATE ICE CREAM MIXTURE

Batch Number	Sugar Per Cent	Chocolate Liquor Per Cent	Cocoa Per Cent	Age of Mixture		
				4 Hours	24 Hours	48 Hours
1	14	0.0	0.00	49.7	49.7	49.0
2	14	2.4	1.50	50.4	49.7	50.4
3	14	1.8	1.12	49.0	49.0	49.7
4	14	1.2	0.75	48.3	48.3	48.3
5	17	2.4	1.50	49.0	49.7	49.0
6	20	2.4	1.50	47.6	48.3	49.0

CONCLUSIONS

1. Sugar decidedly influences the whipping ability of a chocolate ice cream mixture by depressing the ability of the mixture to incorporate air.

2. Sugar prolongs the freezing time, induces a lower temperature of the ice cream, and creates a physical condition resulting in a lower overrun.

3. Sugar added to a chocolate mixture in excess of the normal amount makes it difficult to obtain an overrun equal to that of a vanilla ice cream with an equal amount of sugar.

4. The proper balancing of the chocolate mixture in respect to the sugar content will furnish a mixture that will freeze equally fast and will attain the same overrun as the vanilla mixture.

5. Chocolate ice creams containing a sugar content in excess of 17 per cent will partially or totally submerge the chocolate flavor, and cause the ice cream to have a sticky and soggy body and texture.

6. A chocolate ice cream with a sugar content above normal will not remain as firm or retain its stability when held in an electric cabinet tempered for vanilla ice cream.

7. The addition of egg powder to a chocolate ice cream mixture improves its whipping ability, increases the viscosity, gives the ice cream a smooth body and a finer texture. Egg powder also partially submerges the chocolate flavor, and removes some of the stickiness of mixtures with a high sugar content.

8. Aging a chocolate ice cream mixture greatly improves its whipping ability, thereby reducing the time to freeze by one-half.

9. The addition of a normal amount of chocolate flavoring material to a basic mixture with a normal sugar content causes some difference in freezing time, increases the viscosity, causes a pronounced chocolate flavor to become apparent, but produces a true chocolate flavor.

10. The reduction of the normal amount of cocoa to three-fourths or one-half of the normal amount usually added to a base mixture improves the flavor of the ice cream and produces a mixture that freezes equally as fast as a vanilla mixture.

11. There seems to be a point of balance at which the chocolate flavoring material and the sugar content produces the most desirable, true chocolate flavor.

12. Chocolate flavoring material acts as a stabilizer in chocolate ice cream mixtures and a reduction of the gelatine content is therefore desirable.

13. The surface tension of the different mixtures containing variable amounts of sugar, egg powder, cocoa and chocolate liquor is not affected to an appreciable degree.

14. A saving in material and manufacturing costs can be effected when the sugar, chocolate flavoring and gelatine content of chocolate ice creams are reduced.

15. There is a desire on the part of the consuming public to consume a larger volume of chocolate ice creams that contain less sugar and chocolate flavoring material because of its true, delicate chocolate flavor.

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