

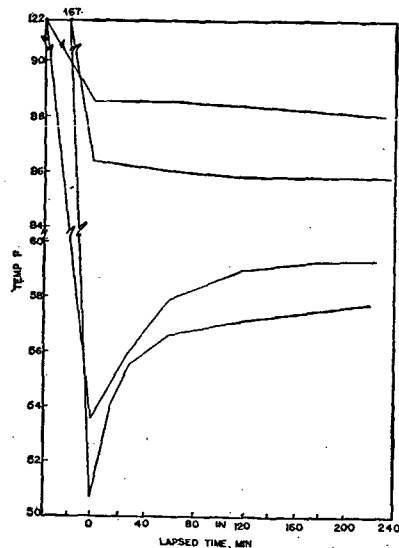


Fig. 2.... Thermal Behavior of Cream Heated to 167 F Followed by Rapid Cooling to 86 F and to 50.7 F. Comparison with Cream Heated to 122 F Followed by Rapid Cooling to 88.5 F and to 53.6 F.¹

1958. Over one billion lb were exported by 20 countries that year.

Refrigeration makes it possible to ship hundreds of millions of pounds of butter per year half-way around the globe.

More butter is manufactured in the United States than in any other country. One-fourth of all the milk produced in this country is used for butter. The 1780 butter manufacturing plants made 1.3 billion lb in 1958. Table 3 shows that the plants located in the East North Central and West North Central states produced 87 percent of the total volume of butter.

Higher sanitary standards for the production of milk on the farm and better cooling and transportation methods have improved the quality of milk and cream now being delivered to the creameries. A larger proportion of the milk produced is now sold in the form of milk than as cream. This has had a favorable influence on the quality of the butter manufactured.

COOLING CREAM AFTER PASTEURIZATION

The three billion pounds of cream pasteurized annually by the creameries in the United States and used in butter manufacture must be cooled immediately after pasteurization. The cream is commonly cooled to 40 to 45 F during spring and summer and to 50 F during fall and winter. Tap water is used first to reduce the temperature to between 80 and 100 F. Refrigerated water or brine is then used to reduce the temperature to that desired. The cream may be cooled by having the cooling medium pass through a revolving coil in the vat

or through the vat jacket, or by using either a plate or a tubular cooler.

If the temperature of 1000 lb of cream is to be reduced by refrigerated water from 100 F to 40 F and the specific heat of the cream is 0.85, the heat units to remove would be:

$$1000 \times (100 - 40) \times 0.85 = 51,000 \text{ Btu}$$

This heat can be removed by 51,000/144 = 354 lb ice at 32 F plus 10% for mechanical loss.

The temperature of the refrigerated water commonly used for cooling cream is 33 to 34 F. The ice-bank system is found very efficient for this. Brine is not used to the extent it was years ago.

The cooling of 300 gal of cream from 100 F to 40 F can be done in a vat using refrigerated water in about one hour.

After a vat of cream has been cooled to the desired temperature it will be observed that an increase in the temperature takes place during the following three hours. The temperature may increase several degrees depending on the rapidity with which the cream was cooled, the temperature to which it was cooled, the richness of the cream and the properties of the fat. The reason for the rise in temperature is the liberation of heat when the fat is changed from a liquid to a crystal form.

H. A. Rishoi has presented data¹ in Fig. 2 that show the thermal behavior of cream heated to 167 F, followed by rapid cooling to 86 F and to 50.7 F as compared with cream heated to 122 F and cooled rapidly to 88.5 F and to 53.6 F. The curves indicate that when cream is cooled to a temperature at which the fat remains liquid, the cooling rate is normal, but when the cream is cooled to a temperature at which some fractions of the fat are known to have crystallized, a spontaneous temperature rise takes place after cooling.

The same investigator determined the amount of heat that was liberated by the part of the milk fat which crystallizes in the temperature range of 85 to 33 F. The results are shown in Table 4 and Fig. 3.

The data in Table 4 show that at a temperature below 50 F about one-half of the heat liberated was evolved in less than 15 seconds.

The information obtained has some practical importance. The heat liberated during fat crystallization constitutes a considerable portion of the refrigeration load required to cool fat-rich cream. Rishoi states:

"If we assume an operation of cooling cream containing 40 percent fat from about 150 to 40 F heat of crystallization evolved represents about 14 percent of the total heat to be removed. In plastic cream containing 80 percent fat it represents about 30 percent and in pure milk fat oil about 40 percent."

CHURNING

It is common practice to churn the cream during the morning following the day it was pasteurized. The cream is stored overnight in a covered stainless steel vat.

Although many creameries still use wood churn barrels it will not be many years before metal, such as aluminum or stainless steel, will be used entirely. The metal must be sand-blasted on the surface that comes in contact with the butter to prevent sticking. Metal churns are more sanitary than wooden churns and they have the advantage of permitting variety in design. They may be circular, cube-shaped, oval or cone-shaped, etc.

A cream pump is unnecessary with a metal churn because the cream from the vat can be drawn into the churn when a vacuum is maintained in it. There is the further advantage that the butter can be worked under a partial vacuum. This results in butter with a closer texture, a brighter appearance

Table 4.... Btu Liberated per Lb of Fat in Cream Cooled Rapidly from About 86 F to Various Temperatures in the 32-68 F Range.

Calculated temperature for zero time:	33.4 F	39.6 F	53.1 F	58.0 F	63.4 F	80.4 F	85.6 F*
First observed temperature:	36.2	43.7	54.5	58.6	63.8	80.4	85.6
Final equilibrium temperature:	39.3	46.1	58.0	60.7	65.3	82.6	85.6
Lapsed time in minutes	Btu Liberated per Pound						
0.25	18.3	16.7	7.75	2.9	2.3	0	0
15	23.6	20.0	12.8	7.2	5.2	0.35	0
30	25.5	23.9	18.0	12.2	9.0	2.1	0
60	30.4	27.5	21.4	14.0	10.2	2.7	0
120	32.4	29.3	25.0	14.7	10.6	2.9	0
180	32.9	30.2	26.6	16.0	10.6	4.3	0
240	34.0	30.9	27.2	17.5	10.6	4.9	0
300	33.6	31.8	27.9	18.4	10.6	5.0	0
360	33.6	32.5	27.2	18.8	10.6	5.0	0

% Heat liberated at zero time compared with that at equilibrium: 54.5 51.3 27.7 20.7 21.7

Total heat liberated compared with that liberated at about 32 F: 100.0 95.7 82.0 55.0 31.0 12.5 0

Iodine values of three samples of butter produced while these tests were in progress were 28.00, 28.55, and 28.24.

* Cooled in an ice water bath.

and a lower air content than when it is worked without a vacuum.

Whereas present day churns used in the United States are equipped for two operating speeds, one for churning and one for working, the churns used in the chief butter-producing countries of Europe permit up to six or eight speeds. American churn manufacturers are now giving attention to constructing churns that permit variable speeds.

The fat content of the cream churned in the American creameries generally ranges from 30 to 40 percent. For greatest efficiency the fat content should range from 35 to 40 percent. The temperature of the cream should be such that an exhaustive churning can take place in from 40 to 45 minutes. It will be satisfactory to have an amount of cream in the churn that will occupy up to 40 percent of the volume of the churn barrel.

The churning temperature during spring and summer generally ranges from 45 to 52 F and during fall and winter from 52 to 60 F. The fat in cream during spring and summer, when the cows consume green feeds, has a lower melting point than during fall and winter. The spring- and summer-produced fat contains a larger percentage of low-melting point glycerides than fat in cream produced in fall and winter.

In order to prevent fall- and winter-produced butter from being too hard and difficult to spread at home refrigerator temperature it is possible to subject the cooled, pasteurized cream to a special temperature treatment prior to churning. The resultant butter is softer and more spreadable than that made in accordance with the usual method.

The buttermilk contains a small amount of fat in the form of small fat globules but this loss should not exceed one percent of the total fat churned.

It is common in some countries where the butter is to be consumed shortly after manufacture to omit washing the butter granules with cold water, but washing is commonly practiced in the United States. Water at a temperature of about 45 F, equal in volume to cream placed in the churn, is usually used. Washing consists of revolving the churn barrel containing the butter granules and water 12 to 15 revolutions. The wash water firms the butter granules slightly so that it is possible to work them together into a mass without having the butter become greasy.

If 1000 lb of water at 45 F is used for washing the butter

granules from 1000 lb of cream it will be necessary during the warmer months of the year to cool the available water to this temperature. If the water temperature is 55 F the heat to be removed is:

$$1000 \times (55 - 45) = 10,000 \text{ Btu}$$

Large creameries have specially constructed tanks for the butter wash water. The smaller plants generally use the vat

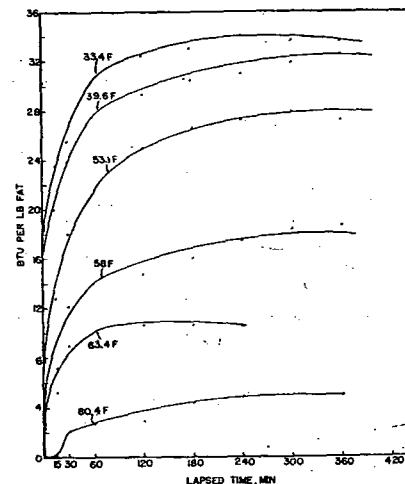


Fig. 3.... Btu Liberated per Lb of Fat in Cream Cooled Rapidly from Approximately 86 F to Various Temperatures in a 32 to 86 F Range¹