broken, freeing the fat from globular form. This permits the accumulation of the fat, free of non-fat portions which formerly held it in suspension.

Concentration from 80 to 98 percent Fat Content

The concentrated oil and serum product at 165 F enters the serum separator which removes the major portion of serum to concentrate the fat to 98.5 to 99 percent. The oil-serum product enters this gravity type separator slightly below center. The fat is directed upward while the serum is directed down and is discharged back into the balance tank for 40 percent cream just ahead of the centrifugal separator. This return serum is thus re-separated so that there is no possible fat loss.

Pasteurization and Cooling 98 percent Fat

The 98.5 percent purity fat is directed to a second section of the plate type heat exchanger in which it is heated to 190 F and is immediately cooled to 110 to 120 F in a third section. It is then directed to a battery of three composition control tanks to standardize components for the desired butter.

Composition Control of the Butter Mix

In this step the various components of fat, moisture, salt, and curd are standardized. Also, a controlled portion of unbroken fat is introduced. This is accomplished by segregation of a portion of the 80 percent cream in the special balance tank which receives cream from the heavy cream separator. The desired quantity is metered by a positive pump into the 98.5 percent fat as it enters the plate heat exchanger for heating to 190 F and subsequent cooling.

The standard Kohman butter test is made on the thoroughly mixed fat and unbroken fat in the composition control tanks. The required quantities of water, salt and color are then added to produce the desired composition. By means of the equipment and procedures available, it is possible to obtain much closer quantitative control than in the production of batch churn butter.

The standardized butter mix in the composition control tanks is thoroughly agitated to insure extremely accurate control throughout the entire quantity in the tank.

Controlled Crystallization and Solidification of the Butter

The thoroughly agitated butter mix is removed from the composition control tanks by means of a small centrifugal pump which supplies a steady pressure to the high pressure pump feeding the chiller at pressures up to 325 lb, thence to the crystallizer and final extruder. The chiller is so designed that the butter mix is cooled from standardizing temperatures of 110 F to approximately 40 F at which temperature it passes to the crystallizer. The design also produces intimate working of the product so that there is a definite controlled seeding of butter crystals. The crystallizer provides for the control of the crystallizing structure during growth.

In passing through this machine the temperature of the product is increased 10 to 11 F deg due to heat of crystallization so that the finished product is discharged at approximately 50 F. The extruding table is such that the product can either be printed directly by means of a conventional butter printer or it can be boxed with a special boxer into standard 60 lb cubes.

MICROBIOLOGY OF BUTTER

Cream pasteurized either at 160 to 165 F for 30 min or at 200 F or higher with the continuous method may contain only one-tenth percent or less of the bacteria that were present in the raw cream. Generally all yeasts and molds are destroyed. Enzymes are inactivated. If the equipment with which the pasteurized cream and the butter come in contact has been thoroughly cleaned and sterilized, it would be expected that the finished butter would contain very few bacteria and no yeasts or molds, but microorganisms are picked up by the cream and butter from the wooden churn, the wash water, and wooden packing utensils. If all metal equipment were used and if the water were first pasteurized it should be possible to manufacture butter containing but a few microorganisms. If a starter is added to cream before churning, the butter will contain numerous lactic acid bacteria but these organisms do not cause deterioration in butter held under refrigeration.

Well-worked butter contains several billion moisture droplets per gram; the majority of the droplets are too small to supply moisture and nutrients for bacterial growth. Salt inhibits the growth of microorganisms. It is important therefore, to thoroughly work the butter so that the brine droplets are uniformly distributed in the butter.

Lipase-producing bacteria, if present in butter, may cause a rancid flavor when the temperature of the butter permits their growth. These organisms may be present in the raw cream, but they are killed by pasteurization. They may be added to butter by untreated wash water. The enzyme lipase hydrolyzes fat with the result that rancid-flavored fatty acids are formed.

Other microorganisms may cause decomposition of protein which is present in small amount in butter. They may also be present in raw cream and in contaminated water. If present in butter held even at a fairly low temperature, such as from 40 to 50 F, they may grow and cause a disagreeable putrid flavor in the butter. Control lies in (*a*) correct pasteurization; (*b*) thorough cleaning of all equipment including sterilization with hot water, steam or chemicals; (*c*) the use of pure water; (*d*) thorough distribution of the brine in the butter.

As yeasts and molds are killed by efficient pasteurization and can be destroyed on the equipment by sterilization with boiling water or chemicals, it is possible to manufacture butter that is free, or practically free, from these organisms. It is important to see that yeasts and molds are not added to butter from parchment paper, butter printers, the hands of the worker, and the air in the workrooms or refrigerators.

STORAGE OF BUTTER

For short-time storage a temperature of the refrigerator of 32 to 40 F is satisfactory. For long-time storage a temperature of − 10 to 0 F should be used. The butter should be protected with a covering so that absorption of odors is prevented, oxidation of the fat on the surface of the butter is minimized, and shrinkage in weight due to evaporation is prevented.

Specification for butter containers issued by the Commodity Stabilization Service of the U. S. Department of Agriculture on April 1, 1957 are:

"(a) Bulk Containers: Bulk butter containers shall be regular slotted corrugated or solid fiberboard containers of not less than 200 pound bursting strength to contain either 60 or 64 pounds net. The inside surfaces of the containers, including the flaps shall be paraffined with not less than 128 F melting point paraffin sufficient to prevent absorption of moisture by the fiberboard. Containers must have printed on two sides CREAMERY BUTTER—KEEP REFRIGERATED."

"Bulk butter containers shall be lined with vegetable parchment paper of not less than 27 pounds basic weight per ream (500 sheets 24" × 36"). The parchment liners shall be of sufficient length and width and so placed in the containers, that all surfaces of the butter shall be completely covered. The liners shall be treated by being held completely immersed in a salt solution at the boiling point for 30 minutes. The salt solution shall contain not less than 15 pounds of salt per 100 pounds of water and shall be changed not less than once a week."

"(b) Print Butter: One pound prints shall be Elgin or Western style solid prints, and properly wrapped with a single sheet of 30 pound basis weight dry waxed vegetable parchment paper or wet strength paper, or with a 20 to 30 pound wet strength paper waxed with a blend of polyethylene and micro-crystalline or paraffin waxes. Thirty-two prints shall be packed on their side in a 200 pound bursting strength regular slotted corrugated or solid fiberboard container. The inside of each shipping container shall be waxed with a fully refined wax, having a melting point of not less than 128 F to a point approximately one inch beyond the score line. As an alternate to waxing one inch beyond the score line of the containers, the entire inside surfaces and the end flaps which form the inside surface of the containers shall be waxed. As an alternate to waxing inside surfaces the containers shall be lined with 30 pound bleached kraft paper waxed to 40 pounds basis weight, or with its equivalent of parchment paper suitably waxed. The liners shall be of sufficient length to line ends, sides, and bottom and have a minimum of 2 inch overlap on the top. Snug-fitting, dry chipboard pads not less than 20 point shall be inserted inside print boxes, two on the bottom and one on the top."

"(c) No. 10 Cans: Six pounds net of butter shall be packed in each can. For domestic shipment, six cans shall be packed in a 200 pound bursting strength regular slotted corrugated or solid fiber-board container."

"One pound print and No. 10 can containers for domestic use shall have printed or stenciled on two sides, BUTTER—KEEP REFRIGERATED (less than 2 weeks below 40, more than 2 weeks 0 F or lower). No lettering on flaps."

The specific heat of butter and other dairy products at temperatures varying from 32 to 140 F is given in Table 5.

The temperature of the butter when removed from the churn ranges from 56 to 62 F. Assuming a temperature of the packed butter of 60 F the heat that must be removed from 1000 lb in order to reduce the temperature to 32 F is:

$$1000 \times (60 - 32) \times 0.52 = 14{,}456 \text{ Btu}$$

It is assumed that the average specific heat at the given range of temperature is 0.52. The heat units that are to be removed from the butter containers and packaging material should be added.

In medium size butter printing operations the butter storage rooms are maintained at 40 F, but in some instances, lower temperatures are desired in order to firm up the butter at a faster rate for handling in an automatic molding and wrapping machine. A Refrigerant 12 system with an automatic hot gas defrost system is used for such a storage room.

DETERIORATION OF BUTTER DURING STORAGE

The development of an undesirable flavor in butter during storage may be caused by (a) growth of microorganisms; (b) absorption of odors from the atmosphere; (c) fat oxidation; (d) catalytic action by metallic salts; (e) activity of enzymes; (f) low pH (high acid) of salted butter.

Normally there will be no growth of microorganisms below 32 F. If salt-tolerant bacteria are present their growth will be slow below 32 F. Growth of microorganisms does not take place at 0 F or below, but some may survive in the butter held at this temperature. It is important to store butter in a room where the atmosphere is free from odors. Butter will readily absorb odors from the atmosphere or from odoriferous materials with which it comes into contact.

A stale, tallowy flavor is caused in the butter when oxidation takes place. The chemical change takes place slowly in butter held in cold storage, but is hastened by the presence of metals or metallic oxides.

With the almost 100 percent replacement of tinned copper equipment with stainless steel equipment, a tallowy flavor is not as common as formerly. Factors that favor oxidation are light, high acid, high pH and metal.

Enzymes present in raw cream are inactivated by the pasteurization temperatures and holding times now used. The only enzymes that may cause deterioration of butter are those produced by microorganisms that gain entrance to the pasteurized cream and butter. The chemical changes caused by enzymes present in butter are retarded by a lowering of the storage temperature.

A fishy flavor may develop in salted butter during cold storage. The development of the defect is favored by high acidity (low pH) of the cream at the time of churning and metallic salts. With the use of stainless steel equipment and the proper control of the pH of the butter this defect now occurs very rarely. For salted butter which is to be stored for several months, even at − 10 F it is advisable to use good quality cream avoid exposing the milk or cream to strong light, copper, or iron, and to adjust the acidity of the cream churned so that the butter serum will have a pH of 7.0.

Table 5 .... Specific Heats of Milk and Milk Derivatives

	32 F	59.0 F	104.0 F	140.0 F
Whey	0.978	0.976	0.974	0.972
Skim Milk	0.940	0.943	0.952	0.963
Whole Milk	0.920	0.938	0.930	0.918
15% Cream	0.750	0.923	0.899	0.900
20% Cream	0.723	0.940	0.880	0.886
30% Cream	0.673	0.983	0.852	0.860
45% Cream	0.606	1.016	0.787	0.793
60% Cream	0.560	1.053	0.721	0.737
Butter	(0.512)[a]	(0.527)[a]	0.556	0.580
Butter Fat	(0.445)[a]	(0.467)[a]	0.500	0.530

[a] For butter and butter fat, values in parenthesis were obtained by extrapolation, under assumption that the specific heat is about the same in the solid and liquid states.

TOTAL REFRIGERATION LOAD FOR A BUTTER MANUFACTURING PLANT

Many dairy plants that manufacture butter are also processing and manufacturing other products such as ice cream, fluid milk products, and cottage cheese. A common refrigeration system is used. The method of determining the refrigeration load is illustrated by the example below.

Example 1: Determine the total refrigeration load for a plant manufacturing butter from 12,600 lb of 30 percent cream per day in 3 churnings.

Solution: The refrigeration requirement is obtained in the following steps A to E.

A. If the cream is separated in the plant rather than on the farm, it would have to be cooled down from 90 F separating temperature to 40 F to 45 F for holding until it is processed.

$$\frac{12{,}600 \times (90 \text{ F} - 40 \text{ F}) \times 0.85}{144} = 3719 \text{ lb Ice}$$

B. After pasteurization, the temperature of the cream is reduced to approximately 100 F with city water, then on down to 40 F with refrigeration.

$$\frac{12{,}600 \times (100 \text{ F} - 40 \text{ F}) \times 0.85}{144} = 4463 \text{ lb Ice}$$

C. After churning, the butter wash water (city water) is usually cooled to 45 F, then used to wash the butter granules. A volume of water equal to the volume of cream churned may be used.

$$\frac{12{,}600 \times (60 \text{ F} - 45 \text{ F}) \times 1.00}{144} = 1313 \text{ lb Ice}$$