THE MANUFACTURE OF ICE CREAM

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Introduction

It is not many years since ice-cream was considered to be a luxury, and was reserved for special occasions such as holidays, picnics and celebrations that occurred during the warm summer months. To-day, ice-cream is used by all classes of people the year round, and is endorsed by leading authorities on nutrition and by many medical men as a highly valuable food combining wholesomeness with a delicacy of flavour that is hard to equal.

From a small beginning, the ice-cream business in Canada has grown steadily until it is now an important part of our great dairy industry. In 1926, according to the Canadian Bureau of Statistics, the total production of ice-cream in Canada totalled 6,897,810 gallons with a value of $9,394,422. This is a per capita consumption of 5.6 pints per annum. For the same year the per capita consumption of ice-cream in the United States was estimated at 2.77 gallons (American), or approximately three times greater than in Canada. It is evident, therefore, that there is an excellent opportunity to expand the ice-cream business in Canada by increasing our per capita consumption of this delectable and highly nutritious dairy product.

The increase in volume of production has been accompanied by a continual improvement in the quality of ice-cream, due to better methods of manufacture as well as a better understanding of the factors involved in the production of high-quality ice-cream. The introduction of power freezers and other ice-cream equipment along with mechanical refrigeration gave a considerable impetus to the industry, and was really the starting point of the decided growth of the wholesale manufacture of ice-cream.

The growth of the ice-cream business with the improvement in quality has brought new conditions for the manufacturer. The consumer is more discriminating in his taste, and competition is keener, so there is need for the highest possible efficiency in manufacturing if the operations of the plant are to be successful.

It is the purpose of this bulletin to bring together for the benefit of beginners in the industry and other interested persons some of the important factors in the production of a good-quality ice-cream.

The Food Value of Ice-cream

One of the important factors in the increased use of ice-cream has been the wide publicity given to recent findings of nutritional authorities regarding the food value of dairy products as a whole. The results of these investigations undoubtedly have brought about a change in the viewpoint of the consuming public, with the result that ice-cream is considered no longer as a luxury, but a very desirable and healthful food. Thus, it is accorded a regular place in the dietary of public dining rooms, restaurants, hospitals, and many homes.

Ice-cream is a true dairy product which contains the four essential food substances naturally found in milk, namely, fat, proteins, carbohydrates, and mineral matter, and in addition supplies the important protective and auxiliary food substances known as vitamins. Milk fat is one of our very best foods, containing, as it does, the very valuable "Fat Soluble A" vitamin. Milk proteins are of the highest quality and contain the important "Water Soluble B"

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vitamin and small quantities of "Water Soluble C" vitamin. The carbohydrates in ice-cream are plentifully supplied by the milk sugar and added cane sugar, while mineral salts, especially calcium, are found in adequate quantities for normal growth and health.

Average commercial ice-cream contains between 34 and 40 per cent of total solids of the very best quality as regards digestibility and energy-producing value, and compares favourably with any other food in this respect.

In addition to being a highly nutritive food, ice-cream is a delicious confection that is relished by nearly all people and makes a handy ready-to-serve dessert for the busy housewife.

Classification of Ice-Creams

Several classifications (1, 2, 3) have been suggested for ice-creams according to the materials used, the methods of manufacture and the flavours used. However, none of these classifications has been accepted as standard. Fisk (4) suggests a logical and comprehensive classification that is based on the materials used with subclasses divided according to the flavouring materials. This classification is as follows:—

I. Plain ice-cream is made from cream, sugar and flavouring, with or without condensed milk or stabilizer.

(1) Plain—flavours are used such as vanilla, chocolate, caramel, coffee, mint and maple.
(2) Fruit—fresh or canned fruits are used for flavours, such as peaches, strawberries, pineapple, etc.
(3) Nut—various nuts as walnuts, almonds, chestnuts, pistachio, furnish the flavouring.
(4) Bisque—flavouring materials as macaroons, marshmallows, grape-nuts, etc. are used.
(5) Mousse—rich whipped cream sweetened and different flavours added.

II. Cooked ice-cream, often known as French or Neapolitan, is made from cream, sugar, eggs and flavouring. As custards they sometimes contain flour or cornstarch.

(1) Parfaits or French—flavours as vanilla or chocolate are common but fruits are sometimes used.
(2) Puddings—these are highly flavoured with various dried and candied fruits, nuts, spices and eggs.
(3) Custards—these contain flour, cornstarch or other similar ingredients and are almost always flavoured with vanilla.

III. Sherbets and ices are made from water, milk, sugar, often egg albumen, and a stabilizer, and flavoured with fruit juices or other natural flavourings.

(1) Ices—made from water, sugar and some natural flavouring without stabilizer or eggs.
(2) Water sherbets—made the same as ices with the addition of egg whites and a stabilizer. If the whole egg is used they are sometimes called souffles.
(3) Punches—ices or water sherbets flavoured with liquors or highly flavoured with fruit juices and spices.
(4) Milk sherbets—made from whole or skim-milk, sugar, egg whites, with or without a stabilizer, and flavoured with some natural flavouring.
(5) Lacto (5)—made from skimmed or whole sour milk instead of sweet milk but otherwise resembles milk sherbets.

Canadian Ice-Cream Standards

Ice-cream standards are outlined in regulations under the Food and Drugs Act, administered by the Department of Health, Ottawa (6). Under these regulations, ice-cream shall not contain more than 2 per cent of stabilizers such as gelatin, starch and gum tragacanth, and must contain at least 10 per cent of milk fat. Fat other than milk fat shall not be used in the manufacture of ice-cream.

The Ingredients of Ice-Cream and their Sources

Commercial ice-cream contains a number of ingredients which are obtained from a variety of sources. These ingredients and the products from which they are obtained are enumerated as follows:—

Milk Fat. Most of the milk fat in ice-cream is obtained by the use of fresh sweet cream, or when sweet cream is scarce, by using unsalted butter. Some fat is supplied by whole milk, condensed milks, evaporated milk and milk powders when these products are used. The amount of fat present in skim-milk products, however, is so small that it is not taken into consideration.

Milk Solids not Fat. All dairy products contain milk solids not fat, but in addition to the sweet cream or whole milk that is used, it is necessary to add additional milk solids not fat by using one or more of the various products that contain a high percentage of this ingredient. Such products as sweetened or unsweetened condensed milk either whole or skim, evaporated milk, and whole or skim-milk powders are used for this purpose with equally good results, providing they are of good quality and handled and proportioned properly in the mix. Market conditions, price and the quality available are factors which influence the selection of these materials.

Sugar. Cane or beet sugar in the granulated form are used in ice-cream. However, when these sugars are high in price or the supply scarce, glucose sugar may be used to supply part of the sugar requirements. In some places glucose sugar is sold under the trade name of cerelose. According to Combs (7) this sugar is only about 74 per cent as sweet as cane or beet sugars, known as sucrose, and should only replace about 35 per cent of the sucrose. Under the Food and Drugs Act of Canada it is illegal to use any sugar but sucrose in ice-cream.

Sweetened condensed milks contain approximately 40 per cent of sugar, and when used the sugar they contain will have to be taken into account when making up the mix.

Gelatin. This is the stabilizer most generally used in ice-cream. It is a colloidal substance obtained from animal bones and tissue which will dissolve in hot water and on cooling will form a jelly. Only gelatin prepared for food purposes should be used and it should have a clean, inoffensive odour. Gelatin is prepared for the market in the form of sheets, shreds or powder, the latter being the most popular form for ice-cream.

Other Stabilizers or Fillers. Vegetable gums, ice-cream improvers, starch and egg yolk powder are sometimes used to supplement or replace the gelatin as an ice-cream stabilizer. The most commonly used vegetable gum is probably tragacanth gum. This gum has the power of absorbing a great deal of water and only very small quantities are necessary.

Ice-cream improvers are purchased ready for use but have the disadvantage of being more expensive and of unknown composition. When purchased, they should be used always according to directions.

Egg yolk and starch are very seldom used in regular ice-cream, but are used in special kinds of ice-cream known as custards and puddings.

Flavouring Materials. The most popular flavour for plain ice-cream is vanilla. This extract is made by dissolving in alcohol the pure essence of the vanilla bean. Although there are several varieties of vanilla bean, the best extract is produced from the best grade of Mexican beans. Inferior extracts are made from the poorer grades of Mexican beans and other varieties or by adulterating the pure extract with artificial vanillin. Orange and lemon flavour extracts are produced by dissolving the pure oils of these fruits in alcohol.

Fresh or preserved fruits of practically every kind are used for flavouring fruit ice-creams, while clean, sound, non-rancid nuts are used for nut ice-creams.

Other flavouring materials used are macaroons, grape nuts, cakes, etc., for what are known as bisque ice-creams.

Chocolate flavouring is made by making a syrup of sugar and either the bitter chocolate or cocoa, by using one and one-half pounds of bitter chocolate or one pound of cocoa with two pounds of sugar. The chocolate or cocoa is mixed with the sugar and enough water or milk is added to make a thick syrup. Then heat in a double boiler until the syrup is smooth, and cool before adding to the mix. This quantity is sufficient for ten gallons of ice-cream.

Water. All ice-cream mixes contain between 60 and 67 per cent of water. Most of this water is present in the milk products, but in some cases, additional water will have to be added to the mix to obtain the proper proportions of all ingredients.

The Relation of the Ingredients to the Quality of Ice-Cream

The various ice-cream ingredients are used for definite purposes and each plays a very important part in determining the quality of the finished product. The function of each ingredient is as follows:—

Milk Fat. The flavour and palatability of ice-cream is largely determined by the milk fat or the milk product that supplies most of the fat. It has been demonstrated many times that nothing can take the place of fresh sweet cream as the basic milk product in ice-cream. Cream of good quality gives a rich delicate flavour to the ice-cream that cannot be obtained by the use of substitutes such as butter. The amount of milk fat also determines largely the food value of the ice-cream as this ingredient is rich in vitamins and heat units.

Milk Solids not Fat. These constituents of milk products bear a very important relation to the texture and body of ice-cream and the overrun obtained. Too much milk solids not fat tend to produce a heavy, soggy ice-cream and may cause sandiness, while too low a proportion gives a light fluffy body and makes it difficult to obtain overrun. In the proper proportions, milk solids not fat improve the texture and body of ice-cream and increase the nutritive value as they are rich in proteins and the water soluble vitamins.

Sugar. Primarily this ingredient is used as a sweetening agent to increase the palatability of the ice-cream, but it also increases the food value. Sugar influences the freezing point of the ice-cream more than any one other ingredient. A high sugar content lowers the freezing point to such an extent that it is more difficult to freeze the mix and keep it frozen.

Gelatin. Gelatin is used in the ice-cream mix to produce a smooth textured product. By absorbing water, it helps to prevent the separation of the sugars and the water in large crystals, which has always been an important factor in the freezing process. Gelatin also increases the viscosity of the mix because it tends to form a gel during the aging period. This increases the amount of overrun that may be obtained by making it possible to incorporate more air in the frozen mixture.

Gelatin also has considerable food value in itself and is important because it aids in the digestion and assimilation of the other food constituents such as proteins.

Flavouring Materials. Flavouring extracts have an important influence on the delicacy and palatability of the finished ice-cream. It is necessary therefore, to use care and judgment in the selection of the flavour extracts. The amount of flavouring material used in ice-cream is so small that the difference in cost per gallon of ice-cream between a good and poor extract is a negligible matter. The manufacturer who wishes to establish a reputation for high quality ice-cream cannot afford to use anything but the best of flavouring materials whether extracts, fruits or nuts.

Composition of Ice-Cream

The composition of the ice-cream mix will depend on the legal standards, the preferences of the consuming public for which the ice-cream is made, and the opinion of the manufacturer as to the best proportions of the various ingredients. According to Canadian Standards, ice-cream must contain not less than 10 per cent milk fat, but the proportions of fat and other ingredients will depend on the quality of the product to be made and the basic formula of the individual plant.

Several studies have been made to obtain the opinion of the consumer as to the best composition for ice-cream. These studies were made by giving representative consumers a choice of ice-creams of various compositions over a period of several weeks and recording their preferences. Williams and Campbell (8) found that 82 per cent of sales were for ice-cream containing 18 per cent milk fat in preference to ice-creams containing 15 and 12 per cent fat. In the case of milk solids not fat, 56·1 per cent of sales were for the ice-creams containing 12 per cent milk solids not fat in comparison to ice-creams of 9 and 6 per cent milk solids not fat.

Sugar influences the palatability of ice-cream, and in this experiment the consumers evidently liked their ice-cream sweet, for over 90 per cent of sales were for ice-cream containing 16 per cent or more of sugar in preference to ice-creams of lower sugar content.

Depew and Dyer (9), in a similar experiment for a different set of consumers, obtained almost the same results. They found that 72 per cent of sales were for ice-cream containing 16 per cent of fat in preference to ice-creams of 12 and 8 per cent fat. For three different lots of ice-cream containing 13, 10, and 7 per cent milk solids not fat, 14 per cent fat, and 15 per cent sugar, 68 per cent of the consumers took the ice-cream with 10 per cent milk solids not fat and 30 per cent took the ice-cream with 13 per cent milk solids not fat. Ice-cream containing 16 per cent sugar was chosen by 85·1 per cent of the consumers in preference to ice-creams containing 14 and 12 per cent of sugar.

Both groups of consumers preferred ice-cream containing 0·5 to 1·0 per cent gelatin to ice-cream in which no gelatin was used.

If these tests give a fair indication of the preferences of the average consumer of ice-cream, the manufacturer should set a fairly high standard for the composition of his ice-cream.

There are no published data that the author is aware of that give completely the average composition of ice-cream as made in Canadian plants. The percentages of butterfat and total solids of eighteen samples of ice-cream submitted in the ice-cream classes at the Dairy Convention at Edmonton, Alta., in 1927 are reported by Kelso (10). These exhibition samples had an average fat content of 13·66 per cent with a maximum of 15·25 per cent and minimum of 12·4 per cent. The average percentage of total solids was 36·46 per cent with a maximum of 39·21 per cent and a minimum of 33·47 per cent.

Although these samples were made for exhibition purposes, they should represent fairly well the composition of our best commercial ice-cream as the legal standard calls for 10 per cent fat as a minimum and the maximum percentage of fat allowed according to the exhibition regulations was 14 per cent.

Combs (11) reported the results of a survey taken among representative plants in the United States. The average composition of the mix used in thirty-one of these factories is as follows:—

Butterfat	11·52	per cent
Milk solids not fat	10·52	"
Sugar	13·95	"
Gelatin	0·45	"
Total solids	36·46	"

The percentage of fat in the mixes varied from 8·5 to 14·2 per cent, while the milk solids not fat varied from 6·67 per cent to 13 per cent.

Bendixen (12), in an address to ice-cream men in Western Canada, suggested several combinations of the principal ingredients that would give a satisfactory composition for commercial ice-cream. A few of the suggested combinations are given in the following table:—

Per cent fat	Per cent milk solids not fat	Per cent sugar	Per cent total solids
10—15·5	9·0	13—15	33—40
10—14·0	9·5	12—16	32—40
10	10·5	12—16	33—37
12	10·5	12—14	35—37
14	10·5	12—15	37—40

It is assumed that 0·5 per cent gelatin is used with all the combinations.

Any of the above combinations of ingredients, when properly handled, should produce a commercial ice-cream of good body and smooth texture, which would be free from the defect of sandiness and would conform to the Canadian standard for butterfat. There are many combinations of the above figures that might be used, but the proportioning of a mix that will best meet his needs is a problem for each individual ice-cream maker to decide.

The composition of the mix having been decided and the materials selected, the next step is to proportion the materials so that the assembled mix will contain the different ingredients according to the standard decided upon.

Standardizing the Ice-cream Mix

An important factor in the production of good commercial ice-cream is uniformity of product. It is important, therefore, that the ice-cream mix should be standardized to the same composition as regards butterfat, milk solids not fat, sugar and gelatin from day to day so that the resulting ice-cream will be uniform in quality.

To obtain uniformity in the composition of the mix, it is essential to know the composition of the various milk products and other ingredients used. The small plant generally does not have the necessary equipment to make an analysis of each product, and the maker will have to depend on the analysis given by the manufacturer. Milk products vary considerably in composition, and the composition of each new supply should be obtained.

The following table compiled from various sources gives the approximate composition of different milk products used in compounding an ice-cream mix. These figures may be used when the exact composition of a dairy product is unknown:—

Approximate Composition of Various Milk Products and Other Ingredients Used in Ice Cream

Product	Per cent fat	Per cent M.S.N.F.	Per cent sugar	Per cent total solids
Skim-milk		9·0		9·0
Whole milk	3·0	8·73		11·73
"	3·5	8·68		12·18
"	4·0	8·64		12·64
Cream	20·0	7·13		27·13
"	30·0	6·24		36·24
"	40·0	5·35		45·35
Evaporated whole milk	8·0	20·0		28·0
Sweetened condensed whole milk	8·0	20·0	41·0	69·0
Condensed skim-milk (sweetened)		28·0	41·0	69·0
Condensed skim-milk (unsweetened)		30·0		30·0
Skim-milk powder	1·0	96·0		97·0
Whole milk powder	26·5	72·0		98·50
Butter (unsalted)	84·0	1·0		85·0
Granulated sugar			100·0	100·0
Gelatin				90·0

However, proportioning an ice-cream mix is just a matter of standardizing the various dairy products used, and every ice-cream maker should thoroughly understand such a procedure.

Acidity is another factor that is receiving attention at the present time in standardizing the ice-cream mix. Some manufacturers are now making a practice of reducing the acidity of the mix to a uniform standard. When the acidity is only slightly high, such a practice may be justified in order to produce uniform quality. Under no circumstances, however, should such a procedure be used to try and cover up flavour defects from very sour or poor-quality products.

The normal acidity of the mix will depend on the acidity of the products used and also on the composition. The use of fresh dairy products of low acidity will produce a mix of lower acid than when the products have a high initial acidity. Also, a mix containing a high percentage of serum solids will have a higher acidity than a mix with a low serum solids content. Dahle (13) found that the acidities for three mixes made from the same materials and with the same fat, sugar and gelatin content, were 0·17, 0·20, and 0·23 per cent when the serum solids content was 8, 10, and 12 per cent respectively.

It has also been demonstrated that the acidity of the mix affects the processes of pasteurization and homogenization. When the mix has a high acidity, it tends to coagulate during pasteurization, and homogenization of a high acid mix will give a much greater viscosity than with a low acid mix.

The acidity of the mix should never be reduced excessively, and should be done with the greatest care or bitter and soapy flavours may develop in the finished product. The ice-cream maker should thoroughly understand the operation of the acid test, which is given on page 27 of this bulletin, and should also know the amounts of the different alkalis required to neutralize one pound of lactic acid. This information is given fully by W. F. Jones in Pamphlet No. 52, Dairy and Cold Storage Branch, Ottawa, on the neutralization of cream for buttermaking.

Calculating the Ice-cream Mix

A few examples of ice-cream mixes are given to illustrate the different materials that are used and how to proportion them to get a mix of a desired composition.

Example I.—A mix of 100 pounds is desired using only cream containing 18 per cent butterfat, sugar and gelatin. The mix is to contain 14 per cent sugar and 0·5 per cent gelatin. The first step is to calculate the number of pounds of sugar and gelatin to be used.

Sugar—14 per cent of 100 pounds = 14 pounds.
Gelatin—0·5 per cent of 100 pounds = 0·5 pound.

As the remainder of the mix is made up of cream, the number of pounds required for 100 pounds of mix is 100 — 14·5 = 85·5 pounds.

If this mix is tabulated, the amount of the various ingredients can be calculated, as the cream contains 18 per cent fat and approximately 7·38 per cent milk solids not fat.

—	Butterfat	Milk solids not fat	Sugar	Gelatin
85·5 lbs. cream	15·39	6·3	....	....
14·0 lbs. sugar	....	....	14·0	....
0·5 lbs. gelatin	....	....	....	0·5
100·0 lbs. mix	15·39	6·3	14·0	0·5

Note.—A simple method of calculating the approximate percentage of milk solids not fat in cream is to find the pounds of milk serum in the cream by subtracting the pounds of fat from the total pounds and multiplying by 9 and dividing by 100, or multiplying the per cent of milk serum by 0·09, as milk serum contains approximately 9 per cent of milk solids not fat.

For example: cream tests 20 per cent fat. This will leave 80 pounds of milk serum in every 100 pounds cream or there will be 80 per cent milk serum. This 80 pounds of the cream contains 9 per cent of milk solids not fat; therefore, 100 pounds cream contains

$$\frac{80 \times 9}{100} = \frac{720}{100} = 7{\cdot}2 \text{ pounds or per cent of milk solids not fat.}$$

It will be noticed that this mix is comparatively high in butterfat and low in milk solids not fat. Such a mix will tend to be rather light and fluffy in texture if sufficient overrun is obtained, and would not be considered as an ideal mix for commercial purposes.

Example II. In this mix of 100 pounds the following materials are used: cream, 20 per cent fat; sweetened condensed skim-milk containing 28 per cent milk solids not fat and 40 per cent sugar; sugar; and gelatin.

The composition of the mix is to be as follows:—

15 per cent butterfat.
9 per cent milk solids not fat.
14 per cent sugar.
0·5 per cent gelatin.

The first step is to calculate the number of pounds of each ingredient that the mix requires:—

Butterfat..	15	per cent	of 100	pounds	= 15	pounds
Milk solids not fat..	9	"	" 100	"	= 9	"
Sugar..	14	"	" 100	"	= 14	"
Gelatin..	0·5	"	" 100	"	=0·5	pound

In this mix all the butterfat is supplied by the cream, so the number of pounds of cream to use is found by dividing the pounds of fat required, which is 15, by the per cent of fat in the cream and multiplying by 100.

$$\frac{15}{20} \times 100 = 75 \text{ pounds cream.}$$

As the milk serum in the cream contains approximately 9 per cent milk solids not fat, the amount of this ingredient supplied by the cream is found by subtracting the pounds of fat (15) from the pounds of cream (75) and considering the remainder as milk serum.

75 – 15 = 60 pounds milk serum.
9 per cent of 60 = 5·4 pounds milk solids not fat.

The cream supplies 5·4 pounds of milk solids not fat but the mix requires 9 pounds of milk solids not fat, which leaves 9 – 5·4 = 3·6 pounds of this ingredient to be supplied by the sweetened condensed skim-milk.

The condensed skim-milk contains 28 per cent milk solids not fat, so the pounds of sweetened condensed skim-milk required is

$$\frac{3 \cdot 6}{28} \times 100 = 12 \cdot 85 \text{ pounds of sweetened condensed skim-milk.}$$

This milk product also contains 40 per cent sugar and will therefore supply 40 per cent of 12·85 pounds = 5.14 pounds sugar.

As the mix requires 14 pounds of sugar, the amount of this material to add is found by subtracting the amount of sugar supplied by the sweetened condensed skim-milk from the total pounds required which is

14 – 5.14 = 8.86 pounds sugar.

The amount of gelatin required has already been calculated and is 0·5 pounds.

If the mix is tabulated it will show as follows:—

—	Butterfat	Milk solids not fat	Sugar	Gelatin
75·0 lbs. of cream	15·0	5·4		
12·85 lbs. sweetened condensed skim-milk		3·6	5·14	
8·86 lbs. sugar			8·86	
0·50 lbs. gelatin				0·5
2·79 lbs. water				
100·0 lbs. mix	15·0	9·0	14·0	0·5

It will be seen from the above table that it was necessary to add 2·79 pounds of water to make up this mix to the required amount of 100 pounds.

Example III. A mix of 100 pounds is required from the following materials: cream, 40 per cent butterfat; skim-milk; unsweetened condensed skim-milk containing 30 per cent milk solids not fat; sugar; and gelatin.

The desired composition of the mix is as follows:—

Butterfat	14	per cent.
Milk solids not fat	10	"
Sugar	14	"
Gelatin	0·5	"

The amounts of the different ingredients are next calculated as follows:—

14 per cent of 100 pounds = 14 pounds butterfat.
10 " " 100 " = 10 " milk solids not fat.
14 " " 100 " = 14 " sugar.
0·5 " " 100 " = 0·5 pound gelatin.

In this mix all the sugar is added as cane sugar and the amount required has been found to be 14 pounds. The amount of gelatin has been calculated as 0·5 pounds. As all the butterfat is supplied by the cream, it will be necessary to add enough to supply the 14 pounds of fat required which is

$$\frac{14}{40} \text{ x } 100 = 35 \text{ pounds cream.}$$

The cream will also supply some milk solids not fat. This is found by finding the pounds of milk serum and taking 9 per cent of that amount.

35 – 14 = 21 pounds milk serum.
9 per cent of 21 = 1·89 pounds of milk solids not fat.

It is necessary next to find the amount of skim-milk and unsweetened condensed skim-milk required to supply the remainder of the milk solids not fat. The milk solids not fat required are 10 pounds, while the cream supplies 1·89 pounds, which leaves 10 – 1·89 = 8·11 pounds of milk solids not fat to be supplied by the other milk products.

The total amount of materials for the mix so far is 14 pounds sugar, 0·5 pounds gelatin and 35 pounds cream = 49.5 pounds. Therefore there are still 100 – 49·5 = 50.5 pounds of the mix to be supplied by the skim-milk and the unsweetened condensed skim-milk. These materials must also supply 8·11 pounds of milk solids not fat. This is equivalent to a milk solids not fat percentage in the standardized product of

$$\frac{8 \cdot 11}{50 \cdot 5} \text{ x } 100 = 16 \cdot 06 \text{ per milk solids not fat.}$$

To standardize a mixture of skim-milk with 9 per cent milk solids not fat and condensed skim-milk with 30 per cent milk solids not fat, Pearson's formula is used as given below:—

Unsweetened condensed skim-milk	30 per cent		7·06 parts of condensed skim-milk
		16·06 per cent	
Skim-milk	9 per cent		13·94 parts of skim-milk
			21·0

To standardize milk products by means of Pearson's formula, draw a rectangle and in the case of this illustration, place in the upper left-hand corner the per cent milk solids not fat in the unsweetened condensed skim-milk, and in the lower left-hand corner the per cent milk solids not fat in the skim-milk. In the centre place the per cent of milk solids not fat desired. Then subtract diagonally the smaller numbers from the larger one and place the figures at the right-hand corners of the rectangle. These figures are the proportions of the different materials to use.

In the mix under consideration, the unsweetened condensed skim-milk and the skim-milk will have to supply 50·5 pounds, therefore there will be

$$\frac{7 \cdot 06}{21} \text{ of } 50.5 = 16.98 \text{ pounds unsweetened condensed skim-milk.}$$

$$\frac{13 \cdot 94}{21} \text{ of } 50 \cdot 5 = 33 \cdot 52 \text{ pounds skim-milk.}$$

The unsweetened condensed skim-milk contains 30 per cent milk solids not fat and will therefore supply 30 per cent of 16·98 = 5·09 pounds milk solids not fat. The skim-milk will supply 9 per cent of 33·52 = 3·02 pounds milk solids not fat.

Tabulating the mix we have the following:—

—	Butterfat	M.S.N.F.	Sugar	Gelatin
35·0 lbs. cream, 40 per cent fat	14·0	1·89		
16·98 lbs. unsweetened condensed skim-milk		5·09		
33·52 lbs. skim-milk		3·02		
14·0 lbs. sugar			14·0	
0·5 lbs. gelatin				0·5
100·00 lbs. total mix	14·0	10·0	14·0	0·5

Example IV.—A mix of 100 pounds is required to be made up from the following materials: cream containing 30 per cent butterfat; whole milk containing 3·5 per cent fat; dry skim-milk containing 96 per cent milk solids not fat; sugar and gelatin.

The mix is to have a composition of

12 per cent butterfat.
10 per cent milk solids not fat.
15 per cent sugar.
0·5 per cent gelatin.

Calculate first the pounds of butterfat, milk solids not fat, sugar and gelatin required.

12 per cent of 100 pounds = 12 pounds butterfat.
10 per cent of 100 pounds = 10 pounds milk solids not fat.
15 per cent of 100 pounds = 15 pounds sugar.
0·5 per cent of 100 pounds = 0·5 pound gelatin.

In this mix no sugar is added in the milk products, so the amount of cane sugar has already been determined and is 15 pounds. The gelatin has also been determined and is 0·5 pound. The amount of cream and whole milk to use is not calculated until the amount of dry skim-milk is determined.

It is estimated that approximately half the milk solids not fat should be supplied by the dry skim-milk. As we require 10 pounds milk solids not fat, 5 pounds will be supplied by the dry skim-milk which contains 96 per cent milk solids not fat. Therefore the pounds of dry skim-milk used will be

$$\frac{5}{96} \times 100 = 5{\cdot}2 \text{ pounds dry skim milk.}$$

In order to find out if this is the proper amount of dry skim-milk to use, determine the number of pounds of cream and milk necessary to add, which is 100 — 20·7 (the mix already supplied) = 79·3 pounds.

The milk and cream supply 12 pounds butterfat, so that there will be 79·3 — 12 = 67·3 pounds milk serum added also.

The milk serum has about 9 per cent milk solids not fat, so it will add to the mix 9 per cent of 67·3 = 6·05 pounds milk solids not fat. This amount added to the milk solids not fat supplied by the dry skim-milk (5·0 pounds) makes a total of 11·05 pounds of milk solids not fat, which is 1·05 pounds more than required. It will therefore be necessary to reduce the quantity of dry skim-milk added by 1/96 x 100 = 1·04 pounds.

This leaves 5·2 — 1·04 = 4·16 pounds of dry skim-milk to be added. As the extra milk and cream will contain some milk solids not fat, the amount of dry skim-milk should be reduced slightly more, say to the even 4 pounds.

This amount (4 pounds) of dry skim-milk will supply 96 per cent of 4 pounds = 3·84 pounds milk solids not fat.

The total amount of the mix is now 4 pounds dry skim-milk + 15 pounds sugar + 0·5 pound gelatin = 19·5 pounds, which leaves 100 — 19·5 = 80·5 pounds of the mix to be supplied by means of milk and cream.

The amount of milk solids not fat supplied by these two products is now determined as previously.

80·5 pounds cream and milk — 12 pounds fat = 68·5 pounds milk serum.

9 per cent of 68·5 pounds = 6·16 pounds milk solids not fat.

The milk solids not fat of the cream and milk (6·16 pounds) added to that of the dry skim-milk (3·84 pounds) makes just the 10 pounds required in the mix.

The next step is to find the proper proportions of cream and milk to supply the 12 pounds of fat that are required. We know that the total amount of the two products is 80·5 pounds which must contain 12 pounds fat, so the milk and cream must be standardized to a test of

$$\frac{12}{80 \cdot 5} \times 100 = 14 \cdot 9 \text{ per cent butterfat.}$$

Using Pearson's formula again we have

Cream 30 per cent		11·4 parts of cream
	14·9 per cent	
milk 3·5 per cent		15·1 parts of milk
		26·5

Therefore the pounds of milk and cream to add will be as follows:—

$$\frac{11 \cdot 4}{26 \cdot 5} \text{ of } 80 \cdot 5 = 34 \cdot 64 \text{ pounds of milk.}$$

$$\frac{15 \cdot 1}{26 \cdot 5} \text{ of } 80 \cdot 5 = 45 \cdot 87 \text{ pounds of cream.}$$

34·63 pounds of 30 per cent cream supplies 10·39 pounds of fat.
45·87 pounds of 3·5 per cent milk supplies 1·61 pounds of fat.

This makes a total of the 12 pounds fat required. If the mix is tabulated we have the following:—

—	Butterfat	M.S.N.F.	Sugar	Gelatin
34·63 lbs. cream 30 per cent fat	10·9	6·16	....	....
45·87 lbs. milk 3·5 per cent fat	1·61			
4·0 lbs. dry skim-milk	....	3·84	....	....
15·0 lbs. sugar	....	....	15·0	....
0·5 lbs. gelatin	....	....	....	0·5
100·00 lbs. mix	12·0	10·0	15·0	0·5

The above example is probably as difficult a problem in the standardizing of a mix as would be found in commercial ice-cream making, as the mix carries two products containing butterfat and three products supplying some of the milk solids not fat.

Example V. A mix of 100 pounds is required and is to be made from unsalted butter containing 84 per cent butterfat; dry skim-milk containing 96 per cent milk solids not fat; sugar; gelatin and water.

The composition of the mix is to be as follows:

Butterfat..	12 per cent.
Milk solids not fat..	10 "
Sugar..	15 "
Gelatin..	0·5 "

As in the previous examples, the first step is to calculate the number of pounds of each ingredient that is necessary for a mix of this composition.

12 per cent of 100=12 pounds butterfat.
10 " " 100=10 " milk solids not fat.
15 " " 100=15 " sugar.
0·5 " " 100=0·5 pound gelatin.

The amounts of sugar and gelatin have already been calculated and are 15 pounds and 0·5 pound respectively, and constitute 15·5 pounds of the total mix.

The butter used, containing 84 per cent fat, supplies all the fat in the mix so the amount of this product to use is found

$$\frac{100}{84} \times 12 = 14{\cdot}28 \text{ lbs. butter.}$$

The dry skim-milk contains 96 per cent milk solids not fat and supplies all of the 10 pounds of this ingredient to the mix as the milk solids not fat in the butter are negligible.

$$\frac{100}{96} \times 10 = 10{\cdot}42 \text{ pounds dry skim-milk.}$$

The total number of pounds in the mix is now as follows:

Butter..	14·28 pounds.
Dry skim-milk..	10.42 "
Sugar..	15.00 "
Gelatin..	0·50 pound.
Total..	40·20 pounds.

The remainder of the mix is made up by the addition of water which is 100 – 40·2=59·8 pounds.

The tabulated mix is as follows:—

——	Butterfat	M.S.N.F.	Sugar	Gelatin
14·28 lbs. butter 84 per cent fat	12·0			
10·42 lbs. dry skim-milk		10·0		
15·0 lbs. sugar			15·0	
0·5 lbs. gelatin				0·5
59·8 lbs. water				
100·0 lbs. mix	12·0	10·0	15·0	0·5

The above is not an ideal mix but it is given to illustrate how such materials may be used when the supply of fresh sweet cream is not adequate for the production of an ice-cream plant. Such a mix could only be made by the use of an homogenizer or viscolizer to reconstitute the milk products into cream.

The examples of mixes as given might not be satisfactory to many ice-cream men, and are only intended to show how a mix is calculated when using the different milk products that are commonly utilized in the commercial manufacture of ice-cream. If these examples are studied and thoroughly understood, it will not be difficult for any maker to calculate a mix of any desired composition from any of the milk products used. The mixes calculated above only show the ingredients in the basic mix to which flavouring materials must be added.

Processing the Ice-Cream Mix

By the term processing is meant the different operations such as mixing the different materials, pasteurizing, homogenizing, cooling, aging, freezing and hardening of the mix, which are used in the manufacture of ice-cream. The first step in the processing is the mixing together of the various materials. There are many variations possible in the details of preparing a mix, which will give equally good results. This operation is carried out in a coil vat or mixing vat equipped with mechanical agitators, in which the mix is also pasteurized.

The common procedure is to add first the fluid milk products to the vat, then the dry milk products, if any are used, and lastly, the sugar and gelatin or other stabilizers and fillers. Colouring materials and flavours are added just before the mix is run into the freezers or sometimes after the batch is in the freezers. When crushed fresh fruits, nuts or other like materials are used for flavouring, these are added after the ice-cream is partially frozen in the freezer.

Some ice-cream men prefer to mix the dry milk products with two or three times their weight of fluid milk and heat to a temperature of 150° F. or over, before adding the balance of the materials. The whole is then pasteurized. Another method is to mix the milk powder with the sugar and add the two together to the fluid standardized cream. The main factor in the preparation of the mix is to see that all materials are thoroughly mixed and dissolved before pasteurization.

The method of adding the gelatin will depend largely on the form in which it is used. If it is in shreds or sheets it will be necessary to first dissolve it in water and heat it to a temperature of about 160° F. If gelatin is treated in this way it is made up in a 10 per cent solution of water and added just before pasteurization. If gelatin is used in the powdered form it may be thoroughly mixed with the sugar first, and added to the mixing vat in this way. Probably the simplest way to add the gelatin is to sprinkle it evenly over the cold mix and allow it to soak for a few minutes before pasteurization is commenced. Either of these methods of adding gelatin gives satisfactory results.

To obtain uniform results in the standardization of the mix, it is very essential that all ingredients be carefully weighed according to the amount of the mix to be prepared. There should be no guesswork as to the amounts of the different materials used, both for the sake of quality and uniformity of product and economy.

PASTEURIZATION

As in other branches of the dairy industry, pasteurization is one of the most important operations in the manufacture of ice-cream. It protects the consumer by destroying any pathogenic bacteria that may have found their way into the raw materials, and improves the keeping quality of the mix and ice-cream by destroying the greater percentage of the total bacteria present. Pasteurization also puts the mix in the best possible physical condition for homogenization or viscolizing.

The temperature for pasteurizing the ice-cream mix should not be less than 145° F. for thirty minutes, or the equivalent. It is necessary also to obtain a thorough heating of every part of the mix for the full thirty minutes with this temperature, or pasteurization may be ineffective so far as destroying possible pathogenic contamination. The ice-cream mix contains such a high percentage of total solids that it is more difficult to obtain thorough pasteurization than with milk. Some manufacturers therefore think it expedient to use a temperature of

150° F. for thirty minutes to insure a margin of safety. Still higher temperatures for shorter holding periods may be used, but when the gelatin is added to the mix before pasteurization, temperatures over 160° F. are not advisable as the gelatin loses some of its jellying powers under these conditions.

The chief purpose of pasteurization, which is the production of a safe and healthful article of food, should be borne in mind, and temperatures and holding periods used that will insure such a product.

HOMOGENIZATION

Homogenization is carried out immediately after pasteurization, although in some plants the mix is cooled to about 110° F. before homogenizing. As the name suggests, the purpose of this process is to produce an homogeneous mix in which all ingredients are finely divided and thoroughly distributed. There are different types of machines on the market for this purpose called homogenizers, viscolizers, or emulsifiers. Although these machines are of somewhat different mechanical construction, they produce practically the same effect on the mix. The mix is forced through a very small valve under high pressure by means of cylinder pumps, which breaks up the fat globules into smaller ones and distributes them evenly through the whole mix, and thereby increases viscosity. The other ingredients also are finely divided and distributed, making a smoother mix which is more easily controlled in the freezing process.

The pressure used by various operators and with various machines varies between 1,500 and 4,000 pounds, with a pressure of about 2,500 pounds most generally employed under average conditions. The pressure used, however, depends on the acidity, composition, and temperature of the mix and the amount of viscosity desired.

A high acidity gives a greater viscosity to the mix under the same homogenization pressure than a low acidity. Homogenization at a low temperature (110° F.) gives greater viscosity than when the mix is treated at pasteurization temperatures. A high serum solids content in the mix and high pressures also increase viscosity. These factors must be taken into consideration in determining the pressures to use in the homogenizing process.

The chief advantages of homogenization may be listed as follows:—

(1) It increases the viscosity of the mix.
(2) It gives greater uniformity of texture and body to the ice-cream.
(3) It increases palatability and apparent richness.
(4) It makes it possible to attain more uniform overrun and to retain it in the frozen ice-cream.
(5) It lessens the danger of churning during freezing.
(6) It makes possible the use of butter and powdered milk products to reconstitute cream when there is a shortage of sweet cream.

COOLING

From the homogenizer the mix is immediately cooled to a temperature of 40° F. or lower. This is generally done over an open tubular cooler by the use of water in the top section and brine in the bottom section. In a small plant where there is no homogenizer, the mix may be cooled in the same vat in which it is mixed and pasteurized.

The cooler should have sufficient capacity to thoroughly cool all the mix as it leaves the homogenizer to at least 40° F. The open cooler should be placed in a clean, dust-free room or serious recontamination of the mix may occur.

AGING THE MIX

The ice-cream mix after cooling is put into storage tanks, or in the case of small plants, into clean cans where it is aged or ripened for twenty-four hours or longer to allow the mix to regain the viscosity lost during pasteurization. The viscosity is increased with the length of time aged and the decrease in temperature. The best temperature for aging is about 32° F. This temperature will effectively retard bacterial growth and any increase in acidity, which may be harmful to the flavour of the finished ice-cream.

The mix should be allowed to age for about twenty-four hours, but in the rush season this may not always be possible, in which case an improver or ripener may be added to assist in producing the required viscosity before freezing. Longer aging periods are not always beneficial as there is a possibility of bacterial increase unless temperatures are carefully controlled.

During aging, the mix should not be handled or agitated any more than necessary as agitation in the mix destroys viscosity.

FREEZING

One of the most important steps in the manufacture of ice-cream is the freezing process. This is purely a mechanical operation, but the ice-cream maker should thoroughly understand what takes place during freezing if the best results are to be obtained in quality and quantity in the finished ice-cream. Freezing is also an important operation from an economic standpoint, as careless work may reduce overrun to such an extent that serious loss in output may result. Furthermore, a thorough knowledge of the mix and freezing process may reduce the time necessary to freeze each batch by several minutes, which would naturally increase the capacity of the plant.

The purpose of freezing is to change the physical condition of the mix so that it is palatable when frozen. The finished product should have smooth texture, good body and a moderate amount of swell or overrun. This is accomplished by cooling the mix to the freezing point, which is usually about 28° to 26° F., depending on the composition of the mix, and at the same time whipping air into it by means of the dashers in the freezer. After the mix reaches the freezing point, the temperature remains stationary for several minutes while the latent heat is being extracted from the mix. During this time air is being whipped into the viscous mix which produces the swell or overrun and gives a smooth texture to the ice-cream. In most plants the practice is to shut off the brine when the mix reached the freezing point, and then whip sufficient air into the semi-frozen mix to procure the desired amount of overrun.

The ice-cream is drawn from the freezer at a temperature of 27° or 26° F. while it is still in a plastic condition and when the overrun has reached sufficient proportions to give smooth texture and good body.

Many investigations on freezing ice-cream have shown the following factors to be most important:—

1. The composition of the mix.
2. The temperature of the mix as it enters the freezer.
3. The temperature of the brine.
4. The volume or rate of flow of the brine.
5. The speed of the dashers.
6. The method of processing the mix.
7. The fulness of the freezer.

The composition of the mix influences the freezing point which in turn affects the rate and time of freezing. A high fat content in the mix tends to raise the freezing point while sugar depresses the temperature at which ice-cream freezes. A mix with a high percentage of sugar will take longer and be more difficult to freeze and keep frozen. The man in charge of the freezer should know the composition of the mix to get the best results possible.

The temperature of the mix also influences the rate and time of freezing. If the mix has a high temperature when it enters the freezer, it requires more refrigeration to cool to the freezing point and also a much longer time. With an improperly processed mix this may result in churning which is not only detrimental to quality, but decreases the overrun considerably as viscosity is lessened to such an extent that the mix will not retain the incorporated air. A good mix may take so long to reach the freezing point, that the whipping will be prolonged and air beaten out of the mix instead of in it. This may result in large ice crystals in the ice-cream which give a coarse texture. The mix should enter the freezer at a temperature as near 32° F. as possible to give the most satisfactory results.

The temperature of the brine, the volume or rate of flow of brine through the freezer and the speed of the dashers are three factors that are very closely related in the freezing process. The speed of the dashers has been thoroughly studied by manufacturers of freezing equipment, and is so regulated that this factor need cause little worry or trouble. The temperature of the brine is important, however, and is under control of the freezer operator. Mortensen (14) found the following temperatures for brine most desirable for different mixes: 6° F. for raw cream, 8° to 10° F. for pasteurized cream, 10° F. for emulsified cream and 14° F. for homogenized cream. Dahle (15) recommends a temperature of 0° F. for the brine, while Bendixen (16) states brine temperatures of 8° to 4° F. are satisfactory. The latter authority also states that there should be a direct relation between the temperature of the brine and the speed of the dashers. The greater the speed of the dashers, the lower the temperature of the brine should be. The volume of the brine flowing through the freezer should be such that the temperature of the outgoing brine should not be more than 5° F. higher than the incoming brine.

When a brine of very low temperature is used, it should be shut off as soon as the mix in the freezer reaches the freezing point. Otherwise the mix is frozen so hard that it is difficult to incorporate air in the mix, resulting in decreased overrun and a coarse textured ice cream. A high brine temperature increases the time necessary to freeze the mix to the proper consistency, and may produce churning of the mix and a greasy ice-cream with a poorly processed mix.

The method of handling the mix influences the freezing process to some extent. Raw cream and pasteurized mixes have less viscosity than homogenized mixes and therefore, such mixes are more easily whipped and should be frozen quickly if overrun is to be retained. Unhomogenized mixes require different treatment, which each manufacturer should determine to meet his own conditions.

According to the best practices, the freezers should be filled only half full. This allows for the optimum swell of the ice-cream mix during freezing. If a freezer is rated with a 40-quart capacity, it should be filled with only 20 quarts of mix.

OVERRUN OR SWELL IN ICE-CREAM

The overrun or swell in ice-cream that occurs during the freezing process may be calculated either by volume or by weight. If the overrun is calculated on a volume basis, it is equal to the difference between the volume of the mix used and the volume of the ice-cream frozen. The formula for computing overrun on the volume basis is as follows:—

$$\frac{\text{Volume of ice-cream obtained—volume of mix}}{\text{volume of mix}} \times 100$$

There is a tendency at the present time, however, to figure the overrun on the basis of weight. The weight of finished ice-cream is much less than the same volume of mix due to the incorporation of air during the whipping.

The formula for calculating the percentage of overrun on the weight basis is as follows:—

Percentage overrun =

$$\frac{\text{The weight of unit volume of mix—the weight of unit volume of ice-cream}}{\text{The weight of unit volume of ice cream}} \times 100$$

Thus, if the weight of one gallon of mix is 10·8 pounds and the weight of one gallon of the ice-cream is 6 pounds, the percentage overrun would be equal to

$$\frac{10{\cdot}8 - 6}{6} \times 100 = 80 \text{ per cent.}$$

The amount of overrun has a marked influence on the quality of the finished ice-cream. A low overrun results in a heavy, soggy ice-cream, coarse in texture, while too great an overrun gives an ice-cream that is light and fluffy which will melt too readily and which will shrink excessively when being dipped from the can.

The proper amount of overrun is a much debated question and will depend a great deal on the composition and method of treating the mix. For example, a mix containing a high percentage of milk solids not fat will allow of greater overrun than mixes of low milk solids not fat. Generally an overrun of approximately 90 per cent will be found satisfactory. But manufacturers should decide on the overrun best suited to the composition of their mixes and other conditions, and then try to keep to the standard set.

The volume of overrun is influenced by many factors, the chief of these being:—

(1) the composition and preparation of the mix.

(2) the manner of freezing.

The composition and processing of the mix are important factors influencing volume of overrun. The percentage of fat in the mix seems to have little influence on the volume of overrun, but solids not fat tend to increase the amount of overrun that may be obtained. Sugar, however, has the opposite effect. Gelatin up to a certain amount will increase overrun because of the viscosity that it imparts to the mix.

The mix that has been aged for 24 hours or longer will give greater overrun than a fresh mix due to greater viscosity, and homogenizing or viscolizing increase overrun by increasing viscosity. In fact, any factor in the composition or method of preparing the mix that increases viscosity tends to increase the overrun that may be obtained.

As overrun is produced during the freezing process, good methods and practices in this operation are conducive to good overrun. Freezing too quickly does not allow sufficient time for proper overrun, while conditions that are responsible for a long freezing period are conducive to too much overrun, that may have to be reduced by beating out the air already incorporated. It is important that the conditions during freezing be so regulated and controlled that the proper amount of overrun is obtained at the time when the mix has been frozen sufficiently.

HARDENING THE ICE-CREAM

As the ice-cream leaves the freezer in a semi-solid condition, it must be hardened before being sold for consumption. The ice-cream is drawn from the freezer into pack cans and then placed in a hardening room cooled by mechanical refrigeration or packed in ice and salt in a hardening cabinet or box. The pack cans should be cooled before being filled with the soft ice-cream, or the warm cans melt the ice-cream that comes in contact with the cans, which produces ice crystals. In many plants the pack cans are lined with a waxed or parchment paper which protects the ice-cream from coming in contact with cans that may be the worse for wear.

Where mechanical refrigeration is used, there are two main types of hardening rooms, one known as the still air type, and the other as the forced air type. In the still air type, the room is cooled by direct expansion coils or coils containing brine, which are usually piped so that they form shelves on which the pack cans are placed. In the forced air hardening room, the ammonia coils are placed at the top of the room and the cold air forced around the cans by means of a fan or blower. The temperature of the rooms usually is kept about 0° F. and the ice-cream is hardened for 12 to 24 hours.

In smaller plants with no mechanical refrigeration, the ice-cream is hardened by means of a mixture of ice and salt in a box or cabinet built for the purpose. These cabinets are made from heavy plank and are watertight but have a hole near the bottom from which the brine may be drawn. Crushed ice to a depth of 4 or 6 inches is placed in the bottom of the tank and after the cans are placed in the tank it is filled up with ice and salt. Most of the salt should be placed in the upper third of the ice, so that it will run down over the rest of the ice as it comes into solution. The cans should be covered to a depth of 4 to 6 inches with ice and salt and left to harden. One part of salt to 15 or 20 parts of ice make a good freezing mixture. If the ice-cream is stored in the box for any length of time, it should be repacked at least twice a day to keep it thoroughly hardened.

Ice-Cream Defects

In common with other food products, all ice-cream does not come up to the ideal quality for the product. This ideal varies more than other dairy products, due to individual preferences in taste and to the many flavours used in the manufacture of ice-cream. But there are certain defects, fairly well defined, that occur in ice-cream because of inferior flavouring materials, the use of poor quality products or careless methods of manufacture.

The common defects that occur in ice-cream may be grouped as follows:—

1. Flavour defects.
2. Defects of body and texture.
3. Defects in richness.
4. Defects in colour, appearance and package.

There are several gradations of defects in flavour. The least serious are those due to the use of too much or too little sugar and too much or too little flavouring materials. These defects are due to individual tastes and can easily be controlled by the ice-cream maker who studies the preferences of his customers. More serious are the flavour defects caused by the use of poor quality ingredients or by improperly proportioning them. Such faults result from the use of old cream or butter having too much acid, too high a proportion of powdered or condensed milk products and egg powder and unnatural flavouring. The worst flavours of all are those described by the terms, salty, bitter, rancid, unclean and metallic. Such flavours are due to a very poor quality of materials, unclean, rusty equipment and carelessness during manufacture.

The common terms used to describe defects in body and texture are as follows: weak or fluffy, soggy, icy, coarse, buttery, and sandy. Such defects are due to an improperly balanced mix and poor methods of manufacture. Weak or fluffy body and texture is caused by too low a percentage of milk solids not fat, too little gelatin or other stabilizer, or by too great an overrun. Such an ice-cream melts too readily and shrinks excessively when dipped from the can. A coarse texture and body lacks smoothness to the tongue and may be due to a lack of milk solids not fat or of gelatin, or may be caused by drawing the ice-cream from the freezer when it is too soft. These conditions are conducive to the formation of large air cells during whipping which break down and form ice crystals. An icy texture and body results from the same conditions as the coarse texture and is characterized by the presence of large ice crystals that are definitely noticeable to the tongue.

Soggy ice-cream is heavy and often times sticky, and is caused by the use of too much solids not fat or total solids and by not freezing to give sufficient overrun.

Sandiness in ice-cream should not be confused with the defect caused by the formation of excessive ice crystals. Sandy ice-cream has a sort of gritty texture very noticeable to the taste, and is caused by the crystallization of the lactose or milk sugar in the ice-cream. This trouble usually develops after hardening, as milk sugar is more soluble in warm solutions than in cold. Sandiness may develop in ice-cream that has too high a content of total solids or milk solids not fat, which gives an excessive amount of milk sugar to the mix. Alternate softening and hardening will often bring on sandiness in ice-cream when there is a high proportion of total solids. The remedy is to proportion carefully the mix so that the concentration of milk sugar will not be too great. It is generally considered that 12 per cent is the maximum amount of milk solids not fat that may safely be used.

Other defects are those due to unnatural colouring in the ice-cream or poor package which detracts from the appearance of the finished product.

A Score Card for Ice-Cream

For the purpose of comparing the quality of ice-cream samples at competitions, it is necessary to have a guide, which is best supplied by a score card. There have been many suggestions put forward for an ice-cream score card, but up to the present, there is no official score card for ice-cream, as there is for butter and cheese. The main points that have been considered on ice-cream score cards used by dairy departments at various agricultural colleges and in connection with competitions are as follows: flavour, body and texture, richness, permanency, colour, package, and bacterial content.

The highest quality ice-cream should have a clean, creamy flavour, a firm, smooth and velvety body and texture, and natural colour for the flavouring material used. It should comply with the legal standards of the country in which it is sold and be put up in clean neat packages, and should have a low bacterial count.

As in the case with other dairy products, flavour is the most important quality in ice-cream. Body and texture are also important as they affect the palatability of the ice-cream and influence the amount that is obtained from a given volume when dished out to individual consumers. In some score cards, the qualities of richness and permanency or the ability of the ice-cream to withstand heat are given definite values. However, richness is controlled by legal standards and permanency is so linked up with body and texture that it is a question whether these characteristics should be considered individually. Colour and package are generally considered separately in judging ice-cream and are allotted points commensurate with their importance.

Although some score cards do not take into consideration the bacterial content of ice-cream, the more recent suggestions give this important matter a place in the score card, and rightly so. Of course the bacterial content of ice-cream cannot be detected by the human senses, but must be determined by laboratory methods. But in nearly all ice-cream competitions, this is being done and the ice-cream scored according to the laboratory records of bacterial counts.

The following score card used by H. A. Bendixen, formerly in the Dairy Department of the University of Idaho, covers these various qualities in ice-cream and seems to offer a very good guide by which ice-cream may be judged. The score card is as follows:—

Flavour	45	points
Body and texture	25	"
Colour	5	"
Package	5	"
Bacteria	20	"
Total	100	"

In this score card, a sample of ice-cream must not contain more than 50,000 bacteria per gramme to obtain a perfect score for bacteria, with a deduction of 1 point for each 25,000 bacteria per gramme above 50,000. The score card recommended by the Committee on Legal Standards and Score Cards of the American Dairy Science Association, sets a standard of 20,000 bacteria per gramme or less for full points. This question of a standard for bacteria in ice-cream is still unsettled, and should receive considerable study to determine a standard that may be reached by commercial plants which give careful attention to cleanliness of equipment, the quality of the products used, and their methods of manufacture.

The Bacterial Content of Ice-Cream

The increasing importance of ice-cream as a food product makes it almost imperative that the quality of the ingredients, methods of manufacture and the cleanliness of plant and equipment should be carefully controlled so that the bacterial count will be reduced to a minimum. Too often in the past, ice-cream has been made in dark out of the way cellars and in a manner that would not inspire the confidence of the consuming public. But such methods are quickly disappearing, and manufacturers are realizing more and more the importance of high quality ingredients and cleanliness of plant, equipment and personnel. There is just as great a necessity for controlling the manufacture of ice-cream from a sanitary standpoint, as with the production and handling of city milk supplies or other food supplies.

For this reason bacteriological examinations of ice-cream are receiving more attention as they afford the best means of indicating the quality of products, the methods of manufacture, and the cleanliness of plant and equipment. Many of the larger ice-cream plants are now carefully controlling all their operations by means of bacterial counts and find them a very important aid in the production of a high quality ice-cream.

Although there is no published data on the bacterial content of Canadian ice-cream, several studies have been made in other places. Fay (17) made a study of 115 samples of Kansas ice-cream and reported a maximum count of 47,000,000 bacteria per gramme and a minimum of 1,500 bacteria per gramme. Seventeen of the samples had a count of over 1,000,000 bacteria per gramme, while 57 samples were below 100,000. These samples were obtained from ice-cream scoring contests.

Hammer (18) reported on a number of samples from different cities during the years 1905-06 to 1911-12. The lowest average count for any one city was 1,800,000 bacteria per gramme. All other average counts were between 15,401,000 and 26,612,371 per gramme. The highest was 8,000,000,000 with a low count of 20,000.

Ayers and Johnson (19) made a study of 185 samples of retail ice-cream during the summer and winter months, the average bacterial count for the summer being 37,859,907 and for winter, 10,388,222. The maximum summer count was 510,000,000 with a minimum count of 120,000. Winter maximum and minimum counts were 114,000,000 and 13,000 respectively.

Fabien (20) reported on 1,110 samples of ice-cream collected from plants in five different cities in the State of Michigan. He found that 697 samples had a count of less than 50,000 bacteria per gramme, while the remainder ranged from 50,000 to 300,000,000 per gramme, which was the maximum count for all samples. The minimum count was 1,000 bacteria per gramme.

Such studies show that some retail ice-cream contains large numbers of bacteria, but that it is possible to produce ice-cream under commercial conditions with a very low count of bacteria.

Sources of Bacteria in Ice-Cream

Investigations (21, 22) by several authorities have shown that there are three main sources of bacteria in ice-cream, namely, from the materials used, from the equipment, and from persons handling the products during manufacture. These investigations demonstrate that the milk and cream used in the mix are the most important sources of bacteria. Other milk products such as condensed and powdered milk and butter may also be a contributing factor to high counts if they are not of good quality.

Gelatin may be a source of large numbers of bacteria, but the better grades are so carefully prepared that gelatin should not be a troublesome factor. In buying this product only the very best grades of edible gelatin should be purchased. Sugar, vanilla and other flavouring extracts are not important as a source of bacteria when they have been properly cared for in the plant.

Properly controlled pasteurization will destroy a large percentage of the bacteria when the whole mix is subjected to the process. If only the milk and cream is pasteurized, there is a danger of high counts from the other products used. However, after pasteurization the ice-cream manufacturer starts out with materials that usually have a very low count.

A high count in the finished ice-cream indicates contamination from the equipment or careless methods of processing the mix. The homogenizer, cooler, and freezer may be fertile sources of recontamination unless these pieces of equipment are kept scrupulously clean and are sterilized each day after using. During homogenization and freezing there is usually an increase in numbers of bacteria present due either to unclean conditions or probably the breaking up of clumps of bacteria during the process. But if the equipment is thoroughly sterilized, the increase will be negligible, and these operations will not be a factor in high counts.

In the manufacture of ice-cream, it is of the utmost importance that the personnel of the plant be particular regarding personal cleanliness and habits. The danger of contamination from such sources lies in the possibility of introducing into the product pathogenic bacteria after pasteurization. This is a matter that should receive the greatest attention from managers and employees at all times. The handling of the product after pasteurization and of the materials that are not pasteurized should be done with great care and precaution.

Cleaning Ice-Cream Equipment

If the ice-cream manufacturer would produce a high quality product containing a low bacterial count, the equipment in the plant must be given careful and conscientious attention at all times. This is one of the most important factors in the production of low count ice-cream for investigations have shown that pasteurization destroys nearly 99 per cent of the bacteria in the raw materials. If equipment is not thoroughly cleaned and sterilized, recontamination of the pasteurized mix is inevitable and high bacterial counts are the result.

In cleaning the ice-cream equipment, the common good practices of washing and sterilizing dairy utensils should be employed. The equipment should first be rinsed thoroughly with cold or lukewarm water. Hot water should never be used for the first rinsing because of the high content of milk solids not fat in the mix which are burnt on to the equipment when hot water is used first. After the first rinse, the machines should be washed with hot water containing a good alkali washing powder. Then, if possible, the machines should be thoroughly scrubbed with a good bristle brush to remove particles of the mix. Cloths or rags should never be used to wash dairy utensils and equipment. After scrubbing, the equipment should be given a thorough rinse with clean hot water, to remove any traces of the alkali wash water and then thoroughly sterilized.

In sterilizing dairy utensils and equipment, the best means is by the use of steam or boiling water. The efficiency of the sterilization will depend on the degree of heat imparted to the equipment and the length of time applied. Small utensils are best sterilized in a sterilizing cabinet where steam can be applied under a few pounds pressure. With mixing vats, open tubular coolers and other equipment this is not possible, but a means should be found to use steam or boiling water for such equipment.

Sanitary pipe lines should be taken apart and thoroughly washed and brushed after use and then steamed for about five minutes. The homogenizer should be taken apart and the valves and other parts thoroughly scrubbed and sterilized by means of steam. If particular care is not given this machine, it offers a very likely source of recontamination to the ice-cream mix.

The freezer will require special care in washing and sterilizing. The machine will be so cold after operation that very hot water should only be applied after several rinsings with water that has been gradually raised in temperature. Otherwise the freezers will be subjected to extreme heat and cold which is injurious to the metal of the equipment.

The pack cans should also receive careful washing and sterilization, and should always be placed in a clean, dry place after sterilization.

Carelessness in the cleaning of equipment is inexcusable in any dairy plant and especially so in connection with the manufacture of ice-cream. With good quality materials, careful pasteurization, and clean equipment, ice-cream can be produced under commercial conditions from day to day with much less than 100,000 bacteria per gramme.

Testing Methods for Ice-Cream

In order to control the composition of the ice-cream mix and to keep down the cost of manufacture, it is very necessary that the ice-cream maker should know the composition of the various ingredients which he uses as well as the final composition of the mix. He is able then to make up a mix of any desired composition, and keep it uniform from day to day. For the large commercial plant equipped with a laboratory and special apparatus, this work offers no serious difficulties. The small plant, however, cannot afford expensive equipment for testing purposes and must use other methods. But the question of checking the composition of the mix is just as important for one as for the other.

There is one piece of equipment that even the small manufacturer cannot afford to be without, and that is the Babcock tester with glassware. This piece of equipment offers the small plant a means of controlling and standardizing the butter fat content of the mix which is the most expensive ingredient. Several modifications of the Babcock test have been worked out for ice-cream, which, with careful operation, give results quite accurate enough for practical use.

The following modifications of the Babcock test have been found to give satisfactory results. The first method is one of the tests used in the Dairy Department of the Ontario Agricultural College and was published by Fisher and Walts (23).

1. Mix thoroughly the ice-cream or ice-cream mix.
2. Weigh out 9 grammes in a whole-milk test bottle.
3. Add 10 c.c. of 95 per cent ethyl alcohol and shake thoroughly.
4. Add 9 c.c. of sulphuric acid, specific gravity 1·82 to 1·83 and shake.
5. Finish the same as for whole milk.
6. Multiply reading by two.

Note.—Where ethyl alcohol cannot be obtained, rubbing alcohol has been found satisfactory.

THE SULPHURIC-ACETIC ACID MODIFICATION

1. Soften and mix sample thoroughly by pouring at least five times.
2. Weigh 9 grammes into a milk test bottle or cream test bottle.
3. Add 10 c.c. acetic acid and shake. Glacial (99·5 per cent) acetic acid is preferable.
4. Add 6 to 8 c.c. of sulphuric acid.
5. Complete test as with milk.
6. Read the test and multiply by two if milk test bottle has been used. With cream test bottle, read directly.

This test is used by the Dairy Department at the Iowa State College of Agriculture with satisfactory results.

THE O.A.C.—GIBSON METHOD

This method is recommended by Prof. A. L. Gibson of the Ontario Agricultural College, Guelph, Ont., and is used by the Dairy Department of the college.

1. Heat the sample of ice-cream in a water bath to about 122° F. and mix thoroughly.
2. Weigh out 9 grammes in milk test bottle by means of a pipette.
3. Add 9 c.c. water and 1 c.c. amyl alcohol or 2 c.c. normal butyl alcohol and mix thoroughly.
4. Add carefully 17·5 c.c. of sulphuric acid, specific gravity 1·78, and shake until all traces of curd have disappeared.
5. Finish the test as for milk.
6. Multiply the reading by two.

In addition to knowing the percentage of fat in the mix or finished ice-cream, it is advantageous to know also the total solids in the mix. Modified tests for this purpose have been recommended and can be made with inexpensive equipment.

The following test was elaborated and is recommended by Prof. A. L. Gibson of the Ontario Agricultural College, and is known as the O.A.C.-Gibson Method for determining total solids in ice-cream.

APPARATUS NECESSARY

1. Small electric hotplate with rheostat attachment for temperature control and furnished with mercury well.

2. Thermometer graduated to 250° C.

3. Balance, capacity 120 grammes, sensitive to ·01 grammes, with weights from 50 grammes to 1 centigramme.

4. Aluminum dish, diameter 4 inches, depth 1 inch.

5. Five-gramme pipette.

6. Steel crucible tongs for lifting dishes.

PROCEDURE.—Heat the electric plate to a temperature of 190° C. The temperature is ascertained by placing the thermometer in the mercury well. Adjust the rheostat so as to maintain as near as possible a temperature of 190° C.

Warm the sample of ice-cream in a water bath to a temperature of 70° C. and stir thoroughly before weighing. Accurately counterpoise the aluminum dish on the balance and with the 5 gramme pipette weigh out exactly 5 grammes of the sample into the dish. Add 3 c.c. of distilled water to the weighed sample and carefully mix so as to make a uniform film of liquid over the bottom of the dish. Place the dish on the electric plate at 190° C. and heat until the sample is a uniform chocolate brown colour. While the sample is being heated, adjust the rheostat so that the temperature will not fall below 180° C. during the heating process. Immediately after the heating process is completed cool the dish to room temperature under ordinary atmospheric conditions and accurately reweigh. The percentage of solids is estimated by multiplying the weight of solids left in the dish by 20.

THE ACIDITY TEST

With a 9 c.c. pipette measure out 9 c.c. of the cream or mix to be tested in a white dish or cup. Rinse out the pipette with 3 or 4 c.c. of warm distilled water and deliver it in the cup. Add 3 to 5 drops of phenolphthalein indicator. From a burette graduated in tenths of cubic centimetres, add slowly a tenth normal solution of sodium hydroxide until a permanent faint pink colour appears. Read from the burette the number of cubic centimetres of alkali used and divide by 10 to obtain the percentage of acid in the mix.

If a ninth normal solution of sodium hydroxide is used, measure out 10 c.c. of mix and titrate. Divide the result by 10 to obtain the percentage of acid.

When possible, more accurate results are obtained if the material is weighed rather than measured. Use the same number of grammes as cubic centimetres.

When larger quantities of cream or mix are used, the percentage of acid may be calculated from the following formula when n/10 alkali is used:—

$$\frac{\text{Number of c.c. of n/10 sodium hydroxide x .009}}{\text{number of c.c. or grammes of sample}} \times 100 = \%\ \text{acid.}$$

Fuller details of this test may be had from Bulletin No. 14, New Series, of the Dairy and Cold Storage Branch, Ottawa.

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