THE EFFECTS OF SUPERHEATING ICE CREAM MIXES MADE IN THE VACUUM PAN

by

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INTRODUCTION

Statistics released by the ice cream industry (7), indicate that 348,046,000 gallons of ice cream were manufactured in the United States during the year 1928. Exports and imports of ice cream being negligible, the consumption of ice cream during this year was equal to the gallonage manufactured.

Production for 1928 was 3.7 per cent greater than during the year 1927. The per capita consumption amounted to 2.9 gallons in 1928 as compared with 2.85 gallons in 1927. In 1918 the per capita consumption of ice cream was 2.14 gallons. During the ten years from 1918 to 1928 this has increased 35.5 per cent.

Ice cream is commonly made up of milk products, sugar, stabilizers and flavoring material. According to Turnbow and Raffetto (16),"probably 90 per cent of the stabilizer now used is gelatin." Based on the previous statement, and calculating the gelatin as .5 of one per cent, the overrun as 100 per cent, the ice cream industry annually uses over seven million pounds of gelatin.

The purposes of milk products in ice cream are to furnish both butter fat and solids not fat. In 1928 (7) nearly 2,000,000 pounds of condensed milk was used in order to furnish the bulk of the solids not fat.

Gelatin as a stabilizer costs the industry over $5,000,000 annually. One phase of this project deals with the possibility of using improved methods of manufacture and omitting gelatin from the mix.

Manufacturers are attempting to omit gelatin, commercially, since the public in the early years of the ice cream industry was prejudiced against the use of gelatin. Some ice cream makers are increasing the total solids content of their ice cream or are using superheated condensed milk in an attempt to eliminate gelatin.

Superheated condensed milk is a product of the vacuum pan, heated after condensing to a temperature of 180°- 190° for a period of eight to ten minutes, by the introduction of live steam. Such treatment results in a heavy viscous product, due to the precipitation of the colloidal albumen, naturally present in dairy products. Peterson and Tracy (10) say that "The albumen carries with it all of the casein." The fact that albumen and gelatin are both colloidal proteins offers the possibility that albumen precipitated by heat, may successfully serve as the stabilizer of the ice cream mix.

REVIEW OF LITERATURE

Gelatin is commonly used as one of the ingredients of ice cream, primarily because of its stabilizing effect on the water of the ice cream mix. It is true that the manner in which gelatin is manufactured at the present time is above criticism. Downey (9) has proved that gelatin is high in food value. Nevertheless, manufacturers and investigational workers are attempting to omit gelatin from their product and substitute methods of manufacture for it.

Superheated condensed skim milk, either plain or sweet, is being used in some sections of the country instead of gelatin. The manufacture of this product necessitates the use of the vacuum pan. The vacuum pan was used to some extent in the manufacture of ice cream mixes prior to 1920. Cruse (1) states that at this time the leading ice cream manufacturers began to use this method of mix manufacture quite commonly because of the economy involved.

Mojonnier (8) states that the new process of condensing the entire ice cream mix was developed and patented by Mojonnier Brothers of Chicago, Illinois. The inventors claimed that the mix could be more cheaply made in this manner, as all serum solids and most of the fat could be secured from whole milk, which is recognized as one of the cheapest sources of serum solids.

Peterson and Tracy (10) carried on some investigational studies relative to condensing the entire mix during the same year in which Mojonnier Brothers received their patent.

They reported that the manufacture of the entire mix in the vacuum pan was productive of a high class mix, as well as economical. They, too, pointed out the possibilities of using whole milk or skim milk as the source of serum solids.

Bacteriological studies made by Peterson and Tracy (10) showed that the number of bacteria per cubic centimeter, after condensing, was in every case below 20,000 which is considered good. However, they preheated to a temperature of 180°- 190°F. which in itself would account for the destruction of a majority of the organism present in the initial mix.

Olson and Fay(9) have shown that it is easily possible to limit the bacteria count in an ice cream mix to 100,000 or less per cubic centimeter, depending largely on the care and methods of processing. Condensed milk was listed as an important source of bacteria contamination in some cases.

In 1925, Tracy (13) made an extensive stpdy of the use of superheated and unsuperheated plain condensed skim milk in ice cream mixes. The superheating process was carried out by heating some of the plain condensed skim milk to a temperature of 188°-190°F. for a period of five to fifteen minutes until it thickened. He gives as a reason for the thickening (sometimes called "liver") coagulation of the albumen, due to heat. The aggregation of the finely divided albumen particles carried with it all of the casein. Tracy found that the superheated condensed milk when used in an ice cream mix, produced a more viscous mix which whipped more readily to a higher overrun than did a like mix containing unsuperheated condensed skim milk. The ice cream containing the superheated condensed skim milk possessed a better body and texture and melted more slowly at room temperatures than did the ice cream containing unsuperheated condensed skim milk. However, the latter had a superior initial flavor which was retained better in storage.

In the work just cited, gelatin was commonly used, but gradually it has been the tendency to use superheated condensed milk and omit gelatin. The main factor in the increased viscosity of mixes containing superheated condensed milk is the precipitation of the colloidal protein, albumen, which is naturally present in milk. Albumen makes up about 20 per cent of the protein found normally in cows' milk. It is precipitated by heat at temperatures above pasteurization in a finely divided state. Albumen has in common many of the properties which gelatin possesses, in that both are colloids of protein origin. However, albumen is an irreversible colloid while gelatin, according to Turnbow and Milner (15) is the most typical example of a reversible colloid. The presence of either in a mix, when the albumen has been precipitated, results in a heavy, viscous mix, depending on amount and methods of processing. Work done at

Illinois by Tracy (16) showed that a mix containing superheated condensed milk gave the appearance of having a higher total solids content than it actually contained by test.

Whether a mix is rehomogenized, the temperature at which homogenization is carried out, pressures and methods of adding gelatin and sugar, all affect the final viscosity of the mix, as shown by Reid and Heims (12) of Missouri and Hening (4) of New York.

Doan (3) found that homogenization decreased the stability of the proteins of dairy fluids, especially when fat was present. This effect increased with fat concentration and with the efficiency of homogenization. He found that when the fluid or plasma thereof was heated prior to homogenization the de-stabilizing effect was decreased. Another factor which affects the protein stability is the amount of soluble calcium present.

Webb and Holm (17) studied the effect different homogenizing pressures and forewarming temperatures exert on the stability of sweet cream, in which they found that an increase in homogenizing pressures decreased the time of the coagulation period as measured at 120°C. They, also, stated that preheating sweet cream, before homogenization, tended to stabilize the proteins. The temperature which they reported as most satisfactory for preheating was 80°C. for raw cream but somewhat lower, 74°C., for cream that had been previously pasteurized. They noted, too, that an increase in viscosity due to higher homogenizing pressures was attended by a cream that was more likely to "feather." Doan's work agrees closely with these investigators.

Holm and co-workers (5) showed that time and temperature of coagulation was increased in the case of evaporated skim milk as the concentration was increased. From this work he developed a formula with which he was able to calculate the time and temperature of coagulation of an evaporated milk of known concentration from an evaporated milk in which the concentration and time and temperature of coagulation were known. He, also, found that the time and temperature of coagulation were increased as the fat concentration increased in whole milk. This was ascribed to the fact that fat had the ability to absorb heat to a greater extent than milk serum.

Dahle and co-workers (11) condensed ice cream mixes in vacuo to contain double the normal solid content, omitting the gelatin. These mixes were stored at temperatures of 0°F., 40°F., and room temperatures. Such mixes had excellent keeping qualities due to the high concentration of sucrose and lactose. Those mixes stored at 0°F. made excellent ice cream after six months storage. Those stored at 40°F. were slightly tallowy but saleable after six months, while those stored at room temperatures for six months were not usable. A heavy precipitate of lactose crystals occurred in all samples, but when diluted with an equal volume of water to adjust composition, pasteurized and homogenized they were dissolved. Gelatin was added after storage and before processing. All mixes froze normally.

In 1930, Tracy (14) further investigated the possibility of making and storing concentrated mixes and concentrated cream for use in mixes. He found that a mix condensed two to one, can be satisfactorily stored at room temperature for a few days, although a temperature of 40°F. or lower is better. Such a mix can be stored at subzero temperature for a period of three months. Storage at higher temperatures is not desirable and he further states that all mixes to be stored should be kept free from copper and iron salts.

In this same experiment he found that cream could be successfully stored in a frozen state for at least three months. However, it should be of high quality, pasteurized, high in fat concentration, should not be allowed to come in contact with copper or iron, and should be stored in closed containers at a temperature of 0°F. or lower.

METHOD OF PROCEDURE

Preparation of Mixes

Number of Mixes Made. This experiment consisted of eight series of ice cream mixes, totaling 42 individual mixes, 38 of which were made partially or wholly in a Roger's Vacuum pan. Four mixes were not made in the vacuum pan, but were prepared in a coil vat for the purpose of comparing it with condensed mixes, which were not superheated.

The condensed mix in each series was taken as the check mix. In all studies two series of mixes were used as checks against each other. Series A and B, for example, were calculated to be exactly the same and to be composed of products which were identical.

The eight series of mixes were designated alphabetically from A to H inclusive. A preliminary mix was condensed and superheated in order to familiarize ourselves with the contemplated project. No freezing data was secured in this trial. It is not further mentioned or used in this experiment.

Composition. All mixes were calculated to contain 12 per cent fat, 10 per cent serum solids, 15 per cent sugar and when gelatin was used, .36 of one per cent.

Ingredients Used in the Mixes. Ingredients used in the mixes were raw cream, raw skim milk, butter (unsalted), and sugar. Gelatin was used in some of the mixes and omitted in other mixes. The calculated total solid content was 37.33 per cent when gelatin was used and 37 per cent when omitted.

In a few cases comparisons were made with mixes made in the usual manner using the ingredients listed above, except that skim milk powder, sweetened condensed skim milk or plain condensed skim milk were used, to obtain the major part of the serum solids.

Processing the Mix. The mixes were preheated to 140°F. then quickly drawn into the vacuum pan, condensed below the concentration desired in order to allow for the moisture added during the superheating process. In a few cases homogenization was used before condensing and after superheating. A few of the mixes were not homogenized.

Use of the Vacuum Pan - Superheating. All series were prepared in a Roger's vacuum pan under 26 to 27 inches of vacuum. The temperature within the pan during its operation ranged from 118° to 130°F. Each series was divided into three or more 40 pound mixes. The condensed mix was used as the control mix. The remaining mixes were superheated at different temperatures and for varying lengths of time, with or without sugar.

Superheating is a heat treatment, accomplished by raising the condensed milk from condensing temperatures

(120°- 130°F to 180°- 190°F.) by the introduction of live steam directly into the milk. The intense heat causes the colloidal albumen to precipitate, resulting in a thickening or increase in viscosity, which is commonly referred to as "liver."

In this experiment the mixes were condensed and superheated in the vacuum pan. After condensing, the mix was withdrawn, the check mix taken out and the remainder divided into equal portions and then superheated.

Gelatin. When gelatin was used it was put in solution and added to the mix after superheating. The water used in dissolving the gelatin assisted in standardizing the mix to the desired composition.

Time of Adding Sugar and Gelatin. In three series the entire mix was superheated. In the remaining series the sugar and gelatin were added after superheating and before homogenization. This procedure was followed in order to study the effect of the heat treatment on sugar, principally.

Homogenization. The effects of homogenizing before condensing and after superheating, singly and together, are studied throughout the experiment. All mixes were homogenized at 3000 pounds pressure at 145°F., except in a few instances when no pressure was used.

Viscosity Determinations. Viscosity determinations at 60°F. were made on several of the mixes both before and after superheating. The McMichael viscosimeter and a No. 27 wire were used in all determinations. Two readings were taken on each sample and the average of the two reported.

Processing and Freezing the Mix

Determining the Length and Temperature of the Superheating Process. Mixes were superheated to various degrees of "liver," as determined by noticing the apparent thickness of the mix to the eye and by tasting. Mixes superheated at temperatures of 200°- 210°F., when taken into the mouth, were similar to a mix high in gelatin content.

The intensity of the superheating treatmentwwas reflected in the flavor of the mix, depending quite largely on the length of time the treatment was sustained.

Homogenizing. A 60 gallon per hour Gaulin, single stage homogenizer was used on all mixes where pressure was desired. Homogenizing pressures were 3000 pounds per square inch at a temperature of 145°F. Immediately after homogenization, the mix was cooled to 40°F. over a surface cooler using brine and water.

Treatment of mixes after Cooling. Mixes were aged over night or for a period of 16 to 20 hours at 40°F. In each series the freezer was precooled by freezing at least once before experimental data were taken.

Determining Fat and Total Solids. All mixes were standardized to the desired percentage and then checked for fat and total solids on the Mojonnier tester.

Freezer and Brine Temperature. A Cherry 40 quart brine freezer was used in all freezing operations. A special Centigrade thermometer, tested and approved by the U. S. Bureau of Standards, was used to determine the temperature of the mix during the freezing and whipping periods. The temperature of the mix was ascertained each minute during the freezing and whipping periods.

Overrun determinations were made each minute after the first minute, using a Mojonnier overrun tester.

Methods Used in Determining Quality of the Final Product

Bacteria Determinations. The number of bacteria per cubic centimeter was determined in each series, on the raw mix, after condensing and after superheating. When the condensed mix was divided into two or more divisions for superheating, the bacteria count was determined for each lot. The samples were taken in sterile bottles at the vacuum pan, after a portion of the mix was withdrawn. These hot samples were immediately cooled with water and ice and then plated. In a few instances counts were made before and after homogenizing. The standard plate method was used in determining the bacterial content of the respective samples.

Judging the Ice Cream. The samples were drawn from the freezer and placed in the hardening room, when the overrun approximated 90 per cent. After hardening they were scored for flavor and body and texture. An attempt was made to compare them with each other in order to study the intensity of the cooked flavor, which usually resulted from superheating and which varied with the degree of superheating.

Storage of Samples. The samples were judged at an early date after freezing and then returned to the hardening room for a period of several weeks to determine if the effect on flavor caused by the heat treatment would disappear in storage. They were then re-scored and criticized. The rate at which samples melted was also observed.

EXPERIMENTAL DATA

Principle Involved in Superheating

Milk naturally contains about .7 per cent albumen. Ice cream is manufactured largely from milk and milk products and it is only natural that it should contain albumen, in proportion to the milk products used.

Albumen together with casein make up the protein of the milk. It is sensitive to heat, being partially precipitated when held at a temperature of 145°F. for 30 minutes. Higher temperatures and longer holding periods result in a more thorough precipitation.

It is colloidal in nature and as it is precipitated it carries the casein with it. This flocculent precipitate is of a gelatinous nature somewhat similar to gelatin.

Gelatin commonly used in ice cream mixes as the stabilizer is somewhat similar to albumen in composition and properties. Both of them are colloidal proteins. They differ mainly from each other in that gelatin is a typical example of a reversible colloid while albumen does not display this property, but is irreversible.

Superheating the mix or the milk products of the mix, results in a thickened more viscous product. It is well known that gelatin added to milk products increases the viscosity. Therefore, if viscosity is to be taken as the index of stabilization of the water of the mix, it is reasonable to expect that albumen naturally present in the ice cream mix might, when precipitated by high temperatures take the place of gelatin.

Increase in Viscosity Due to Superheating and Its Effect on Incorporation of Overrun

If it is reasonable to expect that the higher the superheating temperature and the longer the holding period, the more albumen will be precipitated it is then logical to expect that the degree of viscosity will be directly dependent on the amount of albumen precipitated. Table I shows this very clearly

TABLE I

Increase in Viscosity Due to Superheating

Series G

Mix	Heat Treatment	Centipoises before Treatment	Centipoises after Heating
1	Condensed not superheated	78	155
2	S.H. 190° - 10'	70	205
3	S.H. 200° - 10'	73	220
4	S.H. 200° - 20'	74	305
5	S.H. 210° - 10'	79	465

In Table I five mixes show a definite increase in viscosity depending on the degree of temperature to which they were subjected. The four superheated mixes shown in this table were all heated for the same length of time, but at different temperatures with the exception of one mix. This mix, No. 4, was heated at 200°F. for 20 minutes, whereas mix No. 2, 3 and 5 were heated for 10 minutes.

In this table there is shown a regular and steady increase as the temperature is increased. Mix No. 1 was condensed, but not superheated. The viscosity before condensing was 78 centipoises. After condensing at a temperature of 120°- 130°F., the viscosity was 155 centipoises, an increase of 77 centipoises. Mix No. 2 shows an increase in viscosity from 70 centipoises before condensing to 205 after superheating, an increase of 135 centipoises. The remaining mixes in this table likewise show an increase in viscosity comparable to Mix No. 2. It should be remembered, however, that all superheated mixes, were also subjected to the condensing period.

Indications as shown in this table are that the factors of temperature, superheating and length of the superheating period are all important as to the resulting viscosity. Mix No. 4 was heated to 200°F., the same as Mix No. 3, however, No. 4 was held at this temperature for a period of 20 minutes, whereas, No. 3 was held for only 10 minutes. No. 3 showed an increase in viscosity after the superheating process of 147 centipoises. No. 4 increased in viscosity 321 centipoises.

Both mixes were the same, therefore on the basis of this trial, we may ascribe 174 centipoises of the increase in No. 4 to the additional 10 minutes held, and using Mix No. 3 as an index, we can assume that the viscosity increased 147 centipoises during the first 10 minutes of heating.

Mix No. 5 increased in viscosity from 79 centipoises to 465, an increase of 386 centipoises or 65 centipoises more than Mix No. 4. The heat treatment in No. 5 was 210°F. for

10 minutes, an increase of 10°F., but a decrease of ten minutes in time.

This logical sequential increase in viscosity as shown in Table I is not borne out in Table II, which is shown below:

TABLE II

The Effect of Superheating Temperatures on Viscosity and Whipping Properties of the Mix

Mix No.	Heat Treatment	Centipoises Viscosity	Per cent Overrun after 10 minutes
1F	Condensed	261	85
2F	190°F.- 15 min.	635	85
3F	200°F.- 15 min.	444	80
4F	200°F.- 25 min.	288	89
5F	210°F.- 15 min.	579	73
1G	Condensed	133	97
2G	190°F.- 10 min.	305	90
3G	200°F.- 10 min.	220	94
4G	200°F.- 20 min.	393	73
5G	210°F.- 10 min.	465	73

Series G is shown here again in order to study the effect of superheating on overrun.

Viscosity determinations were not made on Series F before condensing and superheating, however, all mixes in Series F are comparable as are all mixes in Series G, inasmuch as all mixes in each series are subdivisions of one original mix. Both series were made from the same kind of ingredients but on different days. We can logically assume that the viscosities of all mixes in Series F were before processing, approximately the same.

In Series F, shown in Table II all superheated mixes were held at superheating temperatures for a period of 15 minutes with the exception of Mix No. 4 which was superheated for 25 minutes. After condensing Mix No. 1 in this series, showed a viscosity of 261 centipoises or 106 centipoises more than the corresponding mix in Series G. This increase may be accounted for due to the fact that they were not made on the same day.

Mix No. 2 in Series F shows the greatest final viscosity of any mix upon which viscosity determinations were made. The heat treatment in this mix was 190°F. for 15 minutes, whereas, in Mix No. 3, it was 200°F. for 15 minutes. This is exactly opposite from what might be expected as shown by Table I.

Mix No. 4 showed a lower final viscosity than did mix No. 3, yet No. 4 was heated at the same temperature and for a longer period of time. Possibly, as is the case with gelatin, some of the gel strength of albumen may be destroyed by high temperatures and long heat periods. It will be noticed, however, referring to Table II, that all superheated mixes definitely increased in viscosity over the condensed mix.

The influence of viscosity on whipping qualities, is also well illustrated in Table II. After 10 minutes in the freezer, the condensed mix in Series F showed an overrun of 85 per cent, which is higher than the superheated mixes with the exception of mix No. 4, which had a viscosity approximately the same as the condensed mix. The overrun obtained in mix No. 2 was also greater than for mix No. 5. The viscosity of these two mixes, however, approximate each other.

In Series G, the overrun is markedly lower in the mixes having the higher viscosities. The condensed mix showed an overrun of 97 per cent after 10 minutes, whereas the mix superheated to 210°F. for 10 minutes showed only 73 per cent overrun.

An interesting study was carried out in Series H, dealing with viscosities of mixes condensed and superheated, and with three mixes not made in the vacuum pan, but made in the usual manner. Mix No. 1, 2 and 3 were made in a coil vat. No. 1 contained sweetened condensed as its principal source of serum solids, No. 2 plain condensed and No. 3 skim milk powder. No products were superheated. Table III shows the resulting viscosities and the overrun obtained after 10 minutes in the freezer.

TABLE III

The Effect of Superheating on Viscosity and Overrun as Compared with Unsuperheated Mixes

Mix No.	Treatment	Viscosity Centipoises	Per cent Overrun after 10 Minutes
1E	Swt. Condensed	174	95
2E	Pl. Condensed	230	91
3E	Pdw. Skim milk	357	85
4E	Superheated*	415	90
5E	Condensed	261	94

* Temperature 200°F. for 15 minutes.

Mixes 1, 2 and 3 were heated to 145°F. for 30 minutes.

In Table III, the results show that the mix using sweetened condensed as its principal source of serum solids had the lowest viscosity and whipped to the highest per cent overrun in 10 minutes time. The condensed mix whipped to approximately the same overrun but had a higher viscosity of 87 centipoises.

The superheated mix had the highest viscosity, 415 centipoises, but whipped faster than mix No. 3 containing skim milk powder.

This table shows clearly that the heavier, more viscous mixes whip more slowly than do the mixes of lower viscosity and also indicates that the superheating of a mix increases its viscosity over mixes made in the usual manner.

The Effect of Superheating Temperatures, Homogenizing Pressures and Omission of Gelatin on the Incorporation of Overrun

In four of the eight series of this experiment the possibility of substituting the superheating process for gelatin was studied.

In Series A, B, C and D, the gelatin was omitted from two mixes of each series. A and B differ from C and D in that the butter fat which they contained was derived from unsalted butter. The cream from which this butter was made tested .79 per cent acid before neutralization to .2 per cent. Sweet cream was used as the source of fat in Series C and D.

Mixes Deriving Their Fat from Unsalted Butter. Table IV shows the study made on Series A and B. In this table are a total of 10 mixes, four superheated at 205°F. for 10 minutes and four superheated at 210°F. for 20 minutes. The two remaining mixes are the check mixes or the condensed mixes. Gelatin was omitted from four mixes and homogenizing pressures were also omitted in four cases.

TABLE IV

Rate of Incorporating Overrun and Effect of Homogenization on Superheated Mixes Containing no Gelatin

Mix No.	Heat Treatment	% Gelatin	% Overrun at 10 min.	Maximum Overrun	Homogenizing Pressures
1A	Condensed	.35	90	96-11 min.	3000 lbs.
2A	205°F-10 min.	none	101	101-10 "	3000 lbs.
3A	205°F-10 "	none	95	95-10 "	none
4A	205°F-10 "	.35	78	92-13 "	3000 lbs.
5A	205°F-10 "	.35	76	91-13 "	none
1B	Condensed	.35	88	100-11 "	3000 lbs.
2B	210°F-20 min.	none	84	96-11 "	3000 lbs.
3B	210°F-20 "	none	88	94-11 "	none
4B	210°F-20 "	.35	72	90-13 "	3000 lbs.
5B	210°F-20 "	.35	61	90-14 "	none

Mixes 1A to 5A whipped relatively faster than did mixes 1B to 5B. Both series had the same unsalted butter as their source of fat. Brine temperature in A was 2°F. and in B was 3°F. Mix 2A containing no gelatin and receiving 3000 pounds pressure showed an overrun of 101 per cent after 10 minutes in the freezer. Next to it, came mix 3A containing no gelatin and receiving 3000 pounds pressure. The superheated mixes containing gelatin in this series whipped very slowly compared to the unsuperheated mixes.

The condensed mix whipped to 90 per cent after 10 minutes and to a final overrun of 96 per cent at 11 minutes. The final overrun on the two superheated mixes containing gelatin was 92 and 91 per cent, respectively, after 13 minutes in the freezer.

The overrun obtained in series B was relatively lower, but here again the superheated mixes containing gelatin whipped more slowly than the other mixes. At 10 minutes time 3B containing no gelatin had whipped to an overrun of 88 per cent, four per cent higher than mix 2B, which was homogenized with no gelatin at 3000 pounds pressure. The overrun at eleven minutes, however, was slightly greater in mix 2B.

It is quite evident from Table IV that superheated mixes containing gelatin whip very slowly. Homogenizing superheated mixes containing no gelatin appears to aid in obtaining maximum overrun.

Mixes Deriving Their Fat from Sweet Cream.

TABLE V

Rate of Incorporating Overrun and Effects of Superheating the Sugar of Mixes Containing no Gelatin

Mix No.	Heat Treatment	% Gelatin	Time Drawn	% Maximum Overrun	Addition of Sugar
1C	Condensed	.35	8 min.	102	before Condensing
2C	210°F-15 min.	none	7 "	108	before Superheating
3C	210°F-15 min.	.35	8 "	105	before Superheating
1D	Condensed	.35	9 "	95	after Condensing
2D	212°F-20 min.	none	9 "	100	after Superheating
3D	212°F-20 "	.35	10 "	100	after Superheating

TABLE V - Continued

Mix No.	Heat Treatment	% Gelatin	Time Drawn	% Maximum Overrun	Addition of Sugar
4D	212°F-20 min.	.35	11 min.	97	before Superheating
5D	212°F-20 min.	none	9 "	95	before Superheating

All mixes were homogenized at 3000 pounds pressure and at a temperature of 145°F.

The brine temperature used in freezing the mixes in Table V was 0°F. The mixes reached their maximum overrun relatively faster than mixes frozen in other tables.

In both series C and D the mix containing no gelatin froze more quickly to a higher overrun than did those containing gelatin. However, the superheated mix containing gelatin showed a slightly higher overrun when drawn than did the condensed mix.

From the results shown in Table V apparently, heat treatment of the sugar results in faster whipping. From 2C and 3C, the superheating of the mix with sugar, resulted in a faster whipping mix than in the condensed sample. This indicates that superheating with the sugar in the mix aids in obtaining overrun. Other factors, however, may be affected to the extent where this would not be advisable.

It is plain, from this study that superheated sweet cream mixes whip faster than superheated butter mixes and that mixes containing no gelatin whip faster than those containing gelatin.

Rate of Freezing and Overrun Incorporation in Mixes having only the Milk Products Superheated. In Table VI, which is presented below, are given the results of freezing mixes having the milk products superheated as compared with three mixes, having different principal sources of serum solids and made in a coil vat in the usual manner. All mixes contained gelatin and were homogenized at 3000 pounds pressure.

TABLE VI

Rate of Overrun Incorporation in Mixes having Only the Milk Products Superheated

Mix No.	Heat Treatment	Per cent Overrun at 10 minutes	Per cent Maximum Overrun
1E	Condensed	94	102 - 11 minutes
2E	210°F.- 15 min.	90	100 - 11 "
3E *	145°F.- 30 min.	93	95 - 10 "
4E **	145°F.- 30 "	91	90 - 11 "
5E ***	145°F.- 30 "	83	92 - 12 "
1F	Condensed	83	95 - 13 "
2F	190°F.- 15 "	85	97 - 13 "
3F	200°F.- 15 "	80	96 - 12 "
4F	200°F.- 25 "	89	94 - 11 "
5F	210°F.- 15 "	78	96 - 13 "

* Sweetened condensed was the principal source of serum solid in this mix.

** Powdered skim milk was utilized as the principal source of serum solid in this mix

*** Plain condensed skim milk was the principal source of serum solids used in this mix.

In series E the condensed mix whipped to a higher final overrun than any other mix, however, it took one minute longer than did the unsuperheated mix containing sweetened condensed. After 10 minutes in the freezer, however, there was very little difference between the two. 1E had an overrun of 94 per cent, whereas 3E showed an overrun of 95 per cent.

With the exception of the mix 5E, which contained plain condensed as its source of serum solids, the superheated mix whipped more slowly up to 10 minutes. The final overrun showed it to be next to the condensed mix.

In time of whipping, it must be noted that 3E reached 95 per cent overrun in 10 minutes, while all other mixes in this series required 11 or 12 minutes. There is very little difference in overrun obtained in this series.

Series F allows a study of five mixes which were presented in the viscosity studies. After 10 minutes in the freezer, the mix heated to 200° - 25 minutes, showed an overrun of 89 per cent. Next in per cent overrun at 10 minutes is the condensed mix. In mix 4F, the severity of the heat treatment was greatest of any mix. It appears that the high temperatures of superheating over a period of 25 minutes does definitely cause the mix thus heated to lose some of the gel strength which other mixes superheated at lower temperatures and for a shorter period, exhibit.

Following the condensed mix in Series F, according to overrun obtained at 10 minutes, is mix 2F, 3F and 5F in order. This is the exact order in which the severity of the superheating process took place.

The maximum overrun in Series F had a total variance of only three per cent from a low of 94 per cent to a high of 97 per cent. The 94 per cent mix was drawn at the end of 11 minutes, while the mix having 97 per cent overrun was drawn at the end of 15 minutes. Therefore we might expect the 94 per cent mix to be equal or superior to the other mixes, in this series, in overrun incorporation.

Effect of Superheating and Omission of Gelatin on Quality of Resulting Ice Cream

The problem attempted in this phase of the experiment was the substitution of superheating temperatures in place of gelatin. It has been proved, that in omitting gelatin from an ice cream mix, a coarse, grainy bodied ice cream invariably results. By increasing the solids content above 40 per cent this condition may be partially avoided.

The theory employed throughout this part of the work was the possibility of the precipitated albumen exhibiting gel formation equal to the gelatin normally used in ice cream mixes.

In Table VII, there are presented some results of superheating the entire mix excepting gelatin on the body and texture and the flavor of the finished ice cream.

TABLE VII

Effect of Superheating the Sugar in the Mix and Homogenizing Pressures, Effect on Quality of Ice Cream

Mix No.	Heat Treatment	Gelatin	Lb. Homogenization	Flavor	Body & Texture
1A	Condensed	.35	2000	Slightly Metallic	Smooth
2A	205°F-10 min.	none	3000	Cooked	Coarse
3A	205°F-10 min.	none	none	Cooked	Very Coarse
4A	205°F-10 min.	.35	3000	Cooked	Smooth
5A	205°F-20 min.	.35	none	Cooked	Smooth
1B	Condensed	.35	3000	Excellent	Smooth
2B	210°F-20 min.	none	3000	Caramelized	Slightly Coarse
3B	210°F-20 min.	none	none	Caramelized	Slightly Coarse
4B	210°F-20 min.	.35	3000	Caramelized	Smooth
5B	210°F-20 min.	.35	none	Caramelized	Very Smooth

There are 10 mixes shown in Table VII. Two series are represented. It should be remembered that all mixes contained sugar before superheating. Mix No. 1A and 1B are the condensed mixes and serve as the checks. In connection with condensing, we noticed a slight metallic flavor in the ice cream made from several of the condensed mixes. It seems logical that mixes coming in contact with copper, as in the condensing operation, might absorb a metallic flavor. It is generally considered that mixes made in the vacuum pan are cleaner, fresher mixes, usually because such mixes are made from fresh raw products. This metallic flavor, which we noticed was not pronounced, but nevertheless, it could be noticed by the judges.

In both series A and B, the superheated samples containing gelatin exhibited a very smooth body, typical of egg yolk mixes. There was practically no difference in body and texture in either series, even though series A was heated to 205°F. for 10 minutes and series B was heated to 210°F. for 30 minutes.

In flavor, however, there was a distinct difference between the two series. Series B heated to a higher temperature and for a longer period of time, resulted in ice cream that had a very distinct caramelized flavor. This flavor was very pronounced. In series A the superheated samples all showed a cooked flavor, but not the caramel flavor exhibited in series B.

Mix BA, homogenized at 3000 pounds, without gelatin, was coarse in body and texture after freezing. The same was true of all other mixes not containing gelatin. Mixes which were superheated and contained gelatin, showed, however, smooth bodies and textures when examined. It appeared to make very little difference whether or not they were homogenized. Mixes which contained no gelatin and were homogonized were generally smoother and placed higher when ranked than did the mixes containing no gelatin and having no homogenization.

In work shown in Table VIII, superheated mixes were compared with unsuperheated mixes. Results of superheating the main source of serum solids are also presented.

TABLE VIII

The Effect Superheated Sweetened Condensed Milk and Plain Condensed Milk has on the Quality of the Ice Cream

Mix No.	Heat Treatment	% Gelatin	Flavor	Body & Texture
1S	Condensed	.35	Metallic	Very Good
2S	210°F-15 min.	.35	Cooked	Smooth
3S	Swt. Cond. not S. H.	.35	Good	Good - Smooth
4S	Skim Milk Pwd. not S. H.	.35	Good	Distinctly Sandy
5S	Plain Cond. not S. H.	.35	Fair-Old	Godd
1H	Plain Cond. not S. H.	.35	Good	Smooth
2H	Plain Cond. Superheated	.35	Slightly Cooked	Smooth
3H	Plain Cond. Superheated	none	Slightly Cooked	Coarse - Grainy
4H	Swt. Cond. not S. H.	.35	Good	Good
5H	Swt. Cond. Superheated	.35	Badly Cooked	Good
6H	Swt. Cond. Superheated	none	Badly Cooked	Coarse - Grainy

TABLE VIII - Continued

Mix No.	Heat Treatment	% Gelatin	Flavor	Body & Texture
7H	Condensed	.35	Fair	Good
8H	190°F-15 min.	none	Badly Cooked	Coarse - Grainy
9H	190°F-15 min.	.35	Badly Cooked	Good

All samples were homogenized at 3000 pounds pressure.

There are 14 mixes in this table. Mix 2E is the only superheated mix in that series. In flavor it is distinctly cooked. It showed a very smooth body. All mixes contained gelatin except 3H, 6H and 8H. In each case the ice cream from these mixes was coarse and grainy. It appears improbable that the superheating process will take the place of gelatin, as all three of these mixes were superheated.

The condensed mix, 1E, had a metallic flavor when frozen perhaps due to contact with the copper condenser and coils. If this flavor was present in the superheated mixes, it could not be detected. The cooked flavor due to superheating may cover it up, as the metallic flavor was only slightly noticeable.

In this table as in Table VII, all of the superheated mixes exhibited good, smooth bodies and texture when frozen, provided they contained gelatin.

Mix 4E had skim milk powder as its principal source of serum solids. The body and texture of this ice cream was distinctly sandy. It was frozen in the same manner and at the same time as the other samples in series E, however, it whipped more slowly than the other mixes at the time of freezing.

All mixes superheated or containing superheated products were cooked. The superheating process resulted in smoother bodies, but lowered the flavor score.

Bacteriological Studies

Bacteriological studies were made on all mixes before condensing, after condensing and after superheating. In addition several bacteriological counts were made before and after homogenizing and on single ingredients of the mix. The study presented herein, however, deals with the count in the raw mix or check mix, which is the condensed mix and finally the superheated mix. It is true that the bacterial count in the mix at the freezer could be considerably higher than the figures shown here, depending on the sanitary condition of the homogenizer and cooler.

Table IX shows the per cent of bacteria destroyed in nine different mixes.

TABLE IX

Bacterial Destruction in Ice Cream Mixes due to Superheating Temperatures

Mix No.	Bacteria Count per cubic centimeter			
	Raw Mix	After Condensing	After Superheating	Per cent Destroyed
1	225,000	43,000	10,000	95.55
2	500,000	21,000	4,000	99.20
3	151,000	273,000	4,000	97.35
4	161,000	73,500	1,000	[illegible]
5	125,000	Broken	600	99.52
6	500,000	165,000	3,500	99.30
7	15,000,000	4,700,000	3,500	99.98
8	300,000	140,000	200	99.93
9	1,200,000	300,000	300	99.97

The per cent of bacteria per cubic centimeter varied from a low of 95.55 per cent to a high of 99.98 per cent.

The number of bacteria destroyed during the condensing period varied quite widely, depending on the temperatures and length of time of condensing. When the temperatures were relatively high for condensing as 135°F. - 140°F. the bacterial destruction was high but when condensing temperatures were low the bacterial destruction was around 50 per cent and in one case the count was practically doubled after condensing. This can be accounted for in that the vacuum pan was not functioning properly and condensing temperatures were as low as 110°F. - 120°F.

Superheating the samples killed practically all of the bacteria, counts being as low as 200 bacteria per cubic centimeter and the highest being 10,000. With the exception of the mix just mentioned showing a count of 10,000, the highest count to be found among the other eight mixes was 4,000.

Certainly it is true that the superheating process affords efficient pasteurization, although the same cannot be said of condensing. Peterson and Tracy (10) showed that condensing a mix accomplishes the purpose of pasteurization. Undoubtedly this is true, depending, however, that condensing and forewarming temperatures are relatively high. Too, the length of time required for condensing would very materially affect the number of bacteria destroyed.

Temperatures of 200°F. for 10 minutes reduced the number of bacteria to the point where experimental error in plating might affect the count very materially.

DISCUSSION OF THE RESULTS

The time and temperature of superheating the mix determined largely the flavor of the finished ice cream. When the entire mix was superheated at temperatures of 200°F. - 210°F. for a period of 10 - 20 minutes, a distinct caramelized flavor appeared in ice cream frozen from these mixes. If only the milk product ingredients were superheated and the sugar and gelatin added after superheating, a cooked flavor was present in the finished ice cream. The intensity of this flavor depended on the superheating process.

Samples of ice cream frozen from mixes superheated at 190°F. for 10 minutes gave a slightly cooked flavor, while at higher temperatures it was more pronounced.

Tracy (13) reported in 1923 that mixes superheated to 185°F. - 190°F. for a period of 5 - 15 minutes resulted in viscous mixes which whipped more readily to the desired overrun than did mixes that were not superheated. In addition he stated that the body and texture of the ice cream made from these superheated mixes was superior to that made from the unsuperheated mixes, but the flavor was impaired.

This is borne out in the work done in this experiment, except for the fact that as a rule the superheated mixes did not whip faster than the unsuperheated ones. We found that there was little difference in whipping qualities comparing the two types of mixes. As the heat treatment became more severe the mixes became more viscous and whipped more slowly.

The body and texture of the ice cream from these superheated mixes had a "velvety" smoothness that in practically all cases was superior to the ice cream made from the unsuperheated mixes, when gelatin was used.

Early in this work, we attempted to omit gelatin, thinking that perhaps the precipitation of the colloidal albumen, carrying with it the casein, would serve as the stabilizer in the mix.

Ice cream made from superheated mixes, without gelatin, showed in all cases a rough, grainy body, noticeable to many consumers. One party who had no training in ice cream picked two samples out of ten exhibited, that were coarse and grainy. These two samples were the only ones that did not contain gelatin. Both of them had been superheated.

It appears then, that the superheating process as carried out in this experiment will not satisfactorily serve as the stabilizer of the mix. It does aid materially, however, in stabilizing the mix.

Homogenizing the superheated mixes containing no gelatin, improved the body and texture of the ice cream frozen from them. They were not, however, as smooth in body and texture as ice cream frozen from a mix made in the usual manner and containing gelatin.

The number of bacteria destroyed per cubic centimeter, due to the superheating process in practically every case was greater than in ordinary pasteurization. An ice cream mix containing less than 100,000 bacteria per cubic centimeter is considered to have been handled under good, sanitary conditions. In all the bacteria determinations made in this study, 11,000 bacteria per cubic centimeter was the highest count after superheating, even though the count on the raw mix in one series was nearly 13,000,000 bacteria per cubic centimeter.

SUMMARY AND CONCLUSIONS

1. The vacuum pan offers a satisfactory and economical method of making ice cream mixes, when operated by an experienced person and under constant operating conditions.

2. Superheating the entire mix at a temperature of 190° F. for a period of ten minutes or at a higher temperature or for a longer period is deleterious to the flavor of the resulting ice cream.

3. Superheating a mix testing 12 per cent fat, 10 per cent milk solids not fat and 15 per cent sugar, will not satisfactorily stabilize the mix. Gelatin cannot be replaced by the heat treatment.

4. Although superheated mixes are more viscous than unsuperheated mixes, the length of time necessary to freeze is increased only slightly.

5. The body and texture of ice cream made from superheated mixes containing gelatin is equal to or in many cases superior to ice cream manufactured from ordinary mixes. The flavor score is lowered, however, in every case.

6. Bacterial destruction, due to superheating is very efficient. In many cases counts of only 200 to 400 bacteria per cubic centimeter were obtained after superheating.

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