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Methods of Cooling and Storing Cream for Oregon's Dairy Farms

Influence on the Quality of Butter Which Can Be Manufactured

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TABLE OF CONTENTS

	Page
General Summary	3
Extent of Oregon's Butter Industry	5
Size of Dairy Herds	5
Production of Fat per Farm	6
Amount of Cream Produced	6
The Quality of Cream Delivered to Oregon Creameries	7
Frequency of Delivery	7
Acidity of Cream Delivered	7
Quality of Cream Delivered at Present	8
Resumé of Previous Work Regarding Cooling and Storing Cream	8
Climatological Data	10
Plan of the Experiment	11
Results of the Experimental Work	12
Trial 1	12
Trial 2	14
Trial 3	16
Trial 4	17
Trial 5	21
Trial 6	21
Summary	24
1. Air cooling	24
2. Cooling in a tank of still water	24
3. Cooling in a tank of flowing water	24
4. Cooling with the Hydro-Vac	25
Supplementary work	26
Trials 1 and 2	26
Trials 3 and 4	28

GENERAL SUMMARY

USE OF FLOWING WATER THE BEST METHOD

Of the different methods of cooling and storing cream studied in this investigation and reported on in this bulletin, it was found that:

1. Placing a five-gallon can of cream with the cream at a temperature of 90° F. in a tank of flowing water with the water entering and leaving the tank at the rate of one gallon per minute and having a temperature ranging from 47° to 54° F. resulted in maintaining the quality of the cream better than other methods of cooling.

2. The score of butter that could be made from the cream cooled and stored in a tank of flowing water averaged two points higher over a 72-hour storage period than the score of butter that could be made from cream cooled by the air and stored at air temperature when this ranged from 44° to 86° F., and the mean daily temperature ranged from 53° to 77° F. It averaged one point higher than the score of butter that could be made from cream cooled and stored in a tank of still water with the water changed twice daily when the temperature of the water when placed in the tank ranged from 47° to 60° F.

3. Cooling cream quickly by means of a special water cooler with the water that entered the cooler ranging from 47° to 60° F. followed by storing the cream at air temperature resulted in maintaining a better flavor of the cream during the storage period than when the cream was air-cooled and stored at air temperature. Precooling the cream when this was afterwards followed by storing either in a tank of still water or in flowing water was found to be of no additional benefit.

4. 93-score butter could be made from the fresh cream.

92-score butter could be made from cream cooled and stored in flowing water for 24 hours.

91-score butter could be made—

(1) From cream cooled and stored in flowing water for from 48 to 72 hours.

(2) From cream cooled and stored in a tank of still water for 24 hours.

(3) From cream precooled with water and afterwards held at air temperature for from 24 to 48 hours.

GENERAL SUMMARY—*(Continued)*

90-score butter could be made—

(1) From cream air cooled and held at air temperature for 24 hours.

(2) From cream cooled and held in a tank of still water for a period of from 48 to 72 hours.

(3) From cream precooled with water and then stored at air temperature for 72 hours.

89.5-score butter could be made from cream air-cooled and kept at air temperature for 48 hours.

89-score butter could be made from cream air-cooled and kept at air temperature for 72 hours.

ECONOMIC ADVANTAGE OF USE OF FLOWING WATER

If cooling and storing in flowing water results in maintaining the quality of cream for a period up to 72 hours so that butter scoring two points higher can be made than when no cooling other than air cooling is used, this practice would result in greater returns to dairy farmers if they were paid in accordance with the market value of the cream.

With a difference of .95¢ in the market price between 90- and 92-score butter, which is the equivalent of 1.17¢ per pound of fat, the additional income from selling cream from which 92-score butter can be made would be—

For	100	pounds	of	fat	$ 1.17
For	1,000	pounds	of	fat	11.70
For	10,000	pounds	of	fat	117.00
For	100,000	pounds	of	fat	1,170.00
For	1,000,000	pounds	of	fat	11,700.00
For	10,000,000	pounds	of	fat	117,000.00
For	20,000,000	pounds	of	fat	234,000.00

With a difference of 1.35¢ in the market price between 91- and 89-score butter, which is equivalent to 1.67¢ per pound of fat, the additional income from selling cream from which 91-score butter can be made would be—

For	100	pounds	of	fat	$ 1.67
For	1,000	pounds	of	fat	16.70
For	10,000	pounds	of	fat	167.00
For	100,000	pounds	of	fat	1,670.00
For	1,000,000	pounds	of	fat	16,700.00
For	10,000,000	pounds	of	fat	167,000.00
For	20,000,000	pounds	of	fat	334,000.00

Methods of Cooling and Storing Cream for Oregon's Dairy Farms

Influence on the Quality of Butter Which Can Be Manufactured*

By

G. H. Wilster, Hans Hoffmann, and P. M. Brandt

IN the manufacture of butter of high quality, the use of cream that has a good flavor and a smooth texture is fundamental. The buttermakers know that the sweeter and fresher the cream is, the better is the opportunity to make good butter.

The flavor of a large percentage of the cream received by Oregon creameries is such that butter of only mediocre quality can be made from it. From a study of the manufacturing records accompanying the butter sent to the monthly educational butter scorings conducted by the State College during the five years beginning March 1929 and ending February 28, 1934, it has been noted that the cream used generally contained so much acid that neutralization was necessary. The most common defect in the 2,327 samples of butter examined during the five years was "old cream" flavor.

In view of these findings an experiment was conducted at the Oregon Agricultural Experiment Station having for its purpose a study of the conditions under which cream can be kept on farms so that 92-score butter can be made from it in the creameries. The present bulletin reports the findings obtained in this study.

EXTENT OF OREGON'S BUTTER INDUSTRY

The 224,780 cows on Oregon farms produced in 1929† 1,164,239,241 pounds of milk. Considering a fat content of this milk of 4.4 per cent, the total fat present was 51,226,527 pounds. The average yearly production of fat per cow was 228 pounds. A little more than one half of the milk was produced on the 8,150 more specialized dairy farms and the remainder was produced on 33,255 other farms.

Size of dairy herds. The number of dairy cows kept on the farms in Oregon is on an average small. In 1929 the average number of cows milked per farm was only 5. In Minnesota, the state which produces the most butter, the average number per farm during the same year was 8 (fraction omitted), while in Wisconsin, with the greatest number of cows of any state, the number of cows kept per farm was 11, or more than twice as many as were kept per farm in Oregon. The average number of cows milked per farm in the United States in 1929, calculated to the nearest whole number, was 5.

*The authors gratefully acknowledge the helpful suggestions regarding the preparing of the manuscript made by Professor F. E. Price.

†U. S. Census of Agriculture, 1930.

On one-half of 41,360 reporting farms in Oregon in 1929 where cows were milked, only from 1 to 3 cows were kept. A frequency distribution of the cows kept on these farms is shown in Table I.

Table I. SIZE OF MILKING HERDS ON 41,360 FARMS IN OREGON IN 1929*

Size of herds	Number of farms
1 to 3 cows	22,000
4 or 5 cows	6,700
6 to 10 cows	7,500
11 to 20 cows	3,900
21 or more cows	1,260

* Handbook of Dairy Statistics, U. S. Department of Agriculture, 1933.

Production of fat per farm. On the basis of the 1929 census figures, of 41,405 Oregon farms on which cows were milked and a production total of 51,226,527 pounds of fat, the average production of fat per farm was 1,237 pounds. During 1929 it was reported by the State Dairy and Food Commissioner that 24,396 producers had furnished 20,418,093 pounds of fat to 103 creameries from which 25,340,590 pounds of butter were manufactured. The average number of pounds of fat furnished by each producer was 837 pounds. This is less than the average production per farm for all the milk-producing farms in the state and is accounted for (a) partly by the duplication of names of producers furnishing cream to the creameries, since some producers sent intermittently to several creameries during the year, and (b) partly to the smaller number of cows kept on the farms which produce cream for butter than on the farms which produce market milk and milk for cheese.†

Amount of cream produced. If three pounds of cream contain one pound of fat, 61,254,279 pounds of cream contained the fat which was used for butter in 1929. The average yearly production of cream per farm was approximately 2,500 pounds, or 7 pounds each day.

Table II. POUNDS OF CREAM FURNISHED BY PRODUCERS TO EIGHT OREGON CREAMERIES IN 1931

Creameries	Number of producers who furnished cream	Average pounds of cream‡ furnished creamery by each producer per year	Average daily pounds of cream furnished creamery by each producer
		Pounds	Pounds
Coast			
Creamery A	125	3,960	10.9
Creamery B	612	6,280	17.2
Eastern and Southern Oregon			
Creamery A	400	2,316	6.3
Creamery B	400	5,379	14.7
Willamette Valley (Southern part)			
Creamery A	800	2,224	6.1
Creamery B	750	2,419	6.6
Willamette Valley (Northern part)			
Creamery A	725	5,328	14.6
Creamery B	445	1,687	4.6

‡ Three pounds of cream are considered to contain one pound of fat.

If the duplication of names of producers who delivered cream to the creameries is considered, the average amount of cream furnished daily by each producer is estimated to be 10 pounds. It would thus require the production of four days to fill a five-gallon can.

† See Bul. 318, Oregon Agri. Exp. Sta. 1933, p. 73.

The data shown in Table II are taken from a report for 1931 by the Chief of the Division of Food and Dairies, Oregon State Department of Agriculture. It is understood that the producers who furnished the creameries listed with cream do not, as a rule, change from one creamery to another. Hence data may be considered indicative of the amount of cream produced by average-sized farms and delivered to Oregon creameries.

THE QUALITY OF CREAM DELIVERED TO OREGON CREAMERIES

Frequency of delivery. In the delivery of cream to Oregon creameries, the following systems are followed:

1. Auto truck, which picks up the cream at the farm.
2. Cream station—
   (a) Direct delivery by producer.
   (b) Auto truck on route.
3. Direct shipment from farm by truck or train.
4. Individual delivery to creamery by producer.

A study of the frequency of delivery of cream to 60 creameries* was made during the summer, fall, and winter months of 1928 and during the winter months of 1929.

Deliveries were commonly made once or twice weekly. Only eight creameries reported receiving cream three times a week. One creamery reported receiving individual deliveries daily as well as receiving cream once weekly at stations.

Acidity of cream delivered. In the study referred to in the preceding discussion it was noted that no creamery received 100 per cent of its cream in a sweet condition (less than 0.2 per cent acid calculated as lactic). Of the sixty creameries, only one received more than three-fourths of its cream in a sweet condition during the summer. In this instance the cream was gathered by truck. During the winter months six creameries received more than three-fourths of the cream sweet. Four of these received the cream by individual deliveries, one by truck, and one by cream station.

The greatest percentage of the cream delivered to the majority of the creameries contained from 0.2 to 0.6 per cent acid. Nearly all sixty creameries received a certain percentage of cream with an acid content of 0.7 per cent or above. A greater percentage of the cream fell in the high acid group during the summer months than during the fall and winter months. Some creameries received a large percentage of cream with an acid content of 0.7 per cent acid and above during the warm season.

When this study was made, a number of creameries paid a differential for the different grades of cream. Some paid a premium of from 2¢ to 5¢ per pound of fat in sweet cream; some paid a premium of from 2¢ to 4¢

* Larrabee, E. S., Wilster, G. H., 1929, *The Butter Industry of Oregon*, Bul. 258, Ore. Agr. Exp. Sta.

per pound of fat in sweet cream and made a deduction of from 2¢ to 5¢ per pound of fat for second-grade cream. Others paid no premium for sweet cream but made a deduction of from 2¢ to 5¢ per pound of fat for second-grade cream. The method of paying a differential for the different grades of cream has been less common during the years 1930-1934. Whenever a differential has been paid it has, in general, been less than during 1928 and 1929. Butter prices during 1928 and 1929 were higher than they were during the years immediately following, and the difference between the price of the various grades of butter was larger. In 1928 the difference between the wholesale cube price for 92- and 90-score butter on the Portland Dairy Exchange was 1.62¢, which is equivalent to 2¢ per pound of fat. In 1933 the difference was only 0.95¢ per pound of butter, which is equivalent to 1.17¢ per pound of fat. Whenever a premium has been paid for sweet cream during the years 1930-1934, it has generally amounted to either 1¢ or 2¢ per pound of fat.

Quality of cream delivered at present. No study of the quality of the cream delivered to the creameries in the state has been conducted since 1929. Because of the low prices for butterfat and the small premium that has been paid for sweet cream, it is not likely that much improvement in cream quality has taken place since 1929. It is possible that because of better transportation methods through the construction of better roads and the more general development of the truck-gathering system, cream is delivered to the creameries at more frequent intervals.

RESUMÉ OF PREVIOUS WORK REGARDING COOLING AND STORING CREAM

Hunziker, Mills, and Switzer* in 1916 studied the effect of cooling cream by water as compared with cooling it by setting the cans on the floor of the room without the use of water. Cream produced on forty farms near Purdue University was used. One half of the producers held the cream on the farm in cooling tanks with water temperatures ranging from 54° to 68° F., and averaging 58.8° F. The other half held the cream under atmospheric-temperature conditions with temperatures ranging from 42° to 87° F., and mean daily temperatures ranging from 56° to 75° F. The cream was gathered by trucks twice weekly. The tank cream had an average acidity when delivered of 0.38 per cent, and the no-tank cream had an average acidity of 0.52 per cent. The tank cream contained an average of 147,125,000 bacteria per c.c. when delivered to the creamery, and the no-tank cream contained 226,750,000 bacteria per c.c.

The average score of the butter from the tank-cooled cream was 90.69 and that for the butter from the no-tank cream was 88.36. This was a difference of 2.33 points in favor of the butter made from the cream which was cooled by water.

A later experiment by Manhart† of the same experiment station, which also involved a study of water cooling as compared with cooling by air

* Hunziker, O. F., Mills, H. C., and Switzer, H. B., 1916, *Cooling Cream on the Farm*, Bul. 188, Indiana Agr. Exp. Sta.

† Manhart, V. C., 1925, *Cooling Cream on the Farm for Buttermaking*, Bul. 290, Indiana Agr. Exp. Sta.

under atmospheric conditions, further showed the advantage of cooling by water.

In a series of experiments it was found that water cooling increased the score of the resulting butter from 87 to 90 when the cream was delivered at four-day intervals, and from 86 to 88 when delivered at seven-day intervals.

In another experiment Manhart* studied the effect of the time element in the marketing of station cream on the quality of the cream and on the resultant butter. He found that the average score of 31 churnings of butter made from cream delivered by the producer to the cream stations at intervals of from one to four days with the majority of the deliveries at three- and four-day intervals was 88.5 points. When the deliveries were made at intervals of from four to twenty-one days, with the majority of the deliveries made at seven-day or longer intervals, the average score of the resultant butter from 32 churnings was 87.28. The difference in favor of the average score of the fresher cream was 1.22 points.

In a survey of the marketing of cream in Illinois, with special reference to the quality of cream, Brown† found that of a total number of producers of 1544, 1.3 per cent cooled the cream by running water, 4.8 per cent used tubs of water, 9.1 per cent used ice boxes, 8.8 per cent used tanks of water, and 76.0 per cent used no special cooling methods but allowed the cream in the can to cool by air by setting the can most generally in a basement. He found that 84.3 per cent of the farmers failed to cool the fresh cream previous to pouring it into the storage can. As a concluding statement to the study, the investigator suggests that the butter industry in his state would make much progress if a cream-improvement program that provided for payment for cream on the quality basis were generally adopted.

In an experiment which involved a study of cooling and storing cream, Barr‡ found that the acidity of cream kept in cans in a cellar with the air at a temperature of 63.5° F. was 0.47 per cent at the end of 36 hours and 0.50 per cent at the end of 60 hours. When the cream was held in ice water, the acidity was 0.157 per cent at the end of 36 hours, and 0.165 per cent at the end of 60 hours.

Previous work at the Oregon Agricultural Experiment Station§ in connection with studies on the cooling of cream produced by careful methods has shown that:

(1) Three gallons of cream with a beginning temperature of 80° F. when kept in a five-gallon can held in a tank of water at 60° F. and the water changed twice daily remained sweet for 18 hours but had an acidity of from 0.4 to 0.5 per cent after 42 hours.

(2) Three gallons of cream with a beginning temperature of 80° F. when kept in a five-gallon can held in a tank of water at 50° F. and the water changed twice daily contained 0.20 per cent acid at the end of 42 hours and 0.41 per cent acid at the end of 66 hours.

* Manhart, V. C., 1933, *Effect of the Time Element in Marketing Cream for Buttermaking on Quality*, Bul. 383, Indiana Agr. Exp. Sta.

† Brown, C. A., 1934, *Quality of Market Cream in Illinois, Factors Affecting it and Methods of Improvement*, Bul. 396, University of Illinois Agr. Exp. Sta.

‡ Barr, Geo. H., 1931, *The Care of Cream for Buttermaking*, Pamphlet No. 37, New Series. Department of Agriculture, Ottawa, Canada.

§ Price, F. E., Hurd, C. J., and Wilster, G. H., 1932, *Cream Refrigeration on the Farm and the Quality of Butter Manufactured*, Bul. 305, Oregon Agr. Exp. Sta.

(3) Three gallons of cream with a beginning temperature of 80° F. when kept in a five-gallon can held in water at from 35° to 40° F. remained sweet and of good quality for four days (90 hours) so that 92- to 93-score butter could be made from it.

CLIMATOLOGICAL DATA

It is customary on many farms in Oregon to use no special methods for cooling cream after it is obtained from the separator. The cream is simply placed in a can and this left in a cool place, either on a porch on the north side of the farmhouse, or in the shade of a tree. The results of a study of the temperatures of the air which are common in different parts of Oregon will give an idea regarding the temperature which the cream will acquire when it is stored under the above conditions.

The following temperature data were obtained from the Weather Bureau, United States Department of Agriculture. The data are averages obtained from periods ranging from 12 to 70 years.

Table III. MEAN MINIMUM, MEAN MAXIMUM, AND MEAN TEMPERATURES IN OREGON

	Mean minimum temperature		Mean maximum temperature		Mean temperature	
	January	July	January	July	January	July
	Degrees F.	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Degrees F.*
Coast Section						
Astoria	35.4	54.2	46.0	68.7	40.1	60.7
Newport	37.5	49.5	49.8	64.1	43.8	56.8
Marshfield	36.6	50.5	51.4	67.8	44.0	59.1
Willamette Valley						
Portland	34.0	56.1	44.1	77.9	39.0	67.0
Corvallis	32.9	50.2	45.0	80.2	39.0	65.2
Eugene	34.0	51.4	46.0	80.1	40.0	65.8
Southern Oregon						
Grants Pass	31.2	49.7	46.6	89.4	39.0	69.5
Medford	30.2	52.6	45.6	90.5	37.9	71.5
Eastern Oregon						
Bend	20.0	43.7	41.0	84.5	30.5	64.2
Burns	11.0	46.6	35.8	86.2	24.5	66.9
Umatilla	25.4	61.1	39.3	92.6	32.1	76.1
Baker	18.0	49.0	32.7	78.1	25.7	66.1

The data presented show that during the winter months the mean temperature in all sections is low enough greatly to check bacterial growth in cream if the cream is of that temperature. In three sections the mean temperature was below the freezing point of water. In some sections there were a number of days during the winter months when the temperatures were so high that bacterial growth was stimulated. For instance, the temperature rose to maxima of 64°, 58°, 67°, and 59° F., respectively, during the months January, February, November, and December in 1931 at Portland.

During the month of July, the mean temperature in all sections was high enough to cause fairly rapid development of the bacteria in cream if the temperature of cream reached the mean temperature.

It is quite probable that if cream is kept in cans for several days at atmospheric temperature when the temperature during the warmest hours reaches about 90° or 100° F., the temperature of the cream may exceed the mean atmospheric temperature for the 24 hours.

If cream is to be kept on the farm for some time before it is sent to the creamery, it is desirable to cool it quickly to a temperature that will retard bacterial development and to keep it at this temperature until time of shipping.

Even when the temperature of the water available on the farm during the warm season is only slightly lower than the mean temperature of the air, it is advisable to use water for cooling, since the water hastens cooling.

Previous experiments at the Oregon Agricultural Experiment Station* have shown that cooling by air is very slow. It required seven hours for three gallons of cream contained in a five-gallon can to cool from 80° F. to 56° F. when the can was kept in an ice-cooled refrigerator with an average temperature of 45° F. When the can was placed in a tank of 50° F. water, it took only three hours to cool the cream to 56° F.

PLAN OF THE EXPERIMENT

In planning the experiment it was decided to study the following factors with reference to their effects on the quality of cream:

1. Cooling five gallons of cream at 90° F. by placing the can on the floor in the room, using the air in the room as the cooling medium.
2. Cooling and storing cream by placing a five-gallon can of cream at 90° F. in a tank of still water.
3. Cooling and storing cream by placing a five-gallon can of cream at 90° F. in a tank of flowing water.
4. Cooling five gallons of cream at 90° F. by a Hydro-Vac cooler, then storing the cream by placing the can in either a tank of flowing or still water or on the floor in the room without using water.

The cream used was obtained either from farmers delivering sweet cream to a Corvallis creamery or it was cream separated from surplus market milk. A sample was taken from each batch of cream as soon as it was delivered to the State College Creamery to be used for the determination of bacteria present, the acid content, and the fat content. The numbers of bacteria present were determined by the plate method in accordance with the standard method recommended by the American Public Health Association. The acidity was determined by titration with tenth-normal sodium hydroxide and the acid expressed as lactic acid. When making the acid determination 9 grams of cream were used. This was diluted with about 10 c.c. of water and brought to a boil so as to eliminate carbon dioxide. After slight cooling of the diluted cream the titration was made. Fat tests were made by the Babcock method.

As soon as possible after the cream was received it was divided into four parts by filling four new five-gallon cans with cream. Each can was

* F. E. Price, C. J. Hurd, and G. H. Wilster, 1932, *Cream Refrigeration on the Farm and the Quality of Butter Manufactured,* Bul. 305, Oregon Agr. Exp. Sta.

handled separately. All the work of cooling and storing was done in a room in the Dairy Building at the State College. This room had a concrete floor. Whenever it was desired to raise the air temperature in the room a steam radiator was used.

The tank used for cooling the cream in still water was made of galvanized iron. Its dimensions were 18" x 18" x 32", inside measurements, and it held 30 gallons of water after one can of cream was placed in it. The tank used for cooling the cream in flowing water was made from wood and was 11¾" x 17" x 27⅛" inside measurements. The amount of water entering the tank was regulated to one gallon per minute.

The Hydro-Vac cooler* was a device for stirring the cream in the can by means of a small propeller, this being driven by a water wheel. The water used for this was conducted to the outside surface of the can for the purpose of absorbing heat from the cream inside. The cooling by the Hydro-Vac, using city water, occupied 20 minutes, after which the cream was stored as already described.

Six trials in all were made, a different lot of cream being used for each trial. The temperatures of the air of the room during the three first trials were normal and were not adjusted, while during the last three trials the temperature was increased by means of a steam radiator. The temperature of the water used was not adjusted except in trial 4 when the still water at the time of placing it in the tank was regulated to a temperature of 60° F. Corvallis city water, originating on a mountain west of Corvallis, was used in all trials. The temperature of this water ranged, during the period of the experimental work, from 47° to 54° F.

At the end of each three- or four-day storage period the cream cooled and held by each of the four different methods was scored and the quality of butter that could be made from each lot of cream was estimated. The cream was judged by two members of the Dairy department staff. The cans were numbered by a third member. Thus those who did the judging had no information regarding the method used in cooling and storing each can of cream.

It is realized that the work would have been more complete if butter had been made from each lot of cream and the quality of the resultant butter determined. However, in view of the difficulty that would have been experienced in properly neutralizing, pasteurizing, and churning the small batches of cream uniformly, it was decided that it would be better to omit the making of butter. The quality of butter that could be made under average conditions from the 24 different lots of cream was determined in accordance with the flavor of the cream and the acidity, the experience of the two judges serving as a guide. Whenever it is stated in this publication that a certain quality of butter can be made, the score of the butter is based on the opinion and experience of the judges.

RESULTS OF THE EXPERIMENTAL WORK

Trial 1. In this trial the cream used contained 25 per cent of fat. The acidity of the cream when the test was started was 0.12 per cent and the

* Lent for the experiment by the Hydro-Vac Company, Batavia, Ill.

number of bacteria per c.c. was 85,000. One can of cream was held in the room at air temperature, one can was kept in a tank of still water, one can was held in flowing water, and one can was first cooled with the Hydro-vac cooler and then placed in a tank of flowing water. With all methods of cooling, the temperature of the cream before commencing the test was regulated to 90° F.

It should be noted that the air temperature showed similar variations during the first two 24-hour periods but during the period 48 to 74 hours the minimum temperature dropped to 44° F.

Table IV. RESULTS OF COOLING CREAM BY FOUR DIFFERENT METHODS: Trial 1

	Begin	24 hours	48 hours	72 hours
1. *Cream air-cooled* (Minimum air temperature 44° F. Maximum air temperature 62° F.)				
Temperature of cream	90°F.	60°F.	56°F.	49°F.
Temperature of air	.....	51°–62°F.	51°–60°F.	44°–62°F.
Acidity	0.12%	0.64%	0.67%	0.70%
Bacteria per c.c.	85,000	3,650,000	1,150,000	870,000
Score of cream	93, fine	.....	.....	89, sour, vinegar, musty
Score of butter that can be made	93	90–91	89–90	89 or lower
2. *Can of cream held in still water* (Temperature of water when placed in tank 47°–49°F. Water changed at end of each 24 hours.)				
Temperature of cream	90°F.	54°F.	51°F.	51°F.
Temperature of air	.....	51°–62°F.	51°–60°F.	44°–62°F.
Temperature of water in tank at end of each period	.....	54°F.	52°F.	47°F.
Temperature of water placed in tank	47°F.	48°F.	49°F.	48°F.
Acidity	0.12%	0.28%	0.60%	0.63%
Bacteria per c.c.	85,000	3,700,000	6,600,000	480,000
Score of cream	93, fine	.....	.....	91, sour
Score of butter that can be made	93	91–92	91	91
3. *Can of cream held in tank of flowing water* (Temperature of water entering tank 47°–49° F.)				
Temperature of cream	90°F.	51°F.	50°F.	50°F.
Temperature of air	.....	51°–62°F.	51°–60°F.	44°–62°F.
Temperature of water in tank at end of each period	.....	51°F.	50°F.	49°F.
Temperature of in-going water	47°F.	48°F.	49°F.	48°F.
Acidity	0.12%	0.15%	0.47%	0.61%
Bacteria per c.c.	85,000	7,300,000	9,000,000	1,250,000
Score of cream	93	.....	.....	91, sour
Score of butter that can be made	93	92	91	91
4. *Cream cooled with Hydro-Vac cooler, then held in tank of flowing water* (Temperature of water entering tank 47°–49° F.)				
Temperature of cream	90°F.	51°F.	50°F.	50°F.
Temperature of cream after 20 minutes	50°F.	.....	.....	.....
Temperature of air	.....	51°–62°F.	51°–60°F.	44°–62°F.
Temperature of water in tank at end of each period	.....	51°F.	50°F.	49°F.
Temperature of in-going water	47°F.	48°F.	49°F.	48°F.
Acidity	0.12%	0.15%	0.31%	0.61%
Bacteria per c.c.	85,000	2,200,000	16,900,000	1,910,000
Score of cream	93, fine	.....	.....	91, sour
Score of butter that can be made	93	92	91	91

The results obtained in this experiment show that 92-score butter could be made from the cream both when it was cooled in a tank of flowing water and when it was cooled first by the Hydro-Vac cooler for 20 minutes and then kept in flowing water with the water at temperatures ranging from 47° to 49° F. when the cream was kept for not more than 24 hours. At the end of 72 hours of holding, only 91-score butter could be made.

When the cream was kept for not longer than 24 hours in still water, with the temperature of the water when placed in the tank ranging from 47° to 49° F., 91- and perhaps 92-score butter could be made.

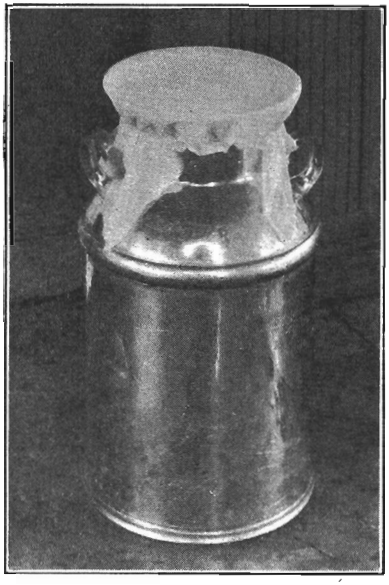

Figure 1. Can of cream cooled in the air—an inefficient method. Note the clean cloth over the mouth of the can. This keeps out insects and other foreign matter.

Air cooling proved the least effective. Butter scoring only 90 or 91 could be made from the cream when it was kept for 24 hours, while after the cream had been stored for 72 hours, the flavor of the cream was pronounced sour and vinegary and butter scoring only 89 or less could be made.

It should be noted that the bacterial counts first showed marked increases and then were followed by decreases during the 72 hours. The decreases were probably caused by the dying-off of bacteria as the cream became older and the acid in the cream increased.

Little change took place during the first 24 hours in the acidities of cream cooled and held in flowing water, while the acidity of cream held in air and in still water increased considerably during this period.

Trial 2. The cream in trial 2 contained 38 per cent fat. The acidity of the cream when it was received was 0.12 per cent and the number of bacteria per c.c. was 2,330,000.

The conditions of this trial were similar to those in trial one. The only difference in handling was that the can of cream after having been cooled with the Hydro-Vac cooler for 20 minutes was held on the floor of the room without the use of water.

Although the fresh cream contained a relatively large number of bacteria the flavor was very good, and it would have been possible to make high-scoring butter from it. It is probable that the bacteria had come from unsterile equipment used on the farm. Any flavor resulting from fermentation brought about by these bacteria was not evident.

This cream did not keep very well by any of the methods used. Some acid had been produced by the bacteria in the water-cooled cream during

Table V. RESULTS OF COOLING CREAM BY FOUR DIFFERENT METHODS: Trial 2

	Begin	24 hours	48 hours	72 hours	96 hours
1. *Cream air-cooled* (Minimum air temperature 51°F. Maximum air temperature 65° F.)					
Temperature of cream	90°F.	59°F.	55°F.	56°F.	55°F.
Temperature of air	.....	52°–65°F.	51°–61°F.	52°–61°F.	52°–61°F.
Acidity	0.12%	0.44%	0.49%	0.56%	0.60%
Bacteria per c.c.	2,330,000	70,000,000	73,000,000	10,700,000	4,800,000
Score of cream	93, fine	.....	.....	.....	89, sour, yeasty, fermented
Score of butter that can be made	93	90–91	89–90	89	89 or lower
2. *Can of cream held in tank of still water* (Temperature of water when placed in tank 47°–49°F. Water changed at end of every 24 hrs.)					
Temperature of cream	90°F.	54°F.	54°F.	57°F.	54°F.
Temperature of air	.....	52°–65°F.	51°–61°F.	52°–61°F.	52°–61°F.
Temperature of water in tank, end each period	.....	54°F.	54°F.	57°F.	54°F.
Temperature of water placed in tank	47°F.	48°F.	48°F.	49°F.	.....
Acidity	0.12%	0.22%	0.38%	0.46%	0.50%
Bacteria per c.c.	2,330,000	89,000,000	54,000,000	21,000,000	5,100,000
Score of cream	93	.....	.....	.....	89, sour, yeasty, fermented
Score of butter that can be made	93	91–92	91	90	89
3. *Can of cream held in tank of flowing water* (Temperature of water ent'ng tank 47°–49°F.)					
Temperature of cream	90°F.	51°F.	52°F.	52°F.	52°F.
Temperature of air	.....	52°–65°F.	51°–61°F.	52°–61°F.	52°–61°F.
Temperature of water in tank, end each period	.....	51°F.	51°F.	52°F.	52°F.
Temperature of in-going water	47°F.	48°F.	48°F.	49°F.	.....
Acidity	0.12%	0.21%	0.38%	0.42%	0.47%
Bacteria per c.c.	2,330,000	86,000,000	69,000,000	27,000,000	14,300,000
Score of cream	93	.....	.....	.....	89, sour
Score of butter that can be made	93	91–92	91	90	89
4. *Cream cooled with Hydro-Vac cooler then held in air* (Air temp. 51°–65°F.)					
Temperature of cream	90°F.	54°F.	54°F.	56°F.	55°F.
Temperature of cream after 20 minutes	51°F.	.....	.....	.....	.....
Temperature of air	.....	52°–65°F.	51°–61°F.	52°–61°F.	52°–61°F.
Acidity	0.12%	0.21%	0.40%	0.47%	0.51%
Bacteria per c.c.	2,330,000	77,000,000	61,000,000	32,000,000	8,700,000
Score of cream	93	.....	.....	.....	89, sour yeasty, fermented
Score of butter that can be made	93	91–92	91	90	89

the first 24 hours and considerable acid had developed in the air-cooled cream during this period. At the end of 24 and 48 hours, a large number of bacteria were present in the cream handled by all four methods, but many of these died during the following two periods.

It was felt by the judges that 91- and perhaps 92-score butter could be made from the cream that had been water cooled after it had been held for 24 hours, whereas butter scoring only 90 or 91 could be made from the air-cooled cream kept for that length of time.

It is significant that cream cooled for 20 minutes by the Hydro-Vac cooler and the can of cream then left exposed to the air, kept considerably better than cream exposed to the air without precooling with water.

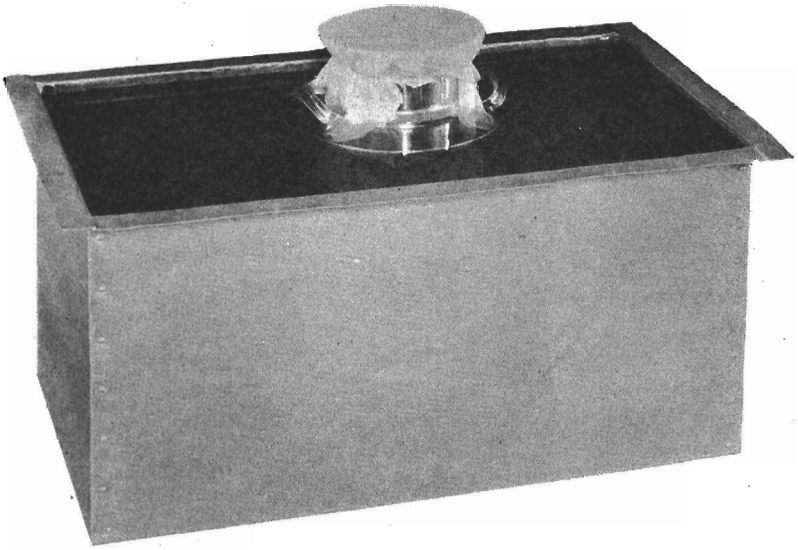

Figure 2. Cooling and storing cream in a tank of still water, a satisfactory method when running water is not available.

Trial 3. The methods used in this trial were identical with those used in the previous two trials with the exception that the cream that was cooled for 20 minutes with the Hydro-Vac cooler was afterwards kept in a tank of still water.

The cream used did not have as good a flavor when received as the cream used in the preceding trials. The number of bacteria in the cream when received was 12,100,000 per c.c. and the acidity was 0.16 per cent, which indicates that some of the lactose in the cream had been changed by bacteria to lactic acid. The fat test of the cream was 33 per cent.

Only 91-score butter could be made from the water-cooled cream after this had been held for 24 hours. After 72 hours of holding, butter scoring 89 or 90 could be made.

The air-cooled cream did not keep as well as the water-cooled cream and a larger number of bacteria developed in this cream than in the cream handled by the other three methods.

The results show that when large numbers of bacteria were present in the fresh cream, water cooling could not be depended on to prevent

Table VI. RESULTS OF COOLING CREAM BY FOUR DIFFERENT METHODS: Trial 3

	Begin	24 hours	48 hours	72 hours
1. *Cream air-cooled* (Minimum temperature 51° F. Maximum temperature 61° F.)				
Temperature of cream	90°F.	59°F.	56°F.	55°F.
Temperature of air	.....	51°–61°F.	52°–61°F.	52°–61°F.
Acidity	0.16%	0.51%	0.56%	0.63%
Bacteria per c.c.	12,100,000	200,000,000	270,000,000	145,000,000
Score of cream	92	.....	.....	89, sour, fermented
Score of butter that can be made	92	90	90	89
2. *Can of cream held in tank of still water* (Temperature of water when placed in tank 48°–49° F. Water changed at the end of every 24 hours.)				
Temperature of cream	90°F.	54°F.	57°F.	54°F.
Temperature of air	.....	51°–61°F.	52°–61°F.	52°–61°F.
Temperature of water in tank at end of each period	.....	54°F.	57°F.	54°F.
Temperature of water placed in tank	49°F.	48°F.	49°F.	.....
Acidity	0.16%	0.31%	0.54%	0.56%
Bacteria per c.c.	12,100,000	89,000,000	68,000,000	86,000,000
Score of cream	92	.....	.....	90, sour
Score of butter that can be made	92	91	90	90
3. *Can of cream held in tank of flowing water* (Temperature of water entering tank ranging 48°–49° F.)				
Temperature of cream	90°F.	52°F.	52°F.	52°F.
Temperature of air	.....	51°–61°F.	52°–61°F.	52°–61°F.
Temperature of water in tank at end of each period	.....	51°F.	52°F.	52°F.
Temperature of in-going water	49°F.	48°F.	49°F.	.....
Acidity	0.16%	0.29%	0.48%	0.56%
Bacteria per c.c.	12,100,000	73,000,000	65,000,000	91,000,000
Score of cream	92	.....	.....	90
Score of butter that can be made	92	91	90–91	sl. cheesy 90
4. *Cream cooled with Hydro-Vac cooler, then held in tank of still water* (Temperature of water placed in tank 48°–49° F.)				
Temperature of cream	90°F.	54°F.	57°F.	54°F.
Temperature of cream after 20 minutes of cooling	52°F.	.....	.....	.....
Temperature of air	.....	51°–61°F.	52°–61°F.	52°–61°F.
Temperature of water in tank at end of each period	.....	54°F.	57°F.	54°F.
Temperature of water placed in tank	49°F.	48°F.	49°F.	.....
Acidity	0.16%	0.28%	0.53%	0.58%
Bacteria per c.c.	12,100,000	52,000,000	82,000,000	66,000,000
Score of cream	92	.....	.....	89 cheesy, vinegary, high acid
Score of butter that can be made	92	91	90	89

(1) development of still larger numbers of organisms, (2) the production of considerable acid, and (3) an undesirable flavor.

Trial 4. In trials 1, 2, and 3 the maximum temperature of the air in the room in which the cream was kept during the four-day storage period ranged from 60° to 65° F. During trials 4, 5, and 6, the maximum temperature was maintained at from 80° to 87° F.

The methods used in trial 4 were similar to those in the preceding trials. When the Hydro-Vac cooler was used the can of cream after cooling was placed in a tank of still water.

The cream used contained 33 per cent fat. The acidity of the cream when it was received was 0.09 per cent, and the number of bacteria present per c.c. was 550,000.

Table VII. RESULTS OF COOLING CREAM BY FOUR DIFFERENT METHODS: Trial 4

	Begin	24 hours	48 hours	72 hours
1. *Cream air-cooled* (Minimum temperature 65° F. Maximum temperature 86° F.)				
Temperature of cream	90°F.	73°F.	71°F.	Discont'd
Temperature of air	80°F.	65°–86°F.	67°–80°F.	
Acidity	0.09%	0.60%	0.64%	
Bacteria per c.c.	550,000	16,600,000	20,200,000	
Score of cream	93	.....	90 cheesy, sour	
Score of butter that can be made	93	90	90	
2. *Can of cream held in tank of still water* (Temperature of water when placed in tank 60° F. Water changed at the end of every 24 hours.)				
Temperature of cream	90°F.	63°F.	62°F.	68°F.
Temperature of air	80°F.	65°–86°F.	67°–80°F.	68°–87°F.
Temperature of water in tank at end of each period	.....	65°F.	65°F.	70°F.
Temperature of water placed in tank	60°F.	60°F.	60°F.	.....
Acidity	0.09%	0.39%	0.55%	0.58%
Bacteria per c.c.	550,000	21,300,000	7,300,000	460,000
Score of cream	93	.....	.....	90 sl. cheesy, sour
Score of butter that can be made	93	91	90	90
3. *Can of cream held in tank of flowing water* (Temperature of water entering tank ranging from 50°–51° F.)				
Temperature of cream	90°F.	51°F.	53°F.	53°F.
Temperature of air	80°F.	65°–86°F.	67°–80°F.	68°–87°F.
Temperature of water in tank at end of each period	.....	51°F.	53°F.	53°F.
Temperature of in-going water	51°F.	50°F.	51°F.	.....
Acidity	0.09%	0.11%	0.24%	0.48%
Bacteria per c.c.	550,000	10,100,000	26,400,000	14,700,000
Score of cream	93	.....	.....	91 sl. sour
Score of butter that can be made	93	92	91–92	91
4. *Cream cooled with Hydro-Vac cooler, then held in tank of still water* (Temperature of water when placed in tank 60°F. Water changed at end of every 24 hours.)				
Temperature of cream	90°F.	63°F.	62°F.	68°F.
Temperature of cream after 20 minutes of cooling	63°F.	.....	.....	.....
Temperature of air	80°F.	65°–86°F.	67°–80°F.	68°–87°F.
Temperature of water in tank at end of each period	.....	65°F.	65°F.	70°F.
Temperature of water placed in tank	60°F.	60°F.	60°F.	.....
Acidity	0.09%	0.36%	0.53%	0.58%
Bacteria per c.c.	550,000	13,400,000	5,800,000	5,100,000
Score of cream	93	.....	.....	90 sl. cheesy
Score of butter that can be made	93	91	90	90

The cream kept in the tank of flowing water remained sweet for twenty-four hours so that 92-score butter could be made from it at the end of that period. When the cream was kept in still water with the water at 60° F. when it was placed in the tank, both when the Hydro-Vac cooler

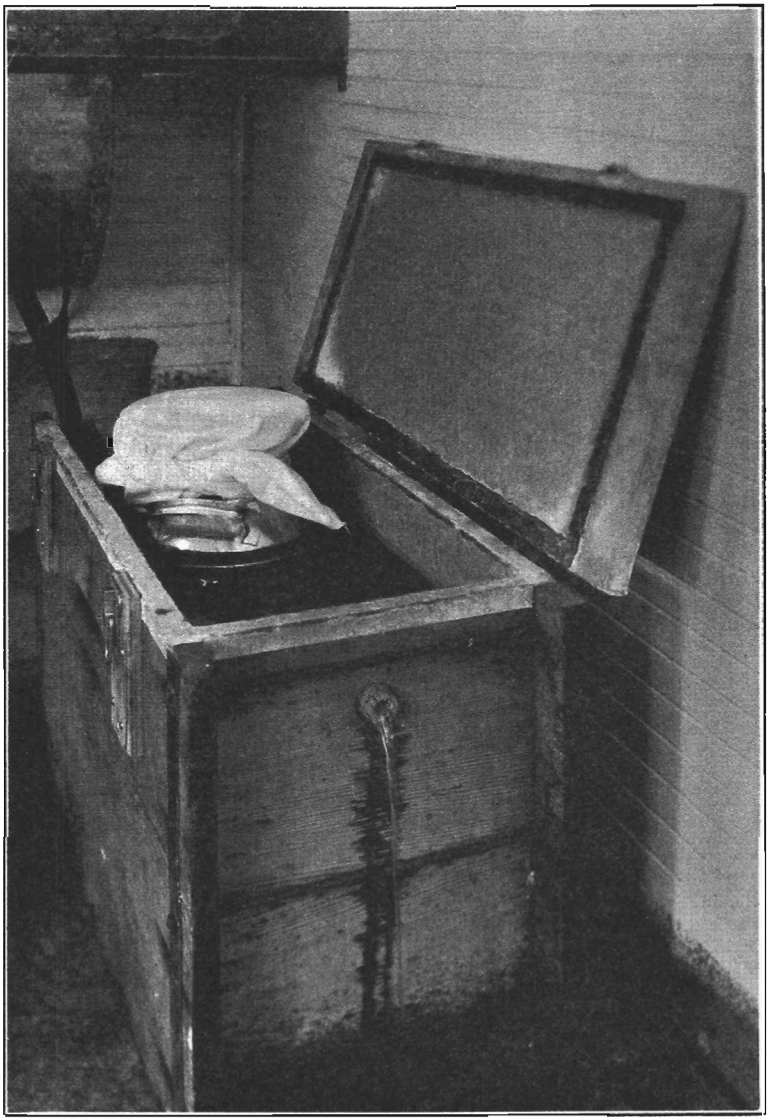

Figure 3. Cooling and storing cream in a tank of flowing water. This was the most satisfactory method. Butter scoring an average of 92 could be made when the cream was cooled and stored by this method for 24 hours, and butter scoring an average of 91 could be made at the end of 72 hours.

was first used and when it was not used, the acid in the cream was nearly 0.40 per cent at the end of 24 hours, so that only 91-score butter could be made. Because of the high air temperature, the can of cream kept on the floor of the room without the use of water soon showed a high acidity with an accompanying development of an objectionable flavor. Hence it was decided to keep it for only 48 hours.

The results obtained are significant, because they show that it was possible to keep cream in flowing water for 24 and up to 48 hours without

Table VIII. RESULTS OF COOLING CREAM BY FOUR DIFFERENT METHODS: Trial 5

	Begin	24 hours	48 hours	72 hours
1. *Cream air-cooled* (Minimum temperature 67° F. Maximum temperature 85° F.)				
Temperature of cream	90°F.	78°F.	75°F.	Discont'd
Temperature of air	84°F.	70°–85°F.	67°–82°F.	
Acidity	0.09%	0.55%	0.61%	
Bacteria per c.c.	900,000	500,000	100,000	
Score of cream	93	.....	89, high acid, sl. cheesy	
Score of butter that can be made	93	90	89	
2. *Can of cream held in tank of still water* (Temperature of water when placed in tank 51°–54° F. Water changed at the end of every 24 hours.)				
Temperature of cream	90°F.	70°F.	68°F.	69°F.
Temperature of air	84°F.	70°–85°F.	67°–82°F.	67°–83°F.
Temperature of water in tank at end of each period	.....	72°F.	71°F.	71°F.
Temperature of water placed in tank	51°F.	52°F.	54°F.	.....
Acidity	0.09%	0.43%	0.53%	0.56%
Bacteria per c.c.	900,000	7,800,000	370,000	570,000
Score of cream	93	.....	.....	90, yeasty
Score of butter that can be made	93	91	90	90
3. *Can of cream held in tank of flowing water* (Temperature of water when entering tank 51°–54° F.)				
Temperature of cream	90°F.	55°F.	54°F.	53°F.
Temperature of air	84°F.	70°–85°F.	67°–82°F.	67°–83°F.
Temperature of water in tank at end of each period	.....	55°F.	54°F.	53°F.
Temperature of in-going water	51°F.	52°F.	54°F.	53°F.
Acidity	0.09%	0.14%	0.42%	0.46%
Bacteria per c.c.	900,000	14,000,000	5,700,000	1,180,000
Score of cream	93	.....	.....	91, high acid
Score of butter that can be made	93	92	91	91
4. *Cream cooled with Hydro-Vac cooler, then held in tank of flowing water* (Temperature of water when entering tank 51°–54° F.)				
Temperature of cream	90°F.	55°F.	54°F.	53°F.
Temperature of cream after 20 minutes of cooling	58°F.	.....	.....	.....
Temperature of air	84°F.	70°–85°F.	67°–82°F.	67°–83°F.
Temperature of water in tank at end of each period	.....	55 F.	54°F.	53°F.
Temperature of in-going water	51°F.	52°F.	54°F.	53°F.
Acidity	0.09%	0.13%	0.42%	0.46%
Bacteria per c.c.	900,000	13,500,000	4,200,000	540,000
Score of cream	93	.....	.....	91, high acid
Score of butter that can be made	93	92	91	91

excessive acidity and objectionable flavor developing in it when the temperature of the water which was flowing into the tank was 50° to 51° F., even though the temperature of the air in the room reached 80° to 86° F. during a number of hours each day. Air cooling, on the other hand, when the temperature ranged from 65° F. during the night to 86° F. during the day was unsatisfactory. A high acidity and an objectionable flavor developed in the cream already during the first 24 hours of holding.

Trial 5. The cream used in trial 5 contained nearly a million bacteria per c.c., but the flavor of the fresh cream when received was very good. The acidity of the fresh cream was 0.09 per cent. The cream contained 41 per cent fat.

The usual four methods of cooling and storing were used. In the case of the fourth method, after the cream had been cooled with water by the Hydro-Vac cooler, the cream was kept for the remainder of the test in a tank of flowing water.

The results obtained show that water cooling by methods 3 and 4 using flowing water, was effective in maintaining the quality of the cream satisfactorily for 24 hours so that 92-score butter could be made at the end of that time. Even keeping the cream for 72 hours would result in butter scoring 91.

On account of the high atmospheric temperature, when the cream was kept in still water the water temperature had increased during each 24-hour period to 71° or 72° F. The bacteria in the cream and the acidity of the cream increased rapidly under this condition. Butter scoring only 90 could be made at the end of 72 hours.

The air-cooled cream, as in trial 4, did not keep well. With a beginning temperature of the cream of 90° F., the temperatures of the cream at the end of the 24 hours with the air temperature ranging from 70° to 85° F. was 78° F., and at the end of 48 hours with the air temperature ranging from 67° F. to 82° F. it was 75° F. In 48 hours the flavor of the cream was sour and cheesy, and butter scoring only 89 could be made.

Trial 6. In trial 6 the four usual methods of cooling and storing were used. When the Hydro-Vac cooler was used, the cream after being water cooled was placed in a tank of still water for the remainder of the test.

The cream when received had a good flavor. It contained 34 per cent fat. The acid content of the fresh cream was 0.09 per cent and the number of bacteria present was 350,000 per c.c.

The cream cooled by flowing water kept similarly to that cooled by flowing water in trial 5. From this cream, 92-score butter could be made at the end of 24 hours, while at the end of 72 hours 91-score butter could be made.

Keeping the cream in still water after first cooling with the Hydro-Vac cooler resulted in cream from which 91-score butter could be made at the end of 24 hours and 90-score butter at the end of 72 hours. The

water in the tank, because of the high temperature of the air, increased to from 70° to 71° F. at the end of each 24-hour period.

Air cooling again proved to be unsatisfactory. At the end of 24 hours, the temperature of the cream was 76° F., the acidity was 0.60 per cent, and the number of bacteria was 1,550,000 per c.c. The flavor of the cream at the end of 48 hours was so poor that butter scoring only 89 could be made.

Table IX. RESULTS OF COOLING CREAM BY FOUR DIFFERENT METHODS:

Trial 6

	Begin	24 hours	48 hours	72 hours
1. *Cream air-cooled* (Minimum temperature 67° F. Maximum temperature 83° F.)				
Temperature of cream	90°F.	76°F.	76°F.	Discont'd
Temperature of air	74°F.	67°–82°F.	67°–83°F.	
Acidity	0.09%	0.60%	0.60%	
Bacteria per c.c.	350,000	1,550,000	940,000	
Score of cream	93	.....	89, high acid, cheesy	
Score of butter that can be made	93	90	89	
2. *Can of cream held in tank of still water* (Temperature of water when placed in tank 52°–53° F.)				
Temperature of cream	90°F.	69°F.	69°F.	68°F.
Temperature of air	74°F.	67°–82°F.	67°–83°F.	64°–83°F.
Temperature of water in tank at end of each period	.....	71°F.	71°F.	70°F.
Temperature of water placed in tank	52°F.	53°F.	52°F.	.....
Acidity	0.09%	0.49%	0.57%	0.60%
Bacteria per c.c.	350,000	10,000,000	850,000	870,000
Score of cream	93	.....	.....	90, high acid, sl. cheesy
Score of butter that can be made	93	91	90	90
3. *Can of cream held in tank of flowing water* (Temperature of water when entering tank 52°–53° F.)				
Temperature of cream	90°F.	53°F.	52°F.	52°F.
Temperature of air	74°F.	67°–82°F.	67°–83°F.	64°–83°F.
Temperature of water in tank at end of each period	.....	53°F.	52°F.	52°F.
Temperature of in-going water	52°F.	53°F.	52°F.	52°F.
Acidity	0.09%	0.13%	0.45%	0.51%
Bacteria per c.c.	350,000	10,500,000	950,000	1,040,000
Score of cream	93	.....	.....	91, sour
Score of butter that can be made	93	92	91	91
4. *Cream cooled with Hydro-Vac cooler, then held in tank of still water* (Temperature of water when placed in the tank 52°–53° F.)				
Temperature of cream	90°F.	69°F.	69°F.	68°F.
Temperature of cream after 20 minutes of cooling	55°F.	.....	.....	.....
Temperature of air	74°F.	67°–82°F.	67°–83°F.	64°–83°F.
Temperature of water in tank at end of each period	.....	71°F.	71°F.	70°F.
Temperature of water placed in tank	52°F.	53°F.	52°F.	.....
Acidity	0.09%	0.45%	0.56%	0.60%
Bacteria per c.c.	350,000	12,100,000	1,120,000	1,040,000
Score of cream	93	.....	.....	90, high acid, sl. cheesy
Score of butter that can be made	93	91	90	90

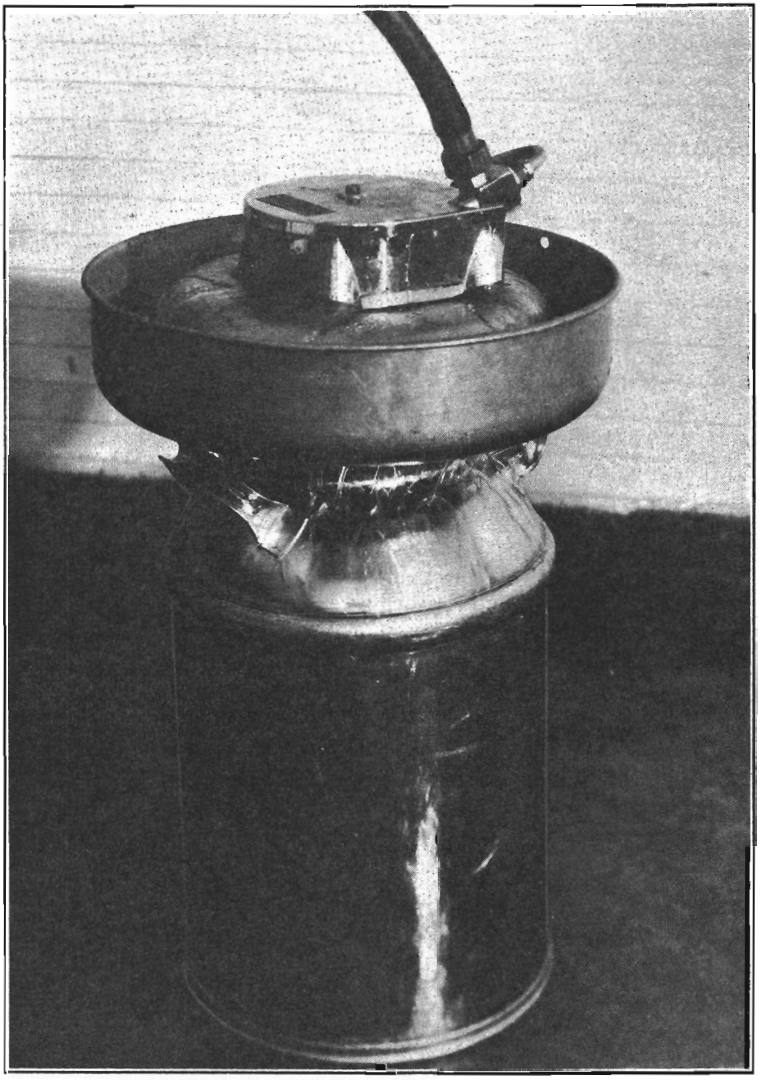

Figure 4. Cooling cream by the Hydro-Vac cooler. Five gallons of cream could be cooled in 20 minutes from an initial temperature of 90° F. to an average temperature of 4° F. above the cooling water when the temperature of the water ranged from 47° to 60° F.

SUMMARY

The data obtained from the work reported may be summarized as follows:

1. **Air cooling.** A five-gallon can of sweet cream with the cream of an initial temperature of 90°F. was placed in a room and allowed to cool to the air temperature. The temperature of the air during three trials varied from 44° to 65° F., and during the other three trials it varied from 65° to 86° F. The cream was kept for periods up to 72 hours. In six trials it was found that—

(1) The bacteria present usually increased to several millions per c.c. during the first two 24-hour holding periods.

(2) The acid increased during the first 24 hours to an average for the six trials of 0.55 per cent and during the following 24 hours to an average of 0.59 per cent.

(3) The butter that could be made from the cream at the end of 24 hours of storage scored an average of 90; at the end of 48 hours, 89 or 90; and at the end of 72 hours (three trials), 89.

Even with a minimum air temperature of 44° F. and a maximum of 62° F., with an initial bacterial count of 85,000 per c.c., the bacteria increased to 3,650,000 in 24 hours, the acid increased to 0.64 per cent, and because of the sour and undesirable flavor it was deemed that butter scoring only 90 or perhaps 91 could be made.

2. **Cooling in a tank of still water.** A five-gallon can of sweet cream with the cream of an initial temperature of 90° F. was placed in a tank of still water with the water changed at the end of 24 hours, the room in which the tank was kept maintained at the temperature given under air cooling, and the temperature of the water when placed in the tank ranged from 47° to 60° F. It was found that—

(1) The bacteria present increased in some trials to several millions per c.c. and in others to many millions per c.c. during the first 24 hours.

(2) The acid increased to averages during the 24-hour, 48-hour, and 72-hour holding periods of 0.35 per cent, 0.53 per cent, and 0.57 per cent, respectively.

(3) Butter made from the cream at the end of each period would score an average of 91 at the end of 24 hours and 90 at the end of either 48 or 72 hours.

3. **Cooling in a tank of flowing water.** A five-gallon can of sweet cream with the cream of an initial temperature of 90° F. was placed in a tank of flowing water with the water flowing through the tank at a rate of one gallon per minute, the temperature of the water which entered the tank

ranged from 47° to 54° F., and the room temperature at which the tank was kept the same as during the preceding trials. It was found that during a 72-hour storage period—

(1) The temperature of the water was not low enough to arrest the growth of microorganisms in the cream. During the first 24 hours of holding, the bacteria had usually increased to several millions and sometimes many millions per c.c.

(2) The average acid content of the cream at the end of each period was 0.17 per cent at the end of 24 hours, 0.40 per cent at the end of 48 hours, and 0.50 per cent at the end of 72 hours. This shows that the acid increased most rapidly during the second 24 hours.

(3) Butter made from the cream kept for 24 hours would have scored an average of 92; after 48 hours, 91; and after 72 hours, 91. Only in one trial (trial 4) did the cream keep in a satisfactory condition for more than 24 hours, so that possibly 92-score butter could be made. The acidity of the cream at the end of 48 hours of storage was 0.24 per cent, and the number of bacteria present was 26,400,000 per c.c. When the cream from this lot was kept at room temperature, the acid had increased in 48 hours to 0.64 per cent, while when the cream from the same lot was kept in still water with the temperature of the water when placed in the tank 60° F., the acid had increased to 0.55 per cent in 48 hours.

4. **Cooling with the Hydro-Vac.** Five gallons of cream were cooled from 90° F. during 20 minutes with a Hydro-Vac cooler to an average temperature four degrees above the temperature of the water used. It was found that—

(1) When the can of cream afterwards was placed on the floor in the room, the cream kept better than when the cream had not been precooled with water. The score of the butter would have been maintained one point higher at the end of each 24-hour storage period, because of precooling the cream.

(2) When a can of cream after having been cooled with a Hydro-Vac was placed in a tank of still water, precooling did not result in any increase in the score of the butter that could be made. Precooling for 20 minutes and then placing the cream in a tank of still water did not on an average result in lower numbers of bacteria or in a lower acid content of the cream during the 72-hour holding period, as compared with cooling the cream by placing the can directly in the tank of water.

(3) Cooling the cream first with the Hydro-Vac followed by placing the can of cream in a tank of flowing water with the water entering the tank at from 52° to 53° F. and holding it for 72 hours was of no advantage over placing the can of cream directly into the tank of flowing water.

In one trial precooling with the Hydro-Vac increased the score of the butter that could be made from the stored cream one point over cooling and storing in the air.

Cooling and storing in a tank of still water increased the score of the butter that could be made from the stored cream one point over cooling and storing in the air.

Table X. SUMMARY OF THE AVERAGE SCORES OF BUTTER THAT CAN BE MADE FROM CREAM DIFFERENTLY HANDLED

	Begin	24 hours	48 hours	72 hours
	Score	*Score*	*Score*	*Score*
1. Air cooling. Minimum temperature 44°F. Maximum temperature 86°F. Mean daily temperatures ranged from 53° to 77°F.	93	90	89.5	89
2. Still water. Temperature of water when placed in tank 47° to 60°F.	93	91	90	90
3. Flowing water. Temperature of water that entered tank 47° to 54° F.	93	92	91	91
4. a. Hydro-Vac. Stored at air temperature. One trial	93	91 or 92	91	90
b. Air cooling	93	90 or 91	89 or 90	89
5. a. Hydro-Vac. Stored in tank of still water. Three trials	93	91	90	90
b. Cream cooled and stored in tank of still water	93	91	90	90
6. a. Hydro-Vac. Stored in tank of flowing water. Two trials	93	92	91	91
b. Cream cooled and stored in tank of flowing water	93	92	91	91

Cooling and storing the cream in flowing water increased the score of the butter that could be made from the stored cream one point over cooling and storing the cream in a tank of still water and would increase the score two points over cooling and storing the cream in the air.

SUPPLEMENTARY WORK

Some supplementary work was done having for its object a study of the rates of growth of bacteria and the development of acid in milk and cream held under different temperature conditions for a period of 72 hours. Four trials were made, two with milk and two with cream. Pint samples were used. For each trial the milk or cream in each lot was divided into six different parts and each kept at a different temperature. No attempt was made to adjust the temperature of the samples prior to beginning the test.

Trials 1 and 2. In trials 1 and 2, in which cream was used, bacterial counts of the two lots when the test began were 32,000 and 8,300, and the acidities 0.1 per cent and 0.09 per cent, respectively. The methods used for determining the numbers of bacteria and the acid present were the same as in the previously reported experiment.

The data obtained with the cream are shown in Tables XI and XII.

Table XI. RATES OF GROWTH OF BACTERIA AND OF DEVELOPMENT OF ACID IN CREAM HELD AT DIFFERENT TEMPERATURES: TRIAL 1

	Begin	12 hours	24 hours	48 hours	72 hours
Rates of growth of bacteria (one-pint samples used, cream testing 38%)	*Bact. per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*
Held in refrigerator temperature 36° to 44° F...	32,000	38,000	69,000	81,000	102,000
Held in flowing water temperature 52° F.....	32,000	52,000	100,000	8,300,000	112,000,000
Held in room temperature 50° to 66° F.....	32,000	198,000	17,000,000	202,000,000	436,000,000
Held in incubator temperature 72° F.....	32,000	3,350,000	720,000,000	130,000,000	218,000,000
Held in room temperature 72° to 81° F.	32,000	118,000,000	970,000,000	*23,800,000	416,000,000
Held in incubator temperature 98.6° F.....	32,000	230,000,000	550,000,000	14,800,000	2,840,000
Rates of development of acid (one-pint samples used, cream testing 38%)	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*
Held in refrigerator temperature 36° to 44° F.....	0.100	0.100	0.100	0.115	0.140
Held in flowing water temperature 52°F.....	0.100	0.100	0.100	0.120	0.140
Held in room temperature 50° to 66° F.....	0.100	0.100	0.100	0.365	0.460
Held in incubator temperature 72° F.....	0.100	0.120	0.245	0.500	0.560
Held in room temperature 72° to 81° F.....	0.100	0.140	0.450	0.535	0.580
Held in incubator temperature 98.6° F.....	0.100	0.330	0.505	0.560	0.630

* Probably low because of an error in plating or because of the lack of growth of the bacteria on agar plate.

Table XII. RATES OF GROWTH OF BACTERIA AND OF DEVELOPMENT OF ACID IN CREAM HELD AT DIFFERENT TEMPERATURES: TRIAL 2

	Begin	12 hours	24 hours	48 hours	72 hours
Rates of growth of bacteria (one-pint samples used, cream testing 33.5%)	*Bact. per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*
Held in refrigerator temperature 88° to 42° F....	8,300	12,600	10,600	11,000	14,200
Held in flowing water temperature 51°–52° F.	8,300	13,300	42,000	1,360,000	10,000,000
Held in room temperature 52° to 66° F.....	8,300	24,000	730,000	55,000,000	550,000,000
Held in incubator temperature 72° F.....	8,300	19,000,000	179,000,000	182,000,000	425,000,000
Held in room temperature 72° to 81° F.....	8,300	16,300,000	134,000,000	229,000,000	160,000,000
Held in incubator temperature 98.6° F.....	8,300	214,000,000	218,000,000	2,870,000	2,830,000
Rates of development of acid (one-pint samples used, cream testing 33.5%)	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*
Held in refrigerator temperature 38° to 42° F.	0.09	.....	0.13	0.14	0.15
Held in flowing water temperature 51°–52° F.	0.09	.....	0.13	0.14	0.15
Held in room temperature 52° to 66° F.....	0.09	.....	0.14	0.18	0.40
Held in incubator temperature 72° F.	0.09	.....	0.26	0.58	0.61
Held in room temperature 72° to 81° F.....	0.09	.....	0.33	0.55	0.59
Held in incubator temperature 98.6° F.....	0.09	.....	0.54	0.58	0.57

In summarizing the results the data show that with all six methods of holding increases in the numbers of bacteria took place during the 72-hour holding period. When the initial count was only 8,300 the cream could be kept for 72 hours in the refrigerator, for 24 hours in flowing water, and for 12 hours in a room, at the temperatures indicated, without showing appreciable increases in the numbers of bacteria or in the acidity. When the initial count was 32,000 the cream could be kept in the refrigerator for 12 hours without an appreciable increase in the numbers of bacteria and acid. At all other temperatures considerable increases took place during the first 12 hours of holding.

When high holding temperatures were used, the bacteria developed rapidly at first, usually reaching maximum numbers at the end of 24 hours, after which decreases in numbers were observed. The decreases can be attributed to the dying-off of organisms as the acid increased.

The bacteria in the cream after holding it for 48 hours in flowing water had increased in trial 1 to 8,300,000 and in trial 2 to 1,360,000, and at the end of 72 hours, the numbers were 112,000,000 and 10,000,000 respectively. Holding the cream at higher temperatures than that of the flowing water resulted in both trials in rapid development of bacteria and production of acid.

Trials 3 and 4. In trials 3 and 4, milk was used. The bacterial counts of the two lots at the beginning of the test were 6,400 and 23,000, and the acidities were 0.195 and 0.185, respectively. The data obtained are shown in Tables XIII and XIV.

Table XIII. RATES OF GROWTH OF BACTERIA AND OF DEVELOPMENT OF ACID IN MILK HELD AT DIFFERENT TEMPERATURES: TRIAL 3

	Begin	12 hours	24 hours	48 hours	72 hours
Rates of growth of bacteria (one-pint samples used, milk testing 5%)	*Bact. per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*
Held in refrigerator temperature 38° to 40° F.	6,400	8,000	8,200	7,600	7,300
Held in flowing water temperature 51°–52° F.	6,400	8,200	10,300	14,800	177,000
Held in room temperature 52° to 67° F.	6,400	40,000	39,000	7,700,000	121,000,000
Held in incubator temperature 72° F.	6,400	29,000	10,000,000	990,000,000	1,170,000,000
Held in room temperature 72° to 82° F.	6,400	1,530,000	48,000,000	1,470,000,000	Wheyed off
Held in incubator temperature 98.6° F.	6,400	73,600,000	Wheyed off	.....	.....
Rates of development of acid (one-pint samples used, milk testing 5%)	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*
Held in refrigerator temperature 38° to 40° F.	0.195	0.195	0.195	0.200	0.180
Held in flowing water temperature 51°–52° F.	0.195	0.200	0.200	0.200	0.190
Held in room temperature 52° to 67° F.	0.195	0.200	0.200	0.200	0.240
Held in incubator temperature 72° F.	0.195	0.200	0.200	Sl. curdled 0.360	Curdled 0.450
Held in room temperature 72° to 82° F.	0.195	0.200	0.200	Curdled Wheyed off	.....
Held in incubator temperature 98.6° F.	0.195	0.220	Curdled Wheyed off	.....	.....

Table XIV. RATES OF GROWTH OF BACTERIA AND OF DEVELOPMENT OF ACID IN MILK HELD AT DIFFERENT TEMPERATURES: TRIAL 4

	Begin	12 hours	24 hours	48 hours	72 hours
Rates of growth of bacteria (one-pint samples used, milk testing 5.2%)	*Bact. per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*	*Bacteria per c.c.*
Held in refrigerator temperature 36° to 44° F.	23,000	Omitted by mistake	34,400	56,000	45,400
Held in flowing water temperature 52° F.	23,000	203,000	1,310,000	41,000,000	358,000,000
Held in room temperature 50° to 66° F.	23,000	1,390,000	21,900,000	40,000,000	163,000,000
Held in incubator temperature 72° F.	23,000	26,900,000	50,000,000	19,800,000	19,300,000
Held in room temperature 72° to 81° F.	23,000	198,000,000	420,000,000	36,000,000	.....
Held in incubator temperature 98.6° F.	23,000	424,000,000	3,400,000,000	.....	.....
Rates of development of acid (one-pint samples used, milk testing 5.2%)	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*	*Lactic acid %*
Held in refrigerator temperature 36° to 44° F.	0.185	Omitted by mistake	0.185	0.190	0.175
Held in flowing water temperature 52° F.	0.185	0.190	0.190	0.190	0.360
Held in room temperature 50° to 66° F.	0.185	0.195	0.195	0.410	0.645
Held in incubator temperature 72° F.	0.185	0.200	0.505	0.770	0.865
Held in room temperature 72° to 81° F.	0.185	0.240	0.600	0.840	.....
Held in incubator temperature 98.6° F.	0.185	0.325	0.830	.....	.....

The results obtained with milk are comparable with those obtained when cream was used. The bacteria developed slowly at the low temperatures and rapidly at the high temperatures.

In trial 3 when the bacterial count at the beginning was low, the numbers showed little change when the milk was kept in the refrigerator and little change occurred during the first 48 hours when the sample was kept in flowing water. The bacteria increased to 14,800 per c.c. when the milk was kept for 48 hours in flowing water and to 177,000 during 72 hours. At higher holding temperatures rapid development of bacteria took place with accompanying increases in acid and curdling of the milk.

In trial 4 when the initial count was 23,000, the count was doubled when the milk was held in the refrigerator for 72 hours, but no measurable increase in acid took place. When the milk was kept in flowing water the count increased nearly ten times during the first 12 hours. With all other methods of holding, the counts increased to above one million after 12 hours of holding.

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