The concentrated and dried milks are manufactured to conserve fluid milk for use where fresh milk is scarce and during seasons of low production. Specialized knowledge and equipment enable processors to manufacture the different concentrated milks by removing part of the water from the milk. The products are the source of concentrated milk solids needed for the preparation of many foods, both in the home and in the food factory.

The names assigned by custom to the concentrated milks have confused the layman and provoked the etymologist. Plain condensed whole and skim milks contain no sugar and are perishable products. Sweetened condensed whole and skim milks are preserved by the addition of sugar. Evaporated milk is not sweetened; it is sterilized in cans. Dried milks may be either dried whole or dried skim milk, except that Congress in 1944 amended the Food, Drug, and Cosmetic Act by providing a statutory definition for dried skim milk under the names “nonfat dry milk solids” and “defatted milk solids.”

Nearly half of the 120 billion pounds of milk produced annually in the United States is consumed as market milk and cream. From the remainder (except the milk used on the farm), such dairy products as butter, cheese, ice cream, concentrated milk, and dried milk are manufactured. Fifteen billion pounds of skim milk, part of that left from the separation of milk for cream and butter, also goes into manufactured milk products. The fluid milk equivalent utilized in the production of the concentrated and dried milks is about 20 billion pounds. Approximately 6½ billion pounds of milk is made into evaporated milk each year, and 280 million pounds is canned as sweetened condensed milk, both largely for household use. The ice cream industry uses about 3 billion pounds of skim-milk concentrates to build up the nonfat milk solids of ice cream. The manufacture of foods other than dairy products requires preparation of milk concentrates from 4 billion pounds of milk. About one-third of the production of concentrated and dried milks is used in beverage milks, cottage and other special cheeses, malted milk, and animal feeds.

**Sweetened condensed milk** is manufactured by a few simple but vital operations. Harmful bacteria and enzymes are destroyed by forewarming. In that treatment, the milk is heated to about 185° F., which helps also to control thickening of the finished milk during storage. The hot milk is drawn into the vacuum pan—in which milk boils at temperatures as low as 100° F. and water is rapidly removed without coloring the milk or giving it a cooked flavor—together with 18 pounds of sugar for each 100 pounds of milk, a sirupy milk, which tastes delicious, is drawn from the vacuum pan and cooled with continuous agitation. Tiny crystals of lactose (milk sugar) grow spontaneously when the condensed milk is stirred at about 85°. Improper cooling causes the growth of large, coarse crystals that make the milk taste sandy. Sweetened condensed milk is packed in cans or barrels. When held at 70° for 6 or 8 months, the product...
CONCENTRATED AND DRIED MILK

darkens and thickens. The change can be greatly retarded by storing it below 60°. Sweetened condensed milk retains its acceptable condition for at least a year if held at a low temperature. It is not damaged at temperatures well below 0° F. because of its high sugar content.

Perishable concentrates, produced and packaged in bulk for food processors, are called plain condensed milk. They contain no sugar and must be held under refrigeration. The manufacturing process consists simply in heating, condensing, and cooling the milk.

Evaporated milk, unlike sweetened condensed milk, contains no added sugar. Spoilage is prevented by sterilization with heat. Steps in the manufacture of evaporated milk are: Forewarming, evaporation, homogenization, standardization, canning, and sterilization.

The time and temperature of forewarming affect the stability of the milk toward heat and the viscosity, or body, developed in it during sterilization. Forewarming is generally done at a temperature of 190° to 212° F., depending on the condition of the milk.

Dairy scientists recently investigated the effect of forewarming milk to temperatures up to 300° on its heat stability and viscosity. They found that milk forewarmed at 250° for 3 to 4 minutes attained a much greater heat stability than when temperatures below boiling were used. The discovery enables manufacturers to raise the solids content of evaporated milk without encountering coagulation difficulties during sterilization. Evaporated milks have been made with a solids content up to 38 percent.

Storage tests on milks containing various percentages of solids, however, have shown that the best milk is produced when the solids are held within the limits of 26 percent to 32 percent. The present evaporated milk with a solids content of 26 percent would be improved in terms of nutritive value and the persistence of good viscosity and body characteristics during storage if the solids content were raised to 28 percent.

Small crystalline particles, about the size of the head of a pin, sometimes appear in stored evaporated milk. They are complex milk salts that have crystallized and settled to the bottom of the can. The conditions governing their separation are little understood; hence their formation cannot always be prevented. Salt crystals in evaporated milk are not harmful, but sometimes they are an annoyance, especially when they obstruct the holes in nipples of babies’ bottles.

Bureau of Dairy Industry chemists have studied evaporated-milk salt crystals. The crystals are composed largely of calcium citrate, with traces of phosphates. Crystals generally do not begin to appear in the milk until it has been in storage 6 months or more. They grow more rapidly when the evaporated milk is held at room temperature than when it is stored at 60° or below. The formation of crystals can be accelerated by adding calcium chloride and sodium citrate or by lightly seeding the milk with calcium citrate.

Early in the Second World War the Government had to store much evaporated milk. Some of it, after being held for 2 or 3 years, showed citrate crystals, a thinning in body, and some separation of fat and protein. Dairy scientists knew that evaporated milk was a remarkably stable product; they determined nevertheless to find a way to increase that stability. They found that the magnitude of the storage change depended partly on the temperature. Below 60° F. changes were slight, but above 90° the product deteriorated noticeably in a few months. It was found advisable to hold evaporated milk at a temperature not to exceed 75° and to turn the cases every 6 weeks to retard fat separation.

Fat separation in evaporated milk depends not only on the efficiency of homogenization, on viscosity, and on conditions of storage, but also on the
approximate composition, degree of concentration, and density of milk and concentrated milks

<table>
<thead>
<tr>
<th>Product</th>
<th>Water</th>
<th>Milk solids not fat</th>
<th>Ash</th>
<th>Sucrose</th>
<th>Degree of concentration</th>
<th>Density at 60°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>87.0</td>
<td>9.1</td>
<td>3.9</td>
<td>3.5</td>
<td>4.9</td>
<td>1.032</td>
</tr>
<tr>
<td>Skim milk</td>
<td>90.5</td>
<td>9.4</td>
<td>3.5</td>
<td>5.1</td>
<td>3.5</td>
<td>1.035</td>
</tr>
<tr>
<td>Evaporated milk</td>
<td>73.7</td>
<td>18.4</td>
<td>7.9</td>
<td>7.0</td>
<td>9.9</td>
<td>2.021</td>
</tr>
<tr>
<td>Plain condensed whole milk</td>
<td>64.0</td>
<td>25.2</td>
<td>10.8</td>
<td>9.7</td>
<td>13.6</td>
<td>2.771</td>
</tr>
<tr>
<td>Plain condensed skim milk</td>
<td>70.0</td>
<td>29.7</td>
<td>3.3</td>
<td>11.1</td>
<td>16.1</td>
<td>3.151</td>
</tr>
<tr>
<td>Sweetened condensed whole milk</td>
<td>28.0</td>
<td>20.0</td>
<td>8.5</td>
<td>7.7</td>
<td>10.7</td>
<td>43.5</td>
</tr>
<tr>
<td>Sweetened condensed skim milk</td>
<td>28.0</td>
<td>29.7</td>
<td>3.3</td>
<td>11.1</td>
<td>16.1</td>
<td>42.0</td>
</tr>
<tr>
<td>Dried whole milk</td>
<td>3.5</td>
<td>69.8</td>
<td>26.7</td>
<td>25.8</td>
<td>38.0</td>
<td>7.501</td>
</tr>
<tr>
<td>Dried skim milk</td>
<td>3.5</td>
<td>95.5</td>
<td>1.0</td>
<td>35.6</td>
<td>52.0</td>
<td>10.201</td>
</tr>
</tbody>
</table>

physical state of the protein that is associated with the fat in the cream layer. Easily dispersed fat layers are less objectionable than layers that are held tightly together by adsorbed, partly denatured protein. Causes for the gradual changes in the milk protein during storage of evaporated milk are still being investigated.

A new canned flavored milk that is high in energy value and suitable for drinking directly from the container was developed by scientists in Government and industry in response to requests by the Army Quartermaster Corps. The milk was wanted for use on invasion beachheads, where the landing forces frequently needed quickly available nourishment. The milk, a sterile product in sealed containers, has excellent storage life. It contains approximately 20 percent total solids; ordinary fluid milk contains about 13 percent. The extra solids consist of sugars, flavoring materials, and added milk solids from concentrated milk. The many flavors tested in developing the formulas included fruits, honey, maple, chocolate, and caramel. Chocolate and caramel gave a product of satisfactory flavor and small batches of both were made commercially for the Quartermaster Corps. These flavored milks have not been extensively manufactured for civilian use, although canned chocolate milk is available in some markets.

DRIED MILK was one of the chief contributions of the dairy industry to winning the Second World War. Before the war the production was largely dried skim milk and dried buttermilk, both byproducts. During the war a great demand for dried whole milk prompted a sevenfold increase in its manufacture. The dried milks are now made by three principal methods, usually designated as spray, atmospheric-drum, and vacuum-drum processes.

In the spray process, partly concentrated milk is sprayed by pressure or centrifugal means into a chamber through which a current of heated air is directed. The shape of the drying chamber may be conical or rectangular, and its size is proportioned to the spray and the amount and direction of the flow of air used. The fine droplets of milk dry almost instantaneously to fine particles of powder, which are removed from the air by gravity and the cyclonic motion of the air, and, in some cases, with the aid of an air-filtering device. Dried milks made by this method are finely divided, very soluble, and hygroscopic.

Although unconcentrated milk can be dried by this method, partly concentrated milk is preferred for economy
CONCENTRATED AND DRIED MILK

and the effect on certain properties of the dried product. The milk usually is concentrated in a vacuum pan or a continuous evaporator. The concentration, which varies with the type of spray and the drier used, may be as great as 44 percent solids. Dried milks made from concentrated milks have particles of larger sizes than those made from unconcentrated milks and can be reconstituted more readily. The dried-milk products also retain less gas when subjected to vacuum in packaging.

Dried skim milks are usually made from skim milks that have been preheated to at least 185° F. for varying periods, because it has been found that the dried product made from milk treated in this way has better baking qualities than products made from milks that have received only a pasteurization treatment.

In manufacturing dried whole milk, the milk must be heated sufficiently to destroy the fat-splitting enzymes, lipases. The temperature and the time of heating needed to destroy the lipases have not been established definitely. However, temperatures of 175° to 180° F. for 30 minutes have been used successfully in the manufacture of dried whole milk. The temperature of the air to be used in drying varies with the make of the drier. It may be from 240° to 320°, depending on the efficiency of the spray, the rate of feed, the degree of concentration of the milk used, and other factors. In the manufacture of this product, it is also important to keep the milk from coming in contact with exposed copper or iron. Extremely small quantities of copper, especially, will accelerate markedly the deterioration of the fat.

In the atmospheric-drum process, steam-heated revolving single or double drums are coated with a film of partly concentrated milk, which dries and is scraped off by close-fitting knives after a partial revolution has been completed. The product is then ground to a powder and packed in barrels or sacks.

Because of the high drum temperature necessary for drying the film, there is a slight discoloration of the product and a partial coagulation of the proteins that makes them insoluble. Driers of this type are used mainly in drying skim milk and buttermilk. The dried milk thus made does not absorb water as readily as powder dried by the spray process.

The vacuum-drum process is essentially a roller process. The rolls, or drums, are enclosed in a chamber that is kept under partial vacuum during the drying operation, thus making it possible to dry milks at temperatures below their boiling points. The products obtained by this process resemble those made by the spray process in solubility, color, flavor, and hygroscopicity.

Great quantities of dried milk were used to feed the Allied armies. Scientists and technicians were called upon to solve the problems of packaging and keeping quality which arose when the milk was subjected to the rigors of wartime storage and shipping.

The spray-dried and vacuum-drum-dried milks have a great avidity for moisture and must be packaged so that they are guarded against absorption of moisture from the atmosphere. Dried skim milk is usually packed in slack barrels of 200-pound capacity with moistureproof double liners, or in moistureproof bags of 100-pound capacity. For Army export the 25- and 50-pound hermetically sealed round or square base-metal cans were the most satisfactory. Metal drums and moisture-proof fiber drums have also been used for export.

Dried whole milk deteriorates relatively rapidly when packaged in contact with air. To retard or prevent spoilage through oxidation of the fat, the product is packed in tin containers of from 1- to 50-pound capacity and the air is removed as completely as possible by evacuation and replaced by an inert gas, usually nitrogen.

Many flavors may develop during the production and storage of dried milks. For the most part, they can be
controlled through the use of advanced methods of manufacture and packaging. Aside from the off-flavors that may be inherent in milk, the principal types of off-flavor likely to be found in dried milks are "cooked" flavors, which are developed during manufacture, and staleness, rancidity, and tallowiness, which may develop during storage.

Some basic rules for the manufacture of spray-dried whole milk of good keeping quality have been developed by research workers:

- Milk of low bacterial count should be dried as soon after it is drawn from the cow as practicable.
- The milk must not come in contact with copper and iron; stainless-steel equipment is best.
- The raw milk must receive a heat treatment of 175° for 30 minutes, or its equivalent in time and temperature of heating, for lipase destruction.
- The moisture content of the powder should be below 2.5 percent.
- Dried whole milk should be gas-packed in tin cans so that the oxygen content of the atmosphere of the container does not exceed 2 percent.
- The temperature of storage should be less than 75° F.

If these conditions are fulfilled, and reasonable care is exercised in the manufacturing operations, the dried milk will remain in good condition for 6 months to 1 year.

Dried skim milk should contain less than 3.5 percent moisture. Powders of more than 5 percent moisture held at high storage temperatures deteriorate very rapidly in color, flavor, and solubility.

Further utilization of milk in the concentrated and dried form will come as improvements are made in these products through advanced methods of processing. Chemists, bacteriologists, dairy technologists, and engineers are constantly engaged on the problems of heating, concentrating, and drying milk.

The development of an improved process for sterilizing fluid concentrated milks affords a great opportunity for increasing their utilization. The production of sterile packaged milks of normal flavor and color and with good chemical and physical stability may some day be possible. Means for accomplishing this include sterilization by dielectric heating, cathode rays, ultrasonics, and antibiotics, or by improved high-temperature, short-time heating. How effective any one of these methods may become in providing the consumer with an acceptable concentrated beverage milk is unpredictable. Most scientists still believe that heat is the surest and safest sterilizing agent. Evaporated milk has already been quickly heat-sterilized by two experimental methods that give products of generally acceptable, though slightly cooked, flavor. By one method, cans of milk are sterilized under severe agitation in less than 4 minutes at 260° F. By the other method, the milk is sterilized at 280° by rapid passage through a special tubular heater, and then aseptically packaged. Both methods produce thin evaporated milk, which lacks long storage stability. The fat and protein separation of such milks during storage must be overcome before these products can be offered to the public with complete assurance that the contents will keep until the can is opened.

Utilization of dried milks will be broadened as scientists gradually learn how to extend the time that a fresh flavor can be retained. There is need, too, for improvement in the physical properties of the powder particle. If dried milk could be made so that it would disperse and dissolve in water as readily as sugar, its popularity with consumers would increase.

B. H. Webb is a principal dairy manufacturing technologist in the Bureau of Dairy Industry. He received the 1943 Borden Award in Dairy Manufacturing from the American Dairy Science Association and the Superior Service Award from the Department of Agriculture in 1948.