HYGIENIC ASPECTS OF THE PROCESSING OF BUTTER, CHEESE, FLAVOURED AND FERMENTED MILKS, AND ICE-CREAM

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The hygienic control of any dairy product, whether it be fluid milk or any one of the various milk products and by-products, is dependent upon the quality of the raw milk and the conditions under which this milk is produced. Therefore it should be recognized that the information presented elsewhere in this monograph is an essential part of the discussion to follow.

Since the hygienic control of milk production is discussed on page 303, and the quality control tests are reviewed in the chapter by Johns on milk control on reception (see page 223), the present discussion will be concerned only with the hygienic control problems related to the processing of various milk products and by-products.

Ideally, the starting raw milk for the production of these milk products and by-products should be of the same high quality as is required for fluid milk. It should be the goal of the industry to strive for the day when all raw milk will have the same high quality, since the higher the quality of the starting material the better the quality of the final product.

Butter

Butter consists primarily of butterfat, a small amount of milk solids and water; it may also contain added salt. The composition of commercial salted butter is about 80.5% butterfat, 16.5% water, 2.0% salt and 1.0% milk solids. In unsalted butter the amount of fat or water, or both, may be slightly higher. The requirements for a satisfactory butter are that it must (*a*) be free from disease-producing micro-organisms and toxic substances of any type, (*b*) be of high nutritive value, (*c*) be free of undesirable extraneous matter, and (*d*) have a pleasing body and flavour. Because of the solid or semi-solid nature of the product and its high fat, low moisture, and salt content, the growth of micro-organisms is somewhat restricted. How-

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ever, the delicate flavour of butter makes the product particularly susceptible to slight changes which might be caused by contaminating organisms. Therefore the hygienic control of butter-making is important in the production of a high-quality product.

Butter can be made from sweet cream, neutralized sour cream or cultured cream. Sweet cream is generally separated from fresh whole milk at the creamery and pasteurized (usually 68.3°-71.1°C (155°-160°F) for 30 minutes). The pasteurized cream is then either churned immediately to produce sweet cream butter or inoculated with special cultures. Farm-separated cream is usually sour and is shipped to a central creamery, where it is neutralized, pasteurized and finally churned. Cultured cream is pasteurized sweet cream to which special cultures are added. There are several methods for using butter cultures: (*a*) a culture is added to the pasteurized cream, which is held at 10°C (50°F) for several hours or overnight, or is ripened at 21.1°C (70°F) for several hours or overnight, and then churned; (*b*) a culture is added to the cream at the time of churning; (*c*) a culture is added at the time the butter granules are formed and is then worked into the butter.

Cream supply. As with all dairy products, the higher the quality of the cream the higher the quality of the butter. Cream separated on the farm presents additional problems in the quality control of butter. This is especially true where gravity separation is practised, as there is opportunity for contamination of the cream while it stands in shallow pans. Care must be exercised that undue contamination will not occur from dust and unclean pans and strainers. Good farm practices in the production of the milk are necessary and special attention should be given to the thorough cleaning of pails, milking machines, etc. If a cream separator is used it must also be cleaned carefully after each use and sanitized with hot water or chlorine solutions before re-use. Collecting cans for the cream should always be cleaned and sanitized. All clean utensils should be stored in a clean, dry area free from dust contamination. Since the cream usually turns sour before it is collected or delivered to the creamery there may be a tendency to use less care in the cleaning of equipment; on the contrary, however, even more care is needed in the cleaning of utensils, since the growth of undesirable organisms can still occur in the sour cream.

At the creamery, if whole milk is received and separated, the separator may become a source of contamination unless properly and thoroughly cleaned. Tanks and vats also must be cleaned and sanitized to prevent contamination of the cream. The cream should have a clean odour and flavour. Putrid, bitter or stale odours or flavours indicate poor-quality cream. Sediment tests are frequently made on cream, but these indicate only the care with which the farmer has handled the milk or cream. A clean sediment pad does not necessarily indicate the quality of the cream from the stand-

point of microbial growth and decomposition, and therefore the test is regarded as of only limited value. Tests for the detection of mould filaments can also be regarded as of only limited value, since they would only detect poor-quality cream in which extensive mould growth had occurred.

Sour cream will normally contain many bacteria, but if the sanitary conditions on the farm are satisfactory, these organisms are usually the lactic types. Commercial neutralizers do not contain appreciable numbers of organisms and are not considered a source of contamination of the cream. However, a good potable water supply should be used in the preparation of the neutralizing solutions.

Cultures. When starter cultures are used in culturing cream the precautions and care of utensils and equipment that have been discussed in the section on cultures for fermented milks (see page 416-417) must be followed.

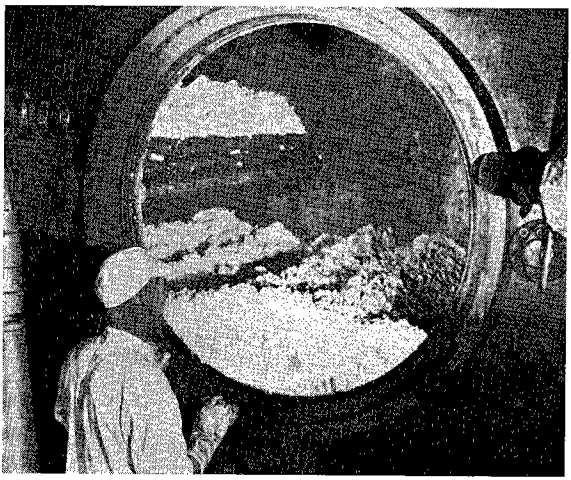
Processing. Various types of churning equipment are available for the production of butter. In many areas wooden churns are in use, and these require special attention to ensure that they will not become a source of contamination during the churning operation. Cracks and crevices may occur, offering excellent opportunities for accumulation of organic matter and subsequent growth of micro-organisms. After churning, the churn should be rinsed by revolving it for about 10 minutes when one-third full of water at 43.3°C (110°F), drained, and then washed with 60°C (140°F) water, containing a washing compound and sequestering agent, by rotating for 15 to 20 minutes. After draining, water at 87.8°C (190°F) is added and the churn is rotated for 15 minutes as a second rinse and then drained thoroughly. The churn is left standing with the opened doors at the top and the opening covered with a screen. Just prior to re-use the churn should be sanitized with a 200 parts per million (p.p.m.) chlorine solution.

Metal churns are easier to clean and sanitize. In plants where continuous butter-making procedures are in use, the usual care in cleaning and sanitizing of all equipment is necessary to prevent contamination of the cream during the churning step.

In the churning operation, the water supply used for washing the butter granules may be an important source of contaminating organisms. Therefore the water supply should be checked to determine its potability and whether or not psychrophilic bacteria are present. It is these psychrophilic bacteria of water origin which can cause the development of putrid and off-flavours in the butter on storage. Water containing these organisms should not be used.

Throughout the butter-making operation, and particularly during working and packaging, care should be taken to avoid contamination of the butter with the hands (see Fig. 1). In these operations, although the actual numbers of organisms may be low, the types may be those which later can

FIG. 1
HYGIENIC BUTTER-MAKING



Note use of rubber gloves.

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FIG. 2
HYGIENIC BUTTER-PACKING

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cause the development of off-odours and flavours. Butter should be packaged in clean sanitary containers which can be properly closed to avoid any possible contamination of the finished product (see Fig. 2).

Bacteriological tests. Since considerable time is usually required in the commercial marketing of butter, a long shelf-life is desired for the product. Routine bacteriological tests do not always indicate the keeping quality of butter. Certain tests are of value for determining the quality of the butter immediately after manufacture. Yeast and mould counts should usually be below 10 per gram and indicate the attention being given to proper sanitation of equipment during manufacture. Coliform tests have been reported as being of some value in the case of butter, the presence of coliform bacteria being indicative of post-pasteurization contamination. Specific tests for proteolytic and lipolytic bacteria, using special media, indicate whether or not these organisms are present in sufficient numbers to cause spoilage.

A satisfactory keeping-quality test which can be used to predict the shelf-life of the product has long been sought by the dairy industry. The present-day tests (Naylor & Guthrie, 1940) are fair but not completely satisfactory. These tests consist in placing samples of butter in glass jars, incubating them at 37°C (98°F) for 48 hours and for 7 days at 21.1°C (70°F), and then observing them for odour, flavour and body characteristics. From these observations some attempt is made to predict the shelf-life of the butter.

Butter made from properly pasteurized cream will not contain any pathogenic bacteria. However, it has been demonstrated that pathogens can survive in butter (Wilson & Tanner, 1945) and therefore all precautions should be taken to prevent contamination of the butter after the cream has been pasteurized and during manufacture. Butter should not be manufactured from raw cream or, if it is, it should be used only for cooking where it will receive adequate heat treatment. This situation emphasizes again the importance of proper pasteurization of the cream and the use of sanitary procedures throughout the manufacturing process.

Cheese

In general terms cheese is the consolidated curd of milk used as food. There are more than 400 varieties of cheese, representing about 19 general types known throughout the world. Most of these types can be made from the same batch of milk merely by variations in the added micro-organisms, enzymes and salt and by changes in the temperature during manufacture and curing. Natural cheeses can be classified into two main groups: (*a*) the unripened soft cheeses with either a low or a high fat content and a high moisture content; and (*b*) the ripened cheeses with varying moisture contents (hard grating cheeses such as Romano, hard cheeses such as Cheddar, semi-soft such as Roquefort, or soft such as Camembert).

It is neither necessary nor possible in a discussion on the hygienic control of cheese-making to describe the details of manufacture of the various types of cheese. Fortunately the hygienic control of one process is applicable to all.

Milk supply. Cheeses are usually made from cow's milk, either whole or skimmed, although in some areas of the world milk from other mammals is used. The milk must be from healthy animals and of good bacteriological quality. Frequently quality-control tests such as the methylene blue or resazurin reduction tests are used. Some areas also employ a fermentation test (Markin & Gumpertz, 1959) to determine the ability of the milk to produce or support the desired fermentation and also to detect the presence of organisms which might result in an undesirable curd. The milk must be free from inhibitory substances, whether natural to the milk, caused by the growth of antibiotic-producing bacteria, or due to antibiotic residues from the treatment of mastitis.

Recently, attention has been focused on the presence of toxin-producing strains of staphylococci in milk for cheese-making. It has been found that these organisms, if provided with the opportunity to grow in the milk and produce toxin, may give difficulty in the final cheese. Therefore control of conditions on the farm should be such that these organisms are not present in the milk or, if present, are there in very low numbers (see chapter by Kaplan, et al. page 11).

Processing. After the milk has been received in the plant it should be promptly cooled or immediately processed. If the cheese to be made requires the normal complement of milk fat, the milk is clarified; if skim-milk is needed, it is separated; and in some plants, it is standardized to a constant fat level. The heat treatment given to the milk varies. Pasteurization of all milk is desirable from the standpoint of the destruction of disease-producing organisms. But while nearly all types of cheese can be made successfully from pasteurized milk, the ripening process occurs much more slowly and, according to some experts, the cheese never reaches the same sharpness and flavour that develops in a raw-milk cheese. Partial heat treatment sufficiently severe to destroy the staphylococci has been recommended in some areas. If the cheese is not made from properly pasteurized milk, it must be held for 60 days before consumption. In any case, the equipment used in clarification, separation and pasteurization requires the same careful cleaning and sanitizing recommended for the equipment used in the making of other dairy products. In addition, pipelines, vats and other utensils should be thoroughly cleaned and sanitized each day.

The milk is next pumped into vats of different types, depending upon the type of cheese to be produced. The milk is heated to the desired temperature and the necessary cultures added. At one time, cheese-makers depended on the bacteria normally present in the milk to produce the necessary

FIG. 3
HYGIENIC CHEESE-MAKING

Note use of rubber gloves.

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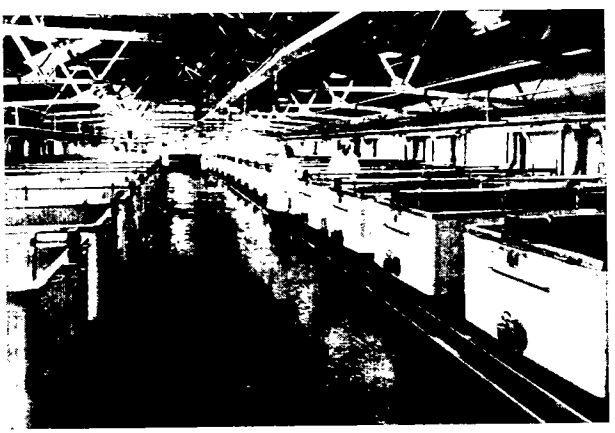
FIG. 4
CHEESE-MAKING ROOM



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acid in the cheese. Today, however, most cheese-makers rely on the action of special added cultures. The procedures for the propagation of starter cultures are discussed in the section on cultures for fermented milks (see pages 416-417), to which the reader is referred for details of hygienic control.

Good, active cultures should be used. Care must be taken to ensure that contaminants are not present in the culture and that the organisms are active and the ones needed for the type of cheese to be produced. In some cheeses rennet is also used to promote the formation of the curd. The rennet should be of high quality so that undesirable organisms are not added at the same time. Throughout the curdling step the milk should be protected from undue air contamination.

When the curd has formed to the desired firmness, it is quickly cut with curd knives into small cubes, to facilitate the draining of the whey. The operations from this point vary, depending upon the type of cheese being made. From the point of view of hygienic control, precautions must be taken to avoid every possibility for contamination (see Fig. 3, 4). Curd knives, paddles, draining cloths, presses, forms, etc. must be handled in a sanitary fashion and cleaned and sanitized after each day's use.

The unripened, soft cheeses are highly perishable and their shelf-life is limited even under the best storage conditions. Cottage cheese in particular should receive additional comment. During manufacture it is essential that the proper amount of acidity develops, because if the pH is too high spoilage organisms, which always contaminate the product to some degree, are able to grow rapidly and make the product unsaleable. The water used for washing the curd can frequently be a source of the *Pseudomonas* types which later cause spoilage. Yeast and mould contamination from the air or improperly sanitized containers may also give rise to trouble. *Pseudomonas,* yeasts and moulds are the organisms most frequently implicated in the spoilage of cottage cheese. Every effort must be made to keep contamination by these organisms at a minimum. Care in cleaning and sanitizing equipment such as vats, knives, paddles or rakes, and containers will aid greatly in the control of these organisms. In some plants it has been found that condensate from the ceiling or pipes over the vats may be a source of *Pseudomonas* types, and this condition should be avoided if possible. Spraying or fogging the area with chlorine solutions may be of value for the control of this type of contamination. Low-temperature (refrigerator) storage is essential for ensuring a maximum shelf-life; 4.4°-7.2°C (40°-45°F) has been found to be a better storage temperature than 10°C (50°F) or above.

It should be noted that the harder the cheese (i.e., the lower the moisture content) the longer the shelf-life of the product. Some of the ripened semi-soft cheeses also have a limited shelf-life. This may be due in part to the continued action of the ripening organisms, which, if allowed to act too long, may cause the cheese to become overripe. Many of the hard cheeses improve with age, as the organisms or enzymes responsible for flavour and

FIG. 5
CHEESE PRODUCTION

Reproduced by courtesy of Professor P. Solberg, Norwegian Agricultural College, Vollebekk, Norway

FIG. 6
CHEESE STORAGE

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body characteristics are slow-acting. However, during the ripening period the storage rooms must be maintained at the temperature and humidity necessary for the particular variety of cheese. These storage rooms must be maintained in a satisfactory sanitary condition for the cheese in question. Insect infestation of these areas must be avoided (see Fig. 5, 6).

Many of the hard cheeses are protected by a coating of wax which prevents contamination of the cheese and loss of moisture during storage. Other cheeses receive the same protection by the development of a hard surface rind. These protective coverings are typical of various cheeses and make the hard varieties less perishable than the soft and semi-soft varieties.

Fluid Milk Products

Flavoured milks

Flavoured milks are recognized as beverage products containing milk to which has been added flavouring materials such as chocolate, fruit flavours or syrups and possibly colouring material. The milk product used is usually skimmed or partially skimmed milk with a reduced fat content, but may even be a reconstituted milk powder. The product may be pasteurized or sterilized or prepared from pasteurized milk at a milk bar.

The hygienic control of this type of product requires that all milk ingredients meet the same specifications and requirements as apply to fluid milk. In addition, the bacteriological and sanitary condition of flavours, syrups and colouring material must be checked to eliminate possible contamination of the finished product. Only colouring materials and flavours approved by health authorities should be used.

The product should be manufactured in plants where adequate supervision and equipment are available. The products should be pasteurized at temperatures slightly higher than those used for fluid milk. The recommended pasteurization for chocolate milk, for example, is 62.8°C (145°F) for 30 minutes or 73.9°C (165°F) for 15 seconds. Products distributed in areas lacking home refrigeration should be sterilized—preferably by the " in-bottle " process. For distribution at milk bars or other establishments only properly pasteurized milk should be used and the added ingredients should be of high quality. Proper cleaning and sanitizing of utensils and equipment should be practised at all times.

These products should be subjected to the same rigid bacteriological examinations as are carried out on fluid milk. The ingredients should be checked before use to determine their bacteriological quality. The coliform test is of particular value in this instance. Bacterial standards should be the same as for fluid milk.

Fermented milks

Since the early days of history man has known that fresh milk becomes sour more or less rapidly, depending on the temperature at which it is held.

He has long made use of this property for the preparation of countless palatable forms of soured or fermented milk. Each area of the world has developed its own method for the preparation of these products, and thus has arisen a large number of fermented milks, each with its own name and slightly different characteristics. Although several of these products are produced commercially today, little is known about the microbiology of many fermented milks, especially those made in the home and in remote areas of the world where each new batch is inoculated with a portion of the previous batch. Basically, however, all of these products are soured by lactic acid bacteria and some, in addition, undergo an alcoholic (yeast) fermentation.

Fermented milks manufactured commercially are all prepared in the same general fashion, although specific details vary from one product to another. Skimmed milk, partially skimmed milk, whole milk or sometimes concentrated milk or reconstituted dried milk solids is subjected to heat treatments generally more severe than pasteurization, although the range may be from pasteurization to autoclaving temperatures. After cooling to the requisite incubation temperature the milk is inoculated with the appropriate micro-organisms and incubated until the desired acidity, flavour and body characteristics have developed. The product is then cooled and packaged for distribution.

Milk supply. Of all dairy by-products, perhaps fermented milks should receive the most care with respect to selection of the milk supply. This is particularly true in the commercial production of these products, where the loss of product due to lack of growth of the fermenting organisms would amount to a fairly large volume. The milk supply must be of high quality, have a clean flavour and be free from inhibitory substances such as antibiotics, natural inhibitors, or residual sanitizing agents. It is generally considered advisable to check the milk supply frequently to determine the ability of the milk to support the growth of the organisms being used in the fermentation. If dried milk solids are used to fortify the milk or to prepare a reconstituted milk, the powder also should be checked to determine whether or not it will support the growth of the desired organisms.

The treatment of mastitic cows with antibiotics has caused problems for the manufacturer of fermented milks. Unless milk from treated cows is withheld by the farmer for 72 hours after treatment of the cow, sufficient amounts of residual antibiotics can be present in the milk to inhibit the growth of the cultures. Some of the antibiotics (penicillin in particular) will not be completely inactivated by the heat treatments employed in processing. It has been reported that residues of penicillin have been detected in non-fat dried milk solids at levels high enough to inhibit the growth of lactic acid bacteria. Therefore fluid milk and dried milk solids should be checked frequently for the possible presence of inhibitory substances.

Equipment. Plant sanitation is of critical importance in the manufacture of fermented milks. All equipment must be thoroughly cleaned and sanitized. However, in the sanitizing operation, care must be exercised that residual sanitizing agents do not contaminate the milk. This is particularly necessary in the case of the quaternary ammonium compounds, as it has been found that as little as 5 p.p.m. of such compounds can inhibit acid production by *Streptococcus lactis* (Curry & Barber, 1952). Hot water at about 82.2°C (180°F) is regarded as a satisfactory sanitizing agent, and chlorine solutions if properly used also sanitize equipment in a satisfactory manner.

Bacteriophage. Bacteriophage (commonly known as phage) can be a problem in the production of fermented milks and various types of cheese or any product dependent upon the action of bacteria which may be susceptible to the action of phage. Phage may be carried with the culture, may develop in improperly cleaned equipment where milk residues accumulate, may be brought in by contaminated air, and is also present in whey. In areas where cheese whey is returned to the farmer in his milk cans, unless the cans are properly cleaned and sanitized with hot water or sanitizing agents before fresh milk is added, the milk itself can carry the phage and thus contaminate the plant. The rotation of cultures is recommended since phage is strain-specific (phage particles grow and attack only their own specific strain). This rotation is claimed to prevent build-up of the phage in the plant.

Recent developments have indicated that phage can be controlled in cultures by the use of a new type of culture medium. British workers (Reiter, 1956; Tybeck, 1959) have developed a medium, designated "Cockade", which is low in calcium and is reported to prevent the development of phage in cultures that are carried in the medium. Workers in the USA (Hargrove, 1959; United States Department of Agriculture, 1959) have reported that the addition of phosphates to the milk may aid in the control of phage.

Although it is generally recognized that the primary source of phage may be the culture itself, it is known that the plant may become contaminated with phage and present a problem in phage control. Thorough cleaning and sanitizing of equipment must be practised to prevent a build-up of this type in the equipment. In some areas an air-filtration system is regarded as necessary for preventing phage contamination from the air. If a plant becomes contaminated, a thorough clean-up is always necessary and fogging of the area with a strong chlorine solution (2000 p.p.m.) has to be carried out.

In any plant where bacterial cultures are to be used for the manufacture of fermented milks or various types of cheese (especially cottage cheese), it is recommended that a special area away from the manufacturing area of the plant be set aside for the sole purpose of maintaining these cultures. Ideally, this area would be completely removed from the rest of the plant,

even in a separate building. In any case, it should be recognized that special conditions and care to prevent contamination are needed in the propagation of starter cultures.

Cultures. The procedures for maintenance and preparation of cultures must be followed carefully if good, active cultures are to be available for the fermentation. Commercial cultures are available in the dry, liquid or frozen state. The milk used for propagation of the cultures must be carefully selected. It should be of high quality and free from any inhibitory substances; and may be whole milk, skimmed milk or reconstituted milk, depending upon the type of product being made. Whole milk is generally used when a high butter aroma is desired and is usually preferred for mixed cultures containing acid-formers and aroma-producers. All glassware (bottles and pipettes) must be clean and sterile. Milk is usually sterilized in an autoclave, although some plants use a heat treatment of 82.2°-87.8°C (180°-190°F) for one hour. The heated milk is cooled to the requisite incubation temperature, inoculated and incubated until the desired acidity has developed. Cultures are gradually increased in volume from the mother culture to the intermediate culture, the bulk starter culture and finally the culture in the vat. Each transfer must be made with care, using properly cleaned and sanitized equipment and selected milk. Temperatures and times of incubation must be rigidly controlled, not only in the small volumes of the mother and intermediate cultures, but also in the larger volumes of the bulk starter and the vat.

Processing. It has been noted that the milk to be used in the manufacture of fermented milks usually receives a heat treatment somewhat more severe than normal pasteurization. This heat treatment not only completely eliminates pathogenic organisms but also reduces the number of all other organisms which might compete with the added starter cultures.

After the heat treatment, the milk is usually pumped into large vats or tanks, adjusted to the proper incubation temperature and inoculated with the desired culture or cultures. The proper incubation temperature must be maintained throughout the fermentation so that the organisms develop properly and produce the desired acidity and flavour. As soon as the proper acidity and flavour have been attained, the product is rapidly cooled to prevent further growth of the bacteria. The fermented milk is then bottled or packaged with a minimum of agitation, to prevent damage to the body characteristics of the product. The fermented milk should be held at refrigeration temperatures, otherwise the cultures may continue to grow and produce too much acid, making the product unpalatable. Also, unless care has been exercised to prevent contamination of the milk with other organisms, undesirable spoilage may take place.

In the control of the final product, the coliform test is frequently used to determine the care with which the fermented milk has been produced. Since

these products are made from adequately pasteurized milk, the presence of coliform organisms suggests inadequate pasteurization or recontamination after heating, either of which might mean an undesirable product for the consumer.

Ice-Cream

Ice-cream and frozen dairy products are popular food items in the USA and many other countries. Ice-cream generally means a pure, clean, frozen product made from various milk products, dry or liquid forms of glucose, sucrose or corn sugar and water. Generally it contains an edible flavouring material, sometimes fruits or nuts, or both, and frequently edible colouring matter. Other varieties of frozen desserts contain eggs or egg products and all usually have added stabilizers and emulsifiers. These products have been classified on the basis of composition as plain, nut, fruit, mousse, bisque, puddings, custards, ices, sherbets, specials, and novelties. Standards of composition for these products vary from area to area, so no attempt will be made to describe them.

In a discussion of the hygienic control of these frozen desserts attention must be given to the quality standards set up by the controlling authorities. The main purpose of standards is to provide the consumer with a safe, wholesome product. The United States Public Health Service standards are established to promote a greater degree of uniformity and a high level of efficiency in the sanitary control of frozen desserts. The bacteriological standards in force in many areas are the following:

Mix	50 000 per gram (10 coliforms per gram)
Cream	100 000 per ml (pasteurized)
	400 000 „ „ (raw)
Condensed milk	50 000 „ „ (pasteurized)
	200 000 „ „ (raw)

All ice-cream and frozen desserts are pasteurized. In general, the pasteurization standards are: 68.3°C (155°F) for 30 minutes; 79.3°C (175°F) for 25 seconds; and 87.8°C (190°F) for no holding period (the so-called " flash " or vacuum process). Higher temperatures and shorter times of pasteurization are being investigated, and 93.3°C (200°F) for 3 seconds has also been proposed as a suitable standard. All these pasteurization treatments have been thoroughly investigated to ascertain that they are sufficiently severe to bring about complete destruction of all pathogenic organisms. Pathogens themselves have not been used in recent investigations, but the above times and temperatures have been determined by the use of heat-resistant test organisms (Barber, 1951; Speck, 1950).

In the production of frozen desserts the bacteriological condition of the mix is dependent upon the quality of the ingredients. Usually pasteurized products are used in making up the mix, but in all cases the mix should be pasteurized before freezing.

Cream. High-quality, sweet, un-neutralized cream should preferably be used as a source of fat. The bacterial count of the cream should not exceed 100 000 per ml if the cream is pasteurized or 400 000 if it is raw. Care must be taken to select a cream with no off-flavours as these may carry over into the ice-cream. Unless cream produced and processed under sanitary conditions is used, it can be a source of high counts, especially of the thermoduric type of organism. Other permissible sources of fat include frozen cream, butter oil and, in some areas, vegetable fats.

Condensed and dry milk solids. The milk solids in the ice-cream are generally provided by condensed or dry milk products. These products should have bacterial counts of less than 50 000 per ml and should always have been produced under sanitary conditions. The use of high-count products may contribute considerably to the count of the finished product.

Sugar and sweetening agents. Liquid or dry sugar products can be used in the production of ice-cream, depending upon the needs and the equipment in the plants. These products should be of high quality and have low bacterial counts. The concentration of sugar in the finished product is low and therefore the contamination from this source is slight. However, it should be emphasized that the cleaning and sanitizing of tanks for the storage of liquid sugar and of pipelines for the transport of this ingredient should be carefully carried out to prevent possible growth of osmophilic yeast and thermophilic spore-formers in the equipment and the product.

Stabilizers. Stabilizers are used in very low concentrations in frozen desserts. However, high bacterial counts in these ingredients are not desirable. Gelatin, a frequently used stabilizer, should never have a count exceeding 10 000 per gram.

Fruits and nuts. Fruits and nuts may be important sources of contamination, particularly since they are usually added to the product after pasteurization and immediately before freezing. Fruit products also present the problem that they are not generally subjected to heat treatment during processing because of the fragility of the fruit and the desire to maintain the delicate flavour of the fresh fruit. Therefore fruit processors should take all precautions possible to ensure that wholesome raw materials are used and to see that these are handled carefully during processing. Contamination from pickers, handlers, soil, insects, and water is unavoidable, but care should be taken to reduce this contamination to a minimum. Attention should be given to the quality of the water and the sanitary conditions in the fruit-processing plant. When frozen fruits are thawed for use in the ice-cream plant, it is important to prevent contamination and subsequent growth of micro-organisms in the defrosted product.

Nuts, on the other hand, may be sterilized by treatment with an ethylene-oxide carbon-dioxide gas mixture to destroy insects, yeast, moulds and

bacteria. They may also be roasted, and this heat treatment will reduce, if not eliminate, contamination. Special care must be exercised in the addition of these products to the ice-cream to ensure that contamination is not introduced at this point.

Fruits and nuts are usually examined bacteriologically for total counts and for coliforms, yeasts, moulds, and β-haemolytic streptococci. The presence of coliform organisms is generally considered an indication of human, soil, utensil or water contamination. β-Haemolytic streptococci may be present as a result of contamination from human sources. Yeast and mould counts indicate to some extent the degree of ripeness and also the care with which the fruits and nuts were handled, especially the sanitary conditions throughout the processing operation.

Colours and flavours. Only colourings and flavours that have been approved by health authorities should be used. Since these ingredients are also usually added after pasteurization of the mix, unless they are properly prepared and handled they can be a source of large numbers of microorganisms. As a rule these ingredients have low bacterial counts when received. However, colourings may become quickly contaminated if dilute unused solutions are allowed to remain for some time at room temperature in contaminated containers. A good practice is to prepare only enough colour solution for immediate use and to make up fresh solutions every day. Microbiological checks on colourings and flavour materials include determinations for total count, coliforms, yeasts and moulds, and at times tests for β-haemolytic streptococci.

Egg products. Egg solids may be obtained in fresh, frozen or powdered form and unless they have been produced under sanitary conditions they may be a source of bacteria in ice-cream. These products are usually examined for total count, coliform bacteria, yeasts, moulds, putrefactive anaerobes, β-haemolytic streptococci and species of *Salmonella.* Although standards have not been set up for egg products, the total bacterial count should not exceed 10 000 per gram.

Processing. Once all the ingredients have been collected there follow numerous steps in the manufacture of ice-cream. These usually include mixing of ingredients, pasteurization, homogenization, cooling, storage where aging of mix is practised, addition of fruits, nuts, flavouring and colour, freezing, packaging, hardening and, finally, distribution of the frozen hardened product. In all these steps the sanitary care and condition of the equipment involved in the process are important. If every piece of equipment is not properly cleaned and sanitized it may become a source of contamination of the product.

Pasteurization is a critical step in the operation because it is here that the product receives its only heat treatment. The pasteurizing units must be operated in such a manner that every particle of mix is properly heated.

Time and temperature charts must be accurate and frequently checked. For vat (long-hold) pasteurization foam heaters should be used at the top of the vat, otherwise the insulating effect of the foam will prevent all the mix from receiving the necessary heat treatment. After use pasteurizers should be cleaned thoroughly and operation times should be controlled so that build-up of solids in the equipment does not occur.

If the equipment used is properly cleaned and sanitized, the processes which follow do not increase the bacterial count of the product. However, the injector used for the addition of fruits and nuts immediately before freezing may offer an opportunity for contamination if not kept in a sanitary condition. The containers used in the preparation of fruits and nuts prior to addition to the ice-cream also should be cleaned and sanitized before use. All possible opportunities for contamination should be avoided.

Quality control tests. After processing, samples are usually taken for quality control tests. In the laboratory the ice-cream is allowed to melt and samples are weighed into water blanks prior to plating. Bacteriological tests include counts for total bacterial content and for numbers of coliforms, yeasts and moulds. Of these determinations the coliform test is frequently regarded as being most valuable in the detection of post-pasteurization contamination. However, with ice-cream containing fruit products, the coliform test must be interpreted with caution. It has been found that frequently false positive tests are obtained on these products (Barber & Fram, 1955). The false positive reactions are due to the presence of non-coliforms, which are part of the natural flora of many fruits and which, in the presence of the low concentrations of sugar provided by the ice-cream, will grow on the solid coliform media with colony formations typical of the coliform bacteria. A procedure which will eliminate the false positive reactions is the membrane-filter technique (Nutting et al., 1959). The sample is diluted in the usual manner and then heated to 45°C (113°F), a detergent solution is added and the mixture is filtered through the membrane filter. A differential medium allows only the growth of the coliforms on the membrane; the elimination of the sugar by filtration prevents the growth of the false positive types.

When high counts of any of the above organisms are obtained, it is frequently necessary to make use of line-run tests to determine the cause of the high count. Samples are taken at various locations during the processing operation and of all the ingredients. These samples are plated and in this manner the source of contamination is located. Special attention to cleaning and sanitizing of equipment is often found to be necessary to eliminate the cause of the high counts.

Although not directly related to the production of ice-cream, special mention should be made of the possible contamination of ice-cream in eating establishments. All too frequently little attention is given to the sanitary condition of dispensing utensils. Dippers and utensils are often subjected

to a cursory rinse in water heavily contaminated with ice-cream solids. These conditions provide an excellent opportunity for the growth of bacteria, contaminate the dippers and thus the individual serving as well as the bulk container of ice-cream. It is recommended that particular care and instruction be given as to the proper sanitary procedures to be followed in the dispensing of these frozen dessert products. Utensils should be washed thoroughly and sanitized with hot water. If a container of water is needed for the dippers there should either be a continuous flow of fresh, clean water through it or the water should be changed frequently to prevent the growth of micro-organisms.

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