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THE EVAPORATION AND SPRAY SYSTEMS OF COOLING CREAM[1]

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INTRODUCTION

The production of butter fat in Kansas in 1934 amounted to 121 million pounds, of which 57 percent was manufactured into creamery butter. Marketing cream before undesirable fermentations have reduced its value for the manufacture of butter is particularly difficult during the hot summer months. As a rule the cream remains on the farm several days before it is taken to the cream station; still another day or two may elapse before the cream finally reaches the creamery.

Considerable impetus has been given to cream improvement in recent years as a result of the cooperative efforts of the creamery industry and the Kansas State Board of Agriculture. Various attempts have been made by the creameries to improve the conditions under which cream is handled while it is moving from farm to creamery, and particularly while it is in the cream station.

There are approximately 2,500 cream-buying stations in Kansas. Such decentralization in cream procurement has greatly complicated the problem of inspection. The amount of cream handled by some stations is too small to justify the installation of adequate equipment for its proper handling. There is imperative need for simple, inexpensive, and practical methods of cooling cream on the farm, in the cream stations, and while in transit.

The two methods most commonly employed for the cooling of cream are known as the wet-sack or evaporation method and the spray method. The former is more commonly used on the farm and in the smaller cream stations, the latter in the larger cream stations and in the receiving departments of creameries. When wet sacks are used, cooling is accomplished

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by the evaporation of water from the sacks or other suitable wicking material which surrounds the cream cans. The spray system consists of forcing water through a fine spray or atomizer over the outside of the cream cans. Although these methods have been rather extensively used for a number of years, there is little available information on their actual comparative value. This study was initiated in response to frequent requests for more detailed information on the problem from the men in the butter industry of Kansas and at the suggestion of the state dairy commissioner.

In giving the results of the study of the rate and the amount of cooling by the evaporation and the spray methods, the following topics are discussed: Type of wicking material, manner of applying water, air circulation, initial temperature of water (or cream) in cans, room temperature, the effect of room temperature and humidity, the effect of the contents of the can on the rate of cooling, type of spray, volume of water sprayed, effects of initial temperature of water or of cream on cooling, comparison of sweet and sour creams cooled by the spray method, comparison of evaporation and spray systems, and agitation and rate of cooling.

In several trials water was used in the cans instead of cream. The results, however, were later checked with cream. Since in many of the trials the object was to determine the lowest attainable temperature under controlled conditions, the use of water instead of cream in the cans facilitated the procedure.

THE EVAPORATION METHOD

Type of wicking material. — Six 10-gallon cans were filled with water at 90 degrees F. and covered with different kinds of burlap sacks or a special wicking cloth. Each covering was fitted closely around the can and tied at the top, center, and bottom so as to make intimate contact with the can. A thermometer inserted into an opening in the side of each can was used to follow the temperature changes inside the can. One can of water without wicking was used as a control,

TABLE I.—EFFECT OF TYPE OF WICKING ON RATE OF COOLING.

Type of wicking	Temperatures in degrees F.				
	Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.	After 8 hrs.
Sugar sack No. 1	90	85	81	80	79
Sugar sack No. 2	90	84	81	79	78
Special wicking cloth	90	85	81	79	78
Cottonseed meal sack No. 1	90	86	83	80	79
Cottonseed meal sack No. 2	90	86	82	81	80
Two cottonseed meal sacks	90	86	83	81	80
Control—none	90	89	88	87	86

Note.—Room temperature 83 degrees, relative humidity 62 percent. Figures given are the average of two trials.

The data in Table I show that the maximum drop in temperature produced by the evaporation method of cooling was 12 degrees F. There was a spread of 8 degrees between the final temperature of the control can and two of the cans covered with wicking materials. A difference of only 2 degrees existed among the cans covered by the different wicking materials. Two cottonseed meal sacks did not prove to be any more effective than one. A mineral deposit left on the various wicking materials after long use eventually decreased the efficiency and necessitated washing at frequent intervals.

Manner of applying water.— The purpose of this test was to determine whether the simultaneous wicking of water from both the top and bottom of the can would produce lower temperatures than those obtained when water was applied at either the top or the bottom only. The data in Table II show that the method of wetting the sack had no significant effect on the rate and amount of cooling.

TABLE II.—EFFECT OF THE METHOD OF WETTING WICKING CLOTH ON FINAL TEMPERATURE.

Method of wetting	Temperatures in degrees F.				
	Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.	After 8 hrs.
Top only	90	84	82	81	80
Top and bottom	90	85	83	82	82
Bottom only	90	85	84	83	82

Note.—Room temperature 92 degrees, relative humidity 46 percent.

Air circulation.—A study was made to determine what effect circulation of air would have on the efficiency of the evaporation method of cooling. Four cans of water at 90 degrees were used in this trial. One was covered with a sack and placed in a room where the air was circulated by means of an 18-inch high-speed air-blast type of electric fan. Two cans, one with and one without wicking cloth, were cooled in another room where the air was circulated with a 10-inch household electric fan. A fourth can covered with wicking cloth was kept in a room without forced air circulation.

TABLE III.—EFFECT OF AIR CIRCULATION ON RATE AND AMOUNT OF COOLING BY THE EVAPORATION METHOD.

Fan used for circulation of air	Wicking material	Temperatures in degrees F.				
		Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.	After 8 hrs.
Large (a)	Sacks	90	83	78	76	76
Small (b)	Sacks	90	85	81	79	78
Small (b)	No sacks	90	90	90	90	90
None	Sacks	90	87	86	84	84

Note.—Room temperature 88 degrees, relative humidity 53 to 56 percent. Figures given are the average of two trials.

(a) 18-inch, high-speed, air-blast type electric fan.

(b) 10-inch household electric fan.

Data presented in Table III show that the circulation of air improved the efficiency of the evaporation method. At the end of eight hours, the temperature of the can cooled without air circulation was lowered only 6 degrees, whereas the temperature of the covered cans cooled with air circulation was reduced 12 to 14 degrees. The use of the large fan resulted in a final temperature of only 2 degrees lower than that obtained by the use of the small fan. Air circulation alone without wicking was not effective in reducing the can temperature.

Comparison of the results reported in Table III with those in Tables I and II further emphasizes the importance of providing air circulation when the evaporation method of cooling is employed. It will be noted that under the conditions of the tests reported in Tables I and II, it was possible without circulation of the air to lower the temperature of the contents of the can only 8 to 12 degrees in eight hours. Although this is better than no cooling at all, it is apparent from consideration of the results in Table III, that much greater cooling can be effected by providing adequate circulation of the air.

Initial temperature of water in cans.—In Table IV are given the results of duplicate tests in which three 10-gallon cans of water with initial temperatures carefully adjusted to 90, 80, and 70 degrees, respectively, were placed in a room at 95 degrees and cooled by the evaporation method in circulated air. At the end of eight hours the temperature of the water in the can with an initial reading of 90 degrees had dropped to 83 degrees while the temperature of the water which had an initial reading of 70 had increased to 76.

In another test three cans of water were exposed to a temperature of 101 in the direct rays of the sun in order to facilitate evaporation. Two of the cans with initial temperatures of 90 and 70 were covered with wicking material, whereas the third can with an initial temperature of 70 without covering served as a control. At the end of eight hours the can with an initial temperature of 90 had cooled to 83, whereas the can which started at 70 warmed up to 80. During the course of the trial the control can which started at 70 warmed up to 102.

A comparison of the results obtained with the two cans having original temperatures of 70 and exposed out of doors with and without wicking, demonstrates the effectiveness of the evaporation method. It will be observed that the temperature of the control without wicking increased to 102 degrees, whereas the temperature of the can with wicking rose to only 80 degrees. This emphasizes the fact that under extreme conditions the evaporation method may aid in preventing an excessive rise in temperature of the contents of a can.

TABLE IV.—EFFECT OF ORIGINAL TEMPERATURE OF WATER IN CANS ON RATE AND AMOUNT OF COOLING.

Conditions of exposure	Temperatures in degrees F.				
	Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.	After 8 hrs.
Inside a room at 95 degrees; air circulated by a 10-inch electric fan	90	88	86	85	85
	80	79	78	78	77
	70	73	75	75	76
Out of doors at 101	90	87	84	84	83
	70	71	74	78	80
Control—no sacks, out of doors at 101	70	82	90	97	102

Note.—Relative humidity of the room 40 percent, out of doors 26 percent. Figures given are the average of two trials.

Room temperature.—In Table V are presented the results of three trials in which cans of water at 90 degrees were exposed to three different room temperatures. Observations were made on the rate and amount of cooling. Air in the room was circulated by a 10-inch electric fan.

At the end of two hours the temperature of the water in the can exposed at 92 degrees had decreased only 7 degrees, whereas that exposed at 82 and 71 degrees had decreased 14 and 18 degrees, respectively. These differences amounted to 10, 21, and 27 degrees at the end of six hours/ The data also show that the most significant temperature changes were effected during the first two-hour period and that the lowest attained temperatures were reached within approximately six hours.

A comparison of the temperatures of cooled cans and their respective controls at the end of eight hours shows differences of 11, 16, and 20 degrees for the cans held at 92, 82, and 71, respectively. The temperature of the control can exposed at 92 actually increased 1 degree, whereas the temperature in the control cans exposed at 82 and 72 degrees, dropped 5 and 7 degrees, respectively, during the eight-hour period. The results indicate that the higher the room temperature, the slower the rate of cooling and the higher the final attainable temperature in eight hours.

TABLE V.—EFFECT OF ROOM TEMPERATURES ON RATE AND AMOUNT OF COOLING.

Room temperature	Temperatures in degrees F.				
	Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.	After 8 hrs.
92 Degrees					
Sacks for wicking	90	83	81	80	80
Control—no sacks	90	90	90	90	91
82 Degrees					
Sacks for wicking	90	76	71	69	69
Control—no sacks	90	87	86	85	85
71 Degrees					
Sacks for wicking	90	72	65	63	63
Control—no sacks	90	88	85	83	83

Note.—Relative humidity 41 to 43.6 percent, air circulated by 10-inch fan. Figures given are the average of three trials.

The effect of room temperature and humidity.—All of the preceding trials confirmed the obvious influence of temperature and humidity on the final temperature attained when the cooling was effected by evaporation. Another test was designed to study this relationship over an extended period of time and to establish, if possible, the lowest attainable temperatures which might be expected under variable conditions. In this test the temperature changes in a can covered with special wicking cloth were followed continuously for a period of five weeks. During this time it was possible to secure wide variations and different combinations of both room temperatures and humidities. Since this study involved primarily the ultimate attainable temperatures and not the rate of cooling, water instead of cream was placed in the can. From the physical nature of the two substances it is self-evident that water would respond more quickly to changes in external temperature and reach the ultimate temperature with less lag than would cream; also the inevitable spoilage of cream during a test extending over several weeks discouraged its use.

A 10-gallon cream can filled with water was covered with wicking cloth tied securely to the can at the bottom, near the middle, and at the top. A gallon bottle of water inverted over the can kept the lid partially filled with water at all times. The can was also set in a shallow pan of water. In this manner the wicking cloth was kept moist constantly during the test. Water temperatures inside the can were measured with a recording thermometer, the bulb of which was inserted and sealed into an opening in the side of the can. A second thermometer of known accuracy was inserted into a second opening in the side of the can and was used as a check on the recording thermometer. A thermograph and a hygrograph of the recording types were used to follow continuously the room temperature and humidity. To insure good circulation of air about the can, a 10-inch electric fan was operated continuously throughout the experiment. (Fig 1A.)

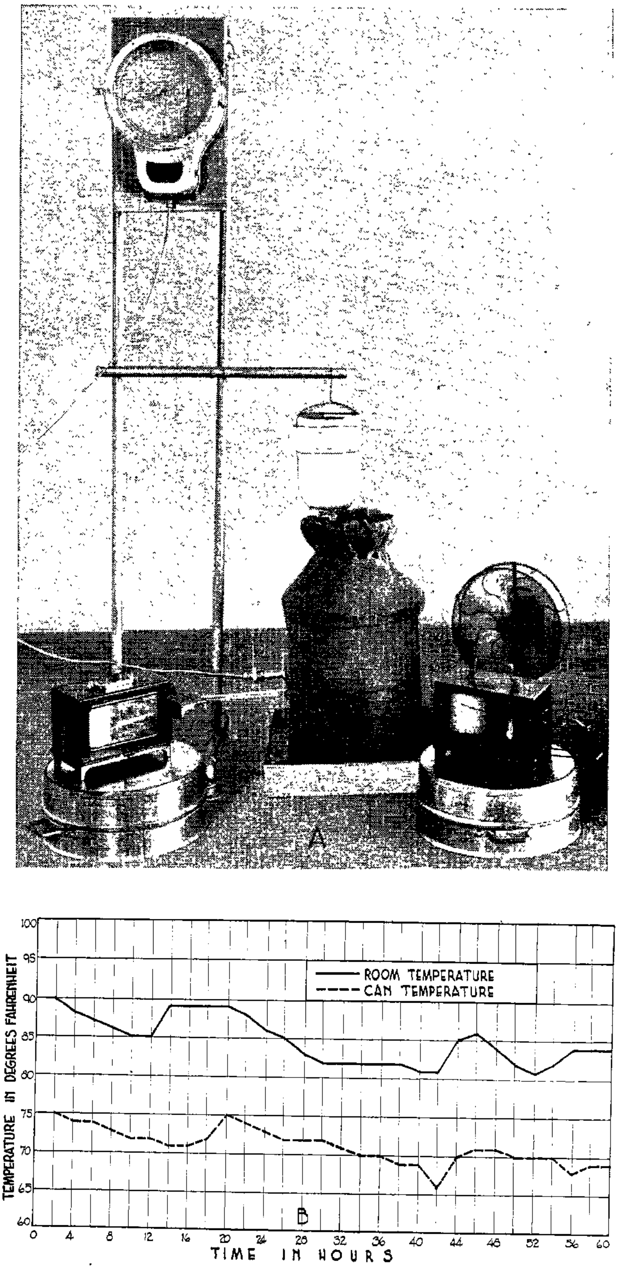

Fig. 1.—(A) Equipment used in the determination of the spread between room temperature and the temperature of a can of water cooled by the evaporation method under varied conditions of room temperature and humidity. (B) Graphs showing the spread between the temperature of the room and of a can of water cooled by the evaporation method.

Variations in room temperature were induced by appropriate regulation of electric heaters, steam radiators, and windows. High humidities were induced by injecting live steam into the room. After the room temperature and the humidity had been adjusted to predetermined values the can was allowed to remain under these conditions for a period varying from about two to five days.

Summarization of the data (Table VI) made it possible to observe the relative effects of various combinations of room temperatures and humidities on the ultimate attainable temperature of the water in the can. The data obtained during the transition periods when temperature and humidity conditions were altered to other levels have been excluded from the final results reported in Table VI.

TABLE VI.—RELATION OF RELATIVE HUMIDITY AND ROOM TEMPERATURE TO THE TEMPERATURE OF A 10-GALLON CAN OF WATER COOLED BY EVAPORATION.

Trial No.	Duration of trial (hrs.)	Relative humidity of room, percent		Room temperature in degrees F.		Can temperature in degrees F.		Difference between room and can temperatures	
		Av.	Range	Av.	Range	Av.	Range	Av.	Range
1	44	22	17-24	107	101-110	81	79-83	26	22-28
2	50	33	20-45	98	91-100	75	76-84	23	15-23
3	114	49	35-57	85	81-90	70	65-76	15	10-20
4	44	69	57-77	86	81-90	78	76-80	8	5-10
5	80	57	38-63	74	71-80	63	56-68	11	10-15
6	76	55	50-58	68	61-70	57	49-58	10	7-15
7	58	49	41-59	54	50-60	49	46-55	5	3-8

Note.—Air circulated by a 10-inch electric fan.

Variations in room temperatures were invariably accompanied by similar changes in the water temperature within the can. The data used in preparing figure 1B were taken from trial 3, Table VI, and cover 60 hours of the 114-hour period. During the course of this trial the room temperature was controlled between 81 and 90 degrees. The parallelism between the temperature changes of the contents of the can and of the room is shown in figure 1B. The graphs not only show the tendency for the temperature of the contents of the can to follow closely the fluctuations in room temperature, but also the maintenance of a fairly constant differential of temperatures under the conditions imposed. Similar relationships were observed at the other room temperatures studied.

A study of the data reported in Table VI shows that the differential between the temperature of the contents of the can and that of the room was greatly influenced by the humidity and the temperature of the room. For example, a comparison of the results in trials 3 and 4 shows that with a relative humidity of 49 percent (trial 3) the temperature of the contents of the can was 15 degrees lower than that of the room, whereas when the relative humidity was 69 percent (trial 4) it was possible to cool the contents of the can only 8 degrees below the room temperature. Except for trial 4, when an abnormally high humidity was induced by injecting live steam into the room, the differences between the temperature of the contents of the can and of the room tended to become less as the room temperature was reduced. The greatest temperature differential, 26 degrees, was observed when the room temperature averaged 107 and the relative humidity 22 percent. On the other hand the least temperature difference, 6 degrees, was observed when the temperature of the room was 54 and relative humidity was 49 percent, (trial 7). It is significant to note, however, that some cooling was effected by evaporation even at such a comparatively low room temperature.

The idea is prevalent among creamery men that the evaporation method of cooling is more efficient in hot weather than in cold weather.

The results in Table VI throw some light on this point. A comparison of the results from trials 1 and 7 shows that under extremely hot conditions it was possible to extract enough heat from the cans to establish a temperature differential of 26 degrees, whereas under the conditions of trial 7, it was only possible to establish a temperature differential of 5 degrees. From the standpoint of the actual number of British Thermal Units extracted from the can, the evaporation method did work more efficiently under the conditions of high room temperatures, but from the standpoint of the ultimate temperature attained the higher the room temperature, the higher the final temperature of the contents of the can. From a practical point of view the object of cooling is to preserve the cream by preventing decomposition. Although it is true that the evaporation method may actually extract more thermal units of heat from cans in hot weather than in cold weather, one must not lose sight of the fact that during hot weather the final temperature of the cream may be higher and the decomposition more rapid.

It would appear from these results that the evaporation method cannot be relied upon to cool cream adequately in exceedingly hot weather. It is, however, certainly much better than nothing. Aside from the limitations of the evaporation method as a cooling device under extreme temperature conditions, the data again suggest the possibilities of the system in preventing an excessive rise in temperature of cream. Any such simple procedure which under extreme conditions will maintain a temperature as much as 26 degrees below that of the room is well worth consideration as a method of refrigerating cream in the buying station.

The effect of the contents of the can on the rate of cooling. — In the trial reported in Table VII, a comparison was made of the rate of cooling water, sweet cream (38 percent fat) of low viscosity, and sour cream (38 percent fat) of high viscosity by the evaporation method. Two thermometers were used in each can, the bulb of one being adjusted to the center of the can and the bulb of the other extending just through the can wall. This arrangement of thermometers made it possible to read the temperature at the center and edge without disturbing the contents of the can.

TABLE VII.—TEMPERATURE CHANGES IN WATER, SWEET CREAM, AND SOUR CREAM COOLED BY THE EVAPORATION METHOD.

Hours held	Temperatures in degrees F.								
	Water			Sweet cream, 38 percent			Sour cream, 38 percent		
	Center	Edge	Dif.	Center	Edge	Dif.	Center	Edge	Dif.
0	90	90	0	89	89	0	89	89	0
2	73	72	1	76	72	4	88	74	14
4	66	65	1	70	67	3	87	71	16
6	63	63	0	67	66	1	85	70	15

Note.—Room temperature 71 to 76 degrees, relative humidity 41 to 52 percent. Figures given are the average of two trials with sweet cream and water and three trials with sour cream. Air circulated with a 10-inch electric fan.

Sweet cream cooled a little more slowly than water and the final temperature of the sweet cream was from 3 to 4 degrees higher than that of the water. The sweet cream at the edge and center cooled at about the same rate. The more highly viscous sour cream cooled more slowly, the lowest temperature reached being 4 degrees higher than that of the sweet cream and 7 degrees higher than that of the water. It is evident from the results obtained in this test covering a six-hour period that the rate of cooling and the final temperature of the contents of the can are quite different for water and cream. Since water and not cream was used in the previously reported trials, attention should be called to the fact that the results obtained with water are not necessarily applicable to cream, especially to sour cream which cools much more slowly.

An important observation demonstrated by this trial was the wide differences in the temperatures at the edge and center of the can of sour cream. These results suggest that extremely thick sour cream cannot be cooled adequately unless some form of agitation is provided during the cooling process.

THE SPRAY METHOD

Type of spray. — The second part of this experiment deals with the spray method of cooling. Two devices for spraying were used; one delivered a very fine mist of water through two nozzles, the other resembled an ordinary lawn sprinkler and delivered a larger amount of water in somewhat coarser streams. Water was sprayed by each of these devices on 10-gallon cream cans containing water. Some of the cans were covered with sacks and others were left uncovered. Table VIII presents the effect of the type of spray used on cans of water with and without sacks.

TABLE VIII.—EFFECT OF TYPE OF SPRAY USED ON CANS OF WATER WITH AND WITHOUT SACKS.

Type of spray	Condition of cans	Temperatures in degrees F.				
		Initial	After 1 hr.	After 2 hrs.	After 3 hrs.	After 4 hrs.
Fine spray	Without sacks	90	83	80	79	78
Fine spray	With sacks	90	83	80	79	78
Coarse spray	Without sacks	90	76	72	71	71
Coarse spray	With sacks	90	76	73	71	71

Note.—Room temperature 72 to 78 degrees, relative humidity 82 to 98 percent. Figures given are the average of two trials. Fine spray delivered 10 gallons per hour at 73 degrees; coarse spray delivered 220 gallons per hour at 66 degrees.

The rate of cooling was faster and the final temperature lower with the coarse spray than with the fine spray. At the end of one hour exposure the temperature of the water in the cans cooled by the fine spray had decreased to 83 degrees, whereas the water in the cans cooled by the coarse spray had decreased to 76, a difference of 7 degrees in favor of the coarse spray. After three hours the water cooled by the fine spray was within 6 degrees of the temperature of the spray water and that cooled by the coarse spray was within 5 degrees of the temperature of the spray water. It appears that the lower efficiency of the fine spray used in this trial may be attributed to the higher temperature of spray water employed. Although the water used in both sprays was from the same source, the slow rate at which it was released from the fine spray permitted the temperature to rise approximately 7 degrees in the pipe lines before the water left the spray nozzle. The fine spray delivered 10 gallons of water per hour, whereas the coarse spray delivered 220 gallons per hour. Slow delivery of water through a pipe line exposed to warm air usually results in an increase in the temperature of the water. On the other hand, if the pipe line passes through a cooling medium, slow delivery may result in lowering the temperature of the water.

The cans without sacks were cooled as effectively as those with sacks. This suggests that with the spray system, cooling is accomplished primarily by the water and not by evaporation. There appears to be no advantage in using sacks around the cans if the spray system of cooling is employed.

Attention is called to the fact that the coarse spray used 22 times as much water as the fine spray, and hence from the standpoint of the amount of cooling per gallon of water required, was less efficient than the fine spray. Although there was a difference of 7 degrees in the final temperatures of the two cans in favor of the coarse spray, the water delivered from the coarse spray was likewise 7 degrees colder than that delivered from the fine spray. Apparently the lower temperature attained in the can cooled by the coarse spray was not wholly due to the increased volume of water used except in so far as the free flow of water from the pipe lines resulted in the delivery of colder water. On the other hand, if the use of a fine spray results in the backing up of the water in the pipe lines and in the use of warmer water, such a spray would tend to defeat the real purpose of the method.

The attempt to combine the spray system and the evaporation method of cooling by breaking the water up into a fine mist is fundamentally unsound. It has already been shown that under certain conditions the retardation of the flow of water by the fine-spray nozzle increases the temperature of the water delivered. As the water is atomized into very fine particles the surface area for the absorption of heat from the surrounding atmosphere is greatly increased with the result that the water which subsequently trickles down over the can has further increased in temperature. The cooling of the air by the resulting absorption of heat by the water would aid only slightly in the cooling of the contents of the can. After all the effectiveness of the spray system depends largely upon the conduction of heat away from the can by cold water and only to a slight degree, if at all, upon the evaporation of the water. It is logical to expect that the air surrounding the cans under a spray would be completely saturated and hence unfavorable for cooling by evaporation. The practice of using a fine mist for the spray has arisen from the assumption that the cooling efficiency of the spray could be further increased by evaporation.

Volume of water sprayed.— The data from preceding experiments suggest the amount of spray water used might have an effect on the rate of cooling. In Table IX are recorded the results of an experiment in which the coarse spray was operated in such a manner as to regulate the amount of water delivered between the limits of 55 and 220 gallons per hour. The rate and amount of cooling was not found to be in proportion to the volume of water used. The difference in final temperature of the contents of the cans was not great when the amount of water was reduced from 220 to 100 gallons per hour, but further reduction to 55 gallons per hour materially reduced the cooling efficiency of the spray.

TABLE IX.—EFFECT OF VOLUME OF SPRAY WATER ON THE RATE OF COOLING.

Volume of spray water	Can temperatures in degrees F.				
	Initial	After 1 hr.	After 2 hrs.	After 3 hrs.	After 4 hrs.
220 gal. per hour	90	73	69	67	66
100 gal. per hour	90	75	70	67	67
55 gal. per hour	90	80	75	72	70
200 gal. per hour not sprayed (a)	90	64	63	63	63

Note.—Room temperature 72 degrees, spray water temperature 64 degrees.

(a) Full stream from hose (62 degrees) directed into lid of cream can and allowed to flow over sides.

Even with the use of only 55 gallons of spray water, the temperature of the water in the can was reduced from 90 to 75 degrees in a period of two hours. When 100 gallons of water per hour was employed, the contents of the can were cooled to this same temperature in a period of only one hour. The most rapid reduction in temperature was effected when a full stream of water was directed on the lid and allowed to flow over the side of the can. With this method of cooling, the water temperature was reduced from 90 to 64 degrees in one hour.

Effects of initial temperature of water or of cream on cooling.—In the experiment reported in Table X, uncovered cans of water with initial temperatures of 90, 80, and 70, respectively, were cooled by the fine and by the coarse sprays. It may be observed that the temperatures in all of the cans tended to approach the same value in a relatively short time, regardless of the initial temperature of the water in the can. The temperature of the spray water seemed to limit the ultimate temperature to which the contents of the cans could be cooled. The results indicate quite definitely that the ultimate temperature which can be obtained with the spray system will be determined more by the temperature of the spray water than by the room temperature, the volume of spray water, or the fineness of the mist created by the spray.

TABLE X.—EFFECT OF INITIAL TEMPERATURE OF WATER IN CANS ON THE RATE AND AMOUNT OF COOLING BY THE SPRAY SYSTEM.

Can No.	Can temperatures in degrees F.				
	Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.	After 8 hrs.
Fine spray, 10 gallons per hour, at 72 degrees					
1	90	79	71	74	73
2	80	76	74	74	73
3	70	71	72	73	74
Coarse spray, 220 gallons per hour, at 68 degrees					
1	90	75	71	70	70
2	80	75	72	70	70
3	70	74	73	72	71

Note.—Room temperature 78 to 83 degrees. Figures given are the average of two trials.

To check on the results of the previous trial in which water was used in the cans, another trial (Table XI) was conducted in which sweet cream containing 40 percent fat was cooled by the spray system. Four cans of sweet cream were employed, two of which were started at an initial temperature of 87 and two were adjusted to 72. One can at each of these temperatures was cooled by means of the spray, whereas the other two cans served as controls. Temperatures were taken at the center of all four cans.

TABLE XI.—EFFECT OF INITIAL TEMPERATURE OF SWEET CREAM ON THE RATE AND AMOUNT OF COOLING BY THE SPRAY SYSTEM.

Can No.	Condition of can	Cream temperatures in degrees F			
		Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.
1	Control (not cooled)	87	86	85	85
2	Cooled with spray	87	77	76	74
	Difference	0	9	9	11
3	Control (not cooled)	72	72	72	73
4	Cooled with spray	72	68	68	68
	Difference	0	4	4	5

Note.—Room temperature 73 degrees; coarse spray, 220 gallons of water per hour at 64 degrees; cream 40 percent fat.

A comparison of the data presented in Tables X and XI shows that water is cooled more rapidly than cream. At the end of six hours, using the coarse spray (Table X), it will be observed that the temperature difference between the water being cooled and the spray water was only 2 degrees, whereas in the case of cream (Table XI), the difference amounted to 10 degrees in the same period of time. Although the temperature of the spray water used to cool the cream was 4 degrees colder than that used to cool the can of water, the final temperature of the cream was 4 degrees above that of the water at the end of six hours.

Cream cooled at a slower rate than water. A comparison of the temperatures of the cooled and uncooled cans of cream shows that the cream with an initial temperature of 87 was cooled by the spray to a temperature 11 degrees lower than its respective control. The cream with an initial temperature of 72 was cooled to a temperature 6 degrees below that of the uncooled control. It should be pointed out that this trial was conducted at a relatively low room temperature (73 degrees). If more typical summer temperatures had prevailed it is logical to expect that the apparent advantage of using the spray would have been more pronounced.

Comparison of sweet cream and sour cream cooled by the spray method.—Since previous experiments in connection with the evaporation method of cooling gave a marked difference in the rate at which sweet cream and sour cream were cooled, a similar trial was planned with the spray system. In this trial (Table XII) temperatures were taken at the center and edge of the cans of sweet cream and sour cream cooled by the coarse spray.

TABLE XII.—RATE OF TEMPERATURE CHANGE IN SWEET CREAM AND SOUR CREAM COOLED BY THE SPRAY METHOD.

Hours held	Temperatures in degrees F.					
	Sweet cream, 40 percent			Sour cream, 35 percent		
	Center	Edge	Dif.	Center	Edge	Dif.
0	88	88	0	89	89	0
2	77	72	5	89	75	14
4	76	70	6	88	69	19
6	74	68	6	86	68	18

Note.—Room temperature 73 degrees; coarse spray, 220 gallons per hour at 64 degrees. Figures given are the average of two trials.

The results show that the sour cream cooled less rapidly and less uniformly than the sweet cream. The temperature of the sweet cream at the center of the can was reduced 14 degrees, whereas the temperature of the sour cream was reduced only 3 degrees at the center of the can during the six-hour period. The differences between the temperatures at the center and edge of the sour cream were from 14 to 19 degrees, whereas for sweet cream the differences were only 5 to 6 degrees F. These results are in harmony with those obtained with the evaporation method (Table VII). The higher viscosity associated with sour cream introduces an important factor in the rate of heat transfer in cream.

Comparison of the evaporation and spray systems.—In this test the evaporation and spray systems were compared for cooling sour cream. Under the conditions of this trial there was no significant difference either in the rate of cooling or in the final temperature of the cream cooled by these two methods. It should be pointed out, however, that the conditions which prevailed were favorable for a high degree of efficiency with the evaporation method, in that the room temperature was comparatively low

(68 degrees) and the relative humidity did not exceed 50 percent. After six hours the temperatures at the center of the two cans cooled by the two methods were exactly the same, having been lowered from 89 to 86 degrees. The temperature at the edge of the can cooled by the spray method was 68 after six hours, and 70 at the edge of the can simultaneously cooled by the evaporation method. A detailed comparison of the results in Table XIII with those in Tables VII and XII shows a marked uniformity in the rate and amount of cooling of sour cream induced by the spray and evaporation systems under the specific conditions of the individual trials. The wide difference between the temperatures at center and edge of the can again emphasizes the necessity of agitation if sour cream is to be cooled uniformly.

TABLE XIII.—COMPARISON OF THE SPRAY AND EVAPORATION METHODS OF COOLING SOUR CREAM.

Method of cooling	Room temperature	Relative humidity, percent	Position of thermometer	Temperatures in degrees F.			
				Initial	After 2 hrs.	After 4 hrs.	After 6 hrs.
Spray, 64 degrees	70	80.5	Center	89	89	89	86
			Edge	89	75	69	68
			Dif.	0	14	20	18
Evaporation	68	50.0	Center	89	88	87	86
			Edge	89	73	71	70
			Dif.	0	15	16	16

Note.—Coarse spray, 220 gallons per hour; cream 38 percent fat. Figures given are the average of two trials.

Agitation and rate of cooling.—The results previously reported in Tables VII, XII, and XIII, show that sour cream cannot be cooled uniformly nor adequately when no method of agitating the cream is provided. In view of these results a trial was planned to determine the influence of agitation on the rate of cooling both sweet cream and sour cream. For this purpose, two cans of sweet cream and two of sour cream were cooled by the spray method. (Table XIV.) In each trial one can of sweet cream and one of sour cream were agitated at 30-minute intervals, whereas the other two cans were not agitated. Agitation materially reduced the differences in temperatures at the center and edge of the can of sour cream. In the nonagitated can of sour cream, temperature differences of 11 and 14 degrees were registered between the center and edge of the can, whereas in the cans which were agitated, these differences ranged from none to 6 degrees. The temperature at the center *of* the can of sour cream was reduced from 83 to 67 when the contents were agitated, as compared with a change from 83 to 78 in the control cans during the six-hour trial. This represents an advantage of **11** degrees in favor of the agitated cream. These data show that sour cream can be cooled quite satisfactorily with the spray system provided some method of agitation is employed.

In the case of sweet cream the temperature was reduced from 86 to 62 at the center of the can when no agitation was provided and to 61 in the can which was agitated during the six-hour trial. These data indicate that the sweet cream cooled quite uniformly with or without agitation.

A comparison of the rate of temperature changes in the sweet cream and sour cream shows that the sweet cream cooled more rapidly and attained a lower temperature than did the sour cream even though the latter was agitated. When the cans were agitated there was a temperature difference of 6 degrees between the sweet cream and the sour cream at the end of the trial, the final temperatures being 67 degrees for the sour cream as compared to 61 for the sweet cream.

TABLE XIV.—EFFECT OF AGITATION ON THE EFFICIENCY OF COOLING SWEET CREAM AND SOUR CREAM BY THE SPRAY METHOD.

Hours held	Temperatures in degrees F.					
	Sweet cream, 35 percent			Sour cream, 35 percent		
	Center	Edge	Dif.	Center	Edge	Dif.
	Not agitated					
0	86	86	0	83	83	0
2	68	66	2	81	67	14
4	63	62	1	80	67	13
6	62	60	2	78	67	11
	Agitated					
0	86	86	0	83	83	0
2	67	66	1	75	69	6
4	63	63	0	69	67	2
6	61	60	1	67	67	0

Note.—Room temperature 67 to 72 degrees; spray water 64 degrees; coarse spray 220 gallons per hour.

DISCUSSION AND SUMMARY

A number of factors which affect the rate of cooling and the final temperatures attainable by the evaporation and spray methods of cooling cream have been studied. The type of wicking used in the evaporation method and the manner of applying water to the wicking material had very little influence on the effectiveness of cooling, although frequent washing of the wicking material helps to maintain its efficiency.

When conditions for cooling by the evaporation method are favorable (comparatively low room temperature and low relative humidity), it will cool cream at about the same rate and to about the same final temperature as will the spray method. Under adverse conditions (high atmospheric temperature or high relative humidity), the spray method of cooling, if satisfactory water is available, will cool faster and to a lower temperature than will the evaporation method. Under such conditions it might be advisable to cool cream quickly with the spray system and then by the use of the evaporation method, protect the cream against undue rise in temperature.

Neither system can be relied upon to cool sour cream effectively and uniformly unless the cream is agitated at frequent intervals. Due to its high viscosity, the rate at which the temperature of sour cream drops is slower than that of sweet cream. This fact may be of some practical importance in retarding temperature increases in sour cream, due to the fact that the rate of heat transfer is slower.

Both systems of cooling have their limitations. Neither will produce temperatures much below 70 degrees in extremely hot weather. At least under ordinary conditions they fail to reduce the temperature of cream sufficiently to hold microbial development definitely in check. The use of these methods of cooling leaves much to be desired in the proper handling of cream. Failure to recognize the limitations of the evaporation method of cooling frequently leads to the erroneous assumption that the higher the room temperature, the lower the temperature to which the cream may be cooled.

Neither of these methods of cooling should be regarded as a final and satisfactory method for cooling cream in the station. Their use, however, is worthy of consideration and should be encouraged until some more practical method can be perfected.

Any method of cooling, even though far from ideal, which will lower the temperature sufficiently to discourage the growth of proteolytic bacteria or yeasts may be considered at least a gesture in the right direction in the solution of a very troublesome problem.

CONCLUSIONS

1. The efficiency of the evaporation method of cooling is not affected materially by the type of wicking cloth.

2. The rate of cooling is approximately the same when the water is drawn by capillarity from the top only as when drawn simultaneously from the top and bottom of the can.

3. The circulation of air in the room with a small fan will increase materially the efficiency of the evaporation method of cooling cream.

4. The initial temperature of the contents of the can and the temperature of the room affect the rate and amount of cooling by the evaporation method.

5. The rate of cooling is greatly increased and the ultimate attainable temperature is effectively lowered with a decreased relative humidity when the evaporation method of cooling is employed. If the relative humidity is held constant, the temperature of the contents of the can follows, with some lag, the temperature of the room and with a rather constant differential.

6. The rate of cooling and final temperatures are about the same for sweet cream and water. Sour cream, due to its greater viscosity, cools at a slower rate and less uniformly unless agitated frequently during the cooling process. Agitation of the sour cream tends to equalize the temperatures at the center and edge of the can and made it possible within a six-hour period to cool to a lower final temperature which is still somewhat higher than that obtained in sweet cream.

7. The efficiency of the spray method of cooling is not increased by the use of a fine mist, but is affected mostly by the temperature of the water used for the spray and the volume of water delivered per unit of time.

8. Cans with and without a sack covering are cooled equally well by the spray method, showing that evaporation plays a relatively small part in the cooling by the spray system.

9. Under the conditions which ordinarily prevail during the summer months, the spray system usually is more efficient than the evaporation method of cooling cream. If the water available for spraying the cans has a temperature of 65 or lower, the final temperature of the cooled cream should be below 70. On the other hand, if the temperature of the air is above 85 degrees and the relative humidity is in excess of 50 percent, the evaporation method cannot be expected to cool cream below 70.

PUBLICATIONS ON DAIRYING AND MILK PRODUCTS

For further information on recent work of the Agricultural Experiment Station on milk production and milk products, the reader is referred to the following publications:

Bul. No.	
255	Dairy Farm Organization in Southeastern Kansas. (76 pp., 15 illus.)
Circ. No.	
24	Better Butter for Kansas. (4 pp., 3 illus.)
146	Making Cottage Cheese on the Farm. (12 pp., 4 illus.)
148	Farm Dairying. (31 pp., 12 illus.)
154	Producing Quality Cream. (18 pp., 7 illus.)
161	Raising Dairy Calves. (12 pp., 5 illus.)
164	Infectious Abortion of Cattle. (11 pp.)
176	Cleaning and Sterilizing Dairy Farm Utensils. (15 pp., 10 illus.)

Copies of any of these publications in which the reader may be interested may be secured as long as available by addressing a request to: Agricultural Experiment Station, Manhattan, Kan.