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Pasteurization of Cream

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South Dakota State College of Agriculture and Mechanic Arts

DAIRY HUSBANDRY DEPARTMENT

PASTEURIZATION OF CREAM

BOWEN PUBLISHING CO., HURON, S. D.

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PASTEURIZATION OF CREAM

By
C. Larsen, J. M. Fuller, V. R. Jones, H. Gregory and M. Tolstrup.

Introduction.

Pasteurization of cream for buttermaking purposes is now a common practice. Some European countries have required for some time that all butter be made from pasteurized cream. In America about two-thirds of our butter is now made from pasteurized cream, and pasteurization of cream for buttermaking is constantly increasing.

Considerable experimental work has been done during the past few years on pasteurization of dairy products. The greater part of the work, however, has been in connection with pasteurization of market milk. It is the purpose of these experiments to determine the efficiency and practicability of the coil cream vat as a cream pasteurizer in the manufacture of butter, the effectiveness of different temperatures of cream pasteurization, and also the keeping properties of the butter made from the cream pasteurized at the different temperatures.

PLAN OF EXPERIMENT.

A 150 gallon coil cream vat, a 20 H. P. return tubular boiler, and a 15 H. P. engine were used in these experiments. The boiler furnished steam for pasteurization and supplied the steam for the 15 H. P. engine, which at the same time ran the coil in the cream vat.

The cream used in the experiments was obtained from the regular college creamery patrons. The cream was of uniform good quality and contained about 30 per cent butterfat. The amount of cream used in each experiment was kept as nearly constant as possible so that the quantity would not be a variable factor.

In each experiment the boiler was filled with water to about one-quarter inch of the top in the glass water gauge. The temperature of the water in the boiler was taken at the valve just beneath the water column, and recorded when the temperature became constant. A fire was then built under the boiler using just enough wood to ignite the coal. The amount of coal was weighed and recorded until the pasteurization process was completed. When the steam pressure reached 73 pounds, the coil in the vat was started and run ten minutes. After thus mixing the cream, samples were taken for chemical and bacteriological analysis and for measurement of fat globules. Time, temperature of cream, acidity, boiler pressure, and speed of coil in cream vat were also recorded at the beginning of each experiment. The speed of the coil in the vat was kept about the same—42 to 45 revolutions per minute.

At the beginning of pasteurization, the water tank connected with the end of the vat, was filled about one-third full of hot water. The pump was started for circulating the hot water through the coils, and at the same time the steam valve connecting the coil of the vat was opened wide. The temperature of the cream was recorded every five minutes until pasteurization temperature was reached. The steam pressure was held near 73 pounds throughout the heating period and the amount of coal required to hold the steam at this pressure was recorded.

Temperature of Pasteurization.

In one series of experiments the cream was heated to 140 degrees F., and held for 25 minutes.

In a second series of experiments the cream was heated to 160 degrees F., and held for 10 minutes.

In a third series of experiments the cream was heated to 180 degrees F., and cooled immediately.

In each method of pasteurization, the cream was cooled to ripening temperature, or about 75 degrees F.

The above average temperatures of pasteurization were used alternately, that is, the first lot of cream was pasteurized at 140 degrees F., the second at 160 degrees F., and the third at 180 degrees F.

In cooling the cream to ripening temperature, the water pipe valve was opened wide to insure a uniform flow of water. The coil of the vat was kept in motion and water forced through by its own pressure. The temperature of the water at the inlet and outlet and the temperature of the cream were recorded each five minute period during the cooling.

After heating the cream, and subsequently cooling it to ripening temperature, samples were again taken for chemical and bacteriological analysis, and for measurement of fat globules. Eight to twelve per cent of starter was added, and each lot of cream ripened as nearly as possible to the same acidity. The per cent of acid developed in the cream varied from .45 to .55. After ripening, which required from two to six hours, the cream was cooled to a few degrees below churning temperature (52 to 56 degrees F.) and held from one to two hours, then churned. The churning period, temperature of wash water, and amount of working were kept as uniform as possible in all experiments.

A sample of five pounds of butter was taken from each churning and packed into an earthen jar. The butter was placed in cold storage, the temperature of which was about 40 degrees F. The acidity and score of the butter was determined when the butter was fresh, and at the end of one month, two months and three months.

TABLE NO. 1.

TIME REQUIRED TO HEAT CREAM AT DIFFERENT STAGES OF PASTEURIZATION.

No. of series	No. of experiments in each series	Lbs. of cream	Per cent. fat in cream	Boiler pressure pounds	Initial temp. of cream	Increase in temperature each five minute period. Degrees F.							
						1st	2d	3d	4th	5th	6th	7th	8th
					Pasteurized at 140 degrees F. for 25 minutes.								
1	5	734	31.69	66.5	59.4	29 0	26.0	23.0	17.0	.....	......	.....	....
2	7	865	29 81	79.0	55.0	29.0	25.0	20.0	17.0	13.0	11.0	......	....
3	4	853	28.26	75.0	58.8	22.0	25.0	22.0	18.2	....	.....	......	....
4	3	592	27.30	75.0	52.7	38.0	32.0	23.0	......	.....	......	......	....
Average		761	29.36	73.9	56.5	29.5	27.0	22.0	17.4	13.0	11.0	......	... .
					Pasteurized at 160 degrees F. for 10 minutes.								
1	5	810	31.44	59.5	59.8	28.0	23.0	21.0	18.0	15.0	10.0	......	....
2	7	914	30.85	81.0	56.2	27.0	26.0	24.0	16.0	15.0	13.0	10.0	....
3	4	820	27.84	74.5	56.8	24.0	27.0	25.0	19.7	14.6	....	.. ..	....
4	4	515	29.90	76.8	54.3	37.7	25.2	25.7	21.3	13.7	......	......	....
Average		765.0	30.00	72.3	56.8	29.1	25.3	23.9	18.7	14.5	11.5	10.0	....
					Pasteurized at 180 degrees F. and cooled immediately.								
1	5	725	29.06	65.0	58.6	29.0	26.0	24.0	18.0	12.0	8.0	5.0	5.0
2	7	930	30.54	84.9	55.0	29.0	27.0	20.0	18.0	12.0	12.0	11.0	10.0
3	4	786	27.61	73.5	58.3	24.0	25.0	23.0	19.0	13.0	9.0	6 5	....
4	3	591	28.40	76.5	57.7	31.0	29.6	24.6	16.0	12.0	10.0	9.0	....
Average		758	28.90	74.0	57.6	28.2	26.9	22.9	17.7	12.2	9.0	7.9	7.5

Efficiency of Coil Cream Vat in Heating Cream.

By referring to Tables No. 1 and 2, it will be noted there were 19 lots of cream pasteurized at 140 degrees F. The average weight of cream in each lot was 761 pounds. With the steam pressure at 73.9 pounds, it required an average of 16.8 minutes to raise the temperature from an average initial temperature of 56.5 degrees F. to 140 degrees F., or the cream was raised five degrees F. for each minute of heating.

Twenty different lots contained an average of 765.0 pounds of cream. With the steam pressure at 72.3 pounds, the temperature of the cream was raised from 56.8 degrees F. to 160 degrees F. in 22.2 minutes, an average increase of 4.6 degrees for each minute of heating.

Nineteen lots of cream containing an average of 758 pounds were pasteurized at 180 degrees F. The average steam pressure was 74 pounds. The average temperature of each lot of this cream was raised 122.6 degrees F; the average time required being 34.4 minutes, or an average increase in temperature of 3.5 degrees for each minute of heating.

TABLE NO. 2.

AVERAGE INCREASE IN TEMPERATURE OF CREAM FOR EACH MINUTE OF HEATING PERIOD.

Past temp. degrees F.	Pounds of cream	Steam pressure, lbs.	Total degrees heated Degrees F.	Heating period, Min.	Increase in temp. per min Degrees F.
140	761.0	73.7	83.5	16.8	5.0
160	765.0	72.3	103.2	22.2	4.6
180	758.0	74.0	122.6	34.4	3.5

The difference of increase in temperature in pasteurization at the above temperatures is undoubtedly due; first, to the loss of heat by evaporation; second, to the difference in temperature of the cream and of the hot water within the coils; and third, to radiation of heat from the vat. It will be noted in Table No. 1 that the rapidity of heating during each five minute period decreased as pasteurization temperature was approached. The rapidity of heating cream to pasteurization temperature is shown by diagram in Fig. 1.

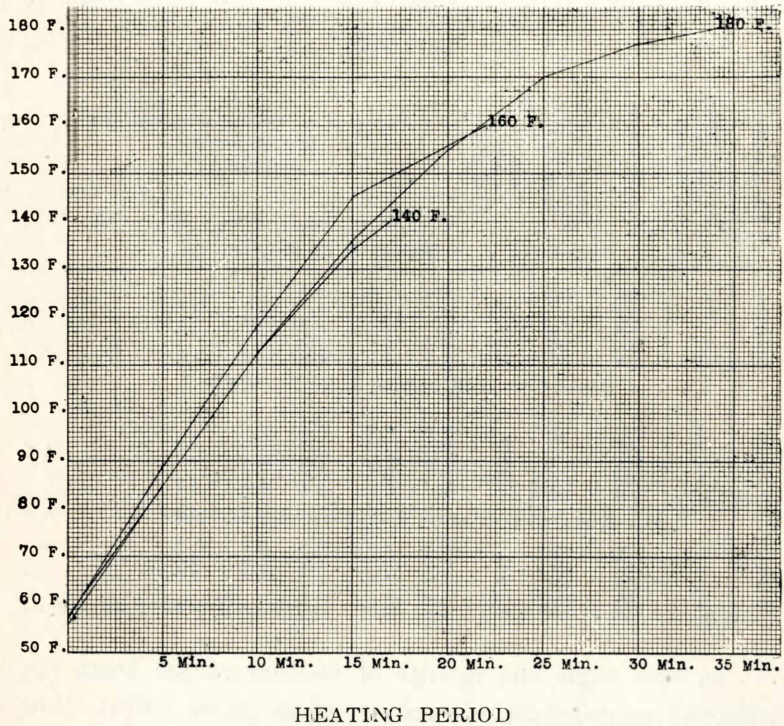

Fig. 1.—Time required for heating cream to different pasteurization temperatures.

Efficiency of Coil Cream Vat in Cooling Cream After Pasteurization.

The accompanying Table No. 3 gives the results that were obtained in the cooling experiments.

TABLE NO. 3.

TIME REQUIRED TO COOL CREAM AT DIFFERENT STAGES OF COOLING.

No. of series	No. of experiments in each series	Lbs. of cream	Temp. of cr'm before cooling Degrees F.	Temp. of water Degrees F.	Decrease in temperature each five minute period. Degrees F.						
					1st	2d	3d	4th	5th	6th	7th
Pasteurized at 140 degrees F. for 25 minutes.											
1	5	734	131	......	25.8	17.4	10.4	....	....	....	....
2	7	865	128	44	21.0	15.0	12.0	13.0	10.0	....	....
3	4	853	128	49	19.0	16.5	10.0	7.0	6.0	....	....
4	3	592	122	54	23.6	14.3	11.0	....	....	....	....
Average		761	127.2	49	22.3	15.8	10.8	10.0	8.0	....	....
Pasteurized at 160 degrees F. for 10 minutes.											
1	5	810	150	......	27.0	22.0	14.0	10.0	....	....	....
2	7	914	150	45	25.0	19.0	14.0	10.0	7.3	....	....
3	4	820	151	48	27.0	21.0	13.0	10.2	5.2	....	....
4	4	515	144.5	57.2	27.0	22.2	12.7	7.7	....	....	....
Average		765.	148.8	50	26.5	21.0	13.4	10.0	6.2	....	....
Pasteurized at 180 degrees F., and cooled immediately.											
1	5	725	180	......	30.0	28.0	22.0	13.0	11.[illegible]	....	....
2	7	930	180	45	32.[illegible]	24.[illegible]	18.0	13.0	9.0	8.0	....
3	4	786	180	50	33.0	25.0	18.0	13.0	9.0	6.0	5.0
4	3	591	180	56.3	55.6	30.0	12.0	....	....	....	....
Average		758	180	50.4	37.6	26.7	18.8	13.0	9 6	7.0	5.0

In this table the results of cooling cream from the different pasteurization temperatures show: first, that the rapidity of cooling from 160 degrees F. to 75 degrees F. is 0.5 degrees per minute less than cooling from 180 degrees F.; and second, that the rapidity of cooling from 140 degrees F. is 1.0 degree per minute less than cooling from 180 degrees F. The amount of water used for cooling the cream to ripening temperature is proportionate to the number of minutes required to cool the cream. This is shown in the following Table No. 4.

TABLE NO. 4.

TEMPERATURE, AND NUMBER OF CUBIC FEET, OF WATER USED IN COOLING CREAM TO CHURNING TEMPERATURE.

Past temp. Degrees F.	Average wt. of cream, lbs.	Temp. of water at intake Degrees F.	Degrees Cooled	Cooling period. Min.	Temperature of water at outlet during each five minute period. Degrees F.					Average rate of cooling per minute Degrees F.	Cubic feet of water used	Cubic feet of water per 100 lbs. of cream
					1st	2d	3d	4th	5th			
140	770	49.0	53.0	17.9	60.0	58.0	56.0	....	...	2.9	54.3	7.5
160	749	56.0	72.6	21.3	65.0	61.0	57.0	56.0	....	3.4	61.6	8.2
180	769	50.4	100.1	26.0	69.0	61.0	60.0	57.1	55.0	3.9	79.1	10.3

Table No. 4 shows the relative efficiency of cooling cream with water from different pasteurization temperatures to the churning temperature. The results of this table show that cream pasteurized at 180 degrees F. and 160 degrees F. cooled more rapidly per minute than cream pasteurized at 140 degrees F.

Fig. 2 shows by diagrams the time required for cooling cream from pasteurization temperatures to ripening temperature.

Effect of Pasteurization of Cream on the Number of Micro-organisms.

As previously explained, the cream was well mixed by rotating the coil for ten minutes before the steam was admitted into the coil of the vat. A sample of cream was taken in a sterile bottle for the determination of the number of micro-organisms per cubic centimeter. After pasteurization of the cream, and just before the starter was added, another sample was taken to determine the number of micro-organisms that survived pasteurization. The samples were carried to the laboratory and immediately plated with lactose agar. The plates were incubated for 56 hours and number of colonies counted.

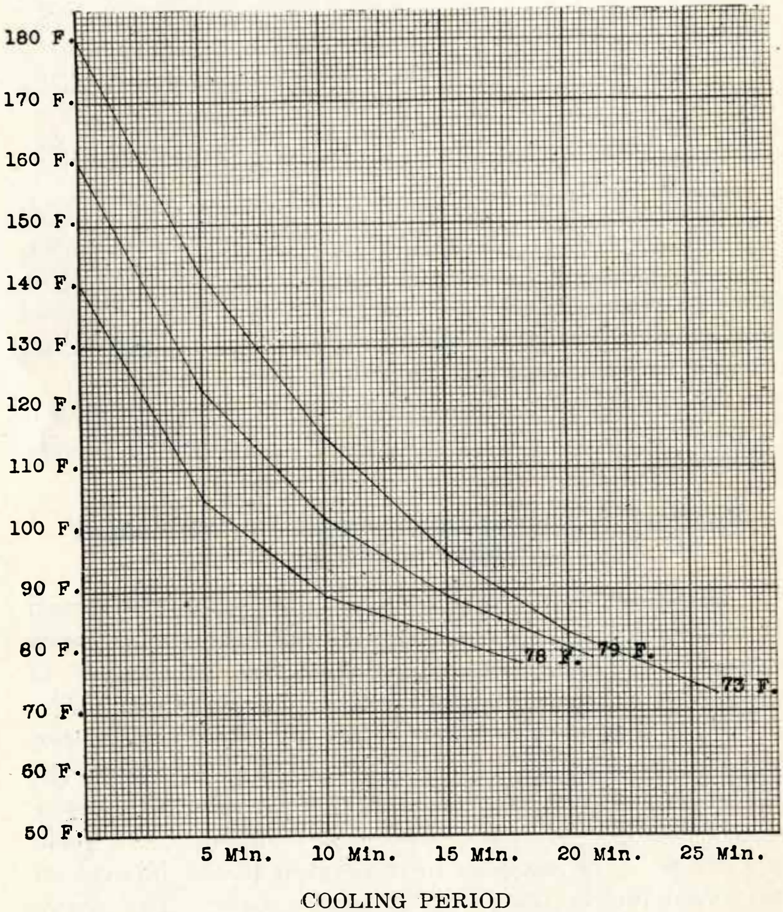

Fig. 2. Time required for cooling cream from different pasteurization temperatures.

TABLE NO. 5.

EFFECT OF PASTEURIZATION OF CREAM ON THE NUMBER OF MICRO-ORGANISMS.

No. of series	No. of experiments in each series	Micro-organisms per cubic centimeter of cream						Per cent killed		
		Acid formers		Molds and non-acid formers		Total		Acid Formers	Molds & non-acid formers	Total
		Raw	Past.	Raw	Past.	Raw	Past.			
		Pasteurized at 140 degrees F. for 25 minutes								
1	5	166,015,000	392,000	11,845,000	3,200	177,860,000	395,200	99.76	99.99	99.79
2	7	119,102,857	369,450	5,696,428	38,650	124.799,285	408,107	99.68	99.39	99.67
3	4	65,266,000	272,250	4,270,750	26,833	69,474,900	294,312	99.58	99.37	99.58
4	3	....	....	....	....	432,666,666	326,333	.....	.....	99.92
Average		116,794,619	344,566	7,270,746	22,896	201,200.212	355,988	99.67	99.58	99.74
		Pasteurized at 160 degrees F. for 10 minutes								
1	5	172,600,000	3,652	4,700,000	1,833	177,300,000	5,685	99.99	99.96	99.99
2	7	300,224,285	42,727	6,081,000	18,823	306,305,285	61,550	99.98	99.69	99.98
3	4	56,300,005	38,137	3,225,000	26,750	59,525,000	51,512	99.93	99.17	99.92
4	3	....	....	....	....	259,650,000	229,200	.....	.....	99.91
Average		176,374,761	28,172	4,662,000	15,802	200,695,071	86,986	99.96	99.60	99.95
		Pasteurized at 180 degrees F. and cooled immediately								
1	5	101,268,750	1,900	4,750,000	845	106,518,750	2,745	99.99	99.98	99.99
2	7	133,881,714	192,420	2,525,143	11,348	136,406,857	203,768	99.96	99.55	99.85
3	4	37,812,500	10,550	2,328,300	13,300	39,558,000	20,530	99.97	99.42	99.95
4	3	....	....	....	....	286,333,333	391.656	.....	.....	99.86
Average		90,987,654	68,290	3,201,147	8,497	142 204,235	154,677	99.95	99.65	99.91

While a large percentage of organisms are killed by each method of pasteurization, it will be noted that a large number resisted the pasteurization temperatures.

There are two important points shown in Table No. 5. The first is the change in the relationship between the "acid-forming bacteria" and the "molds and non-acid formers" due to pasteurization. In cream pasteurized at 140 degrees F. for 25 minutes, the ratio of "acid-forming organisms" to "molds and non-acid formers" is 30 to 1 before pasteurization and 15 to 1 after pasteurization. In cream pasteurized at 160 degrees F. for ten minutes, the ratio of "acid-forming organisms" to "molds and non-acid formers" is 38 to 1 before pasteurization and 2 to 1 after pasteurization.

In cream pasteurized at 180 degrees F. and cooled immediately, the ratio of "acid-forming organisms" to "molds and non-acid formers" is 30 to 1 before pasteurization and 8.5 to 1 after pasteurization. It is evident, therefore, that the acid formers are more easily destroyed than the molds and non-acid forming organisms, especially when higher temperatures are used. It is probable that molds and non-acid forming bacteria which resist pasteurization are the spore forming types. It is probable, too, that the presence of some of the molds and bacteria in pasteurized cream is due to contamination from the air when the vat is exposed during the cooling process. The resistance of the bacteria and mold spores to heat, together with the contamination from the air are two of the factors that cause the existence of these organisms in pasteurized cream. The number of acid formers (lactic acid bacteria) left in the pasteurized cream can be explained in much the same way. No doubt some of the acid formers come from contamination in cooling the cream, and some survive the pasteurization process. It is recognized that some strains of lactic acid bacteria withstand heat to a marked degree.. The thermal death point of lactic acid bacteria ranges from 150 to 160 degrees F., although typical strepoccus lactarius have been isolated whose thermal death point was as high as 172 degrees F. (U. S. Dept. Agr., B. A. I. Bul. 120).

The results of these experiments show that the coil cream vat used as a pasteurizer is effective in destroying bacteria and molds in cream. Only a small number of organisms survive pasteurization by this method.

Effect of Pasteurization on the Size of Fat Globules in Cream.

After the bacteriological analyses were made, the size of fat globules was determined on the same samples of cream. It was necessary to dilute the cream one to one hundred in order to separate the fat globules for measurement. The method used in measuring the globules is as follows:

A drop of one to one hundred dilution of the cream was placed on a hanging drop microscopic slide and examined with a microscope fitted with a graduated eyepiece and an objective magnifying 348 diameters. It was possible with this instrument to measure the globules to .0005 mm. Care was taken to measure each fat globule in each field examined to avoid selection of globules. About one hundred fat globules were measured from each sample of cream, and their average computed.

TABLE NO. 6.

EFFECT OF PASTEURIZATION OF CREAM ON SIZE OF FAT GLOBULES.

No. of series	No. of experiments in each series	Heating period	Cooling period	Total time coils operated	Average size of fat globules in millimeters		
					Before past.	After past.	Difference
		min.	min.	min.			
Pasteurized at 140 degrees F. for 25 minutes							
1	5	17	15	57	0.00289	0.00320	+0.00031
2	7	18	18	61	0.00210	0.00162	-0.00048
3	4	18.5	24.2	67.5	0.00161	0.00138	-0.00025
4	3	13.6	14.6	53.2	0.00171	0.00169	-0.00002
Average		18.0	17.9	60.9	0.00207	0.00197	0.00011
Pasteurized at 160 degrees F. for 10 minutes							
1	5	23.4	16.2	49.6	0.00306	0.00295	-0.00011
2	7	24	24	58	0.00216	0.00155	-0.00061
3	4	22	26	58	0.00164	0.00145	-0.00019
4	4	19.5	19.2	48.7	0.00178	0.00177	-0.00001
Average		22.2	21.3	53.5	0.00216	0.00193	-0.00023
Pasteurized at 180 deerees F., cooled immediately							
1	5	36.6	22.2	58.8	0.00321	0.00317	-0.00004
2	7	35	30	65	0.00211	0.00168	-0.00043
3	4	37	35	72	0.00173	0.00148	-0.00025
4	3	29.6	17	46.6	0.00146	0.00130	-0.00016
Average		34.5	26	60.5	0.00212	0.00190	-0.00022

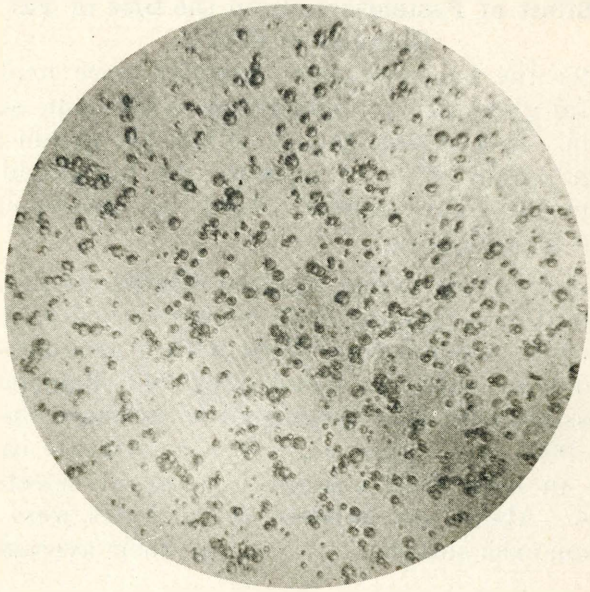

Fig. 3—Fat globules in cream not pasteurized.

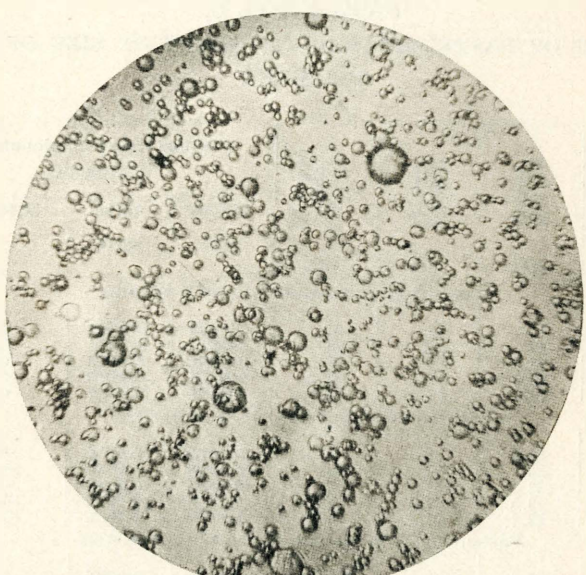

Fig. 4—Fat globules in cream pasteurized at 140 degrees F. and held for 25 minutes.

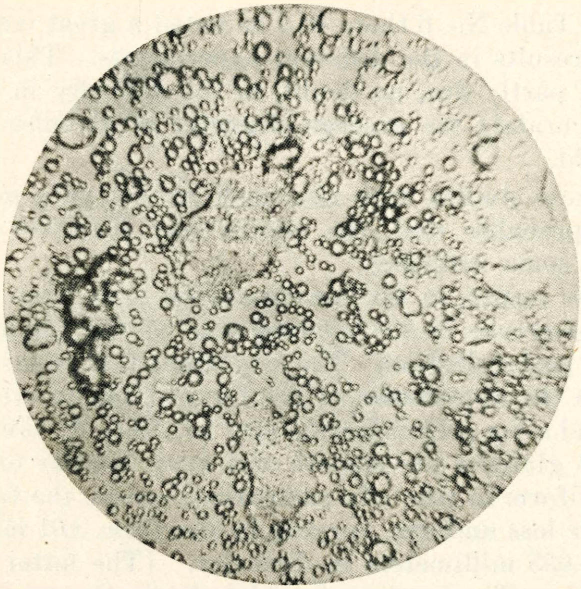

Fig. 5—Fat globules in cream pasteurized at 160 degrees F. and held for 10 minutes.

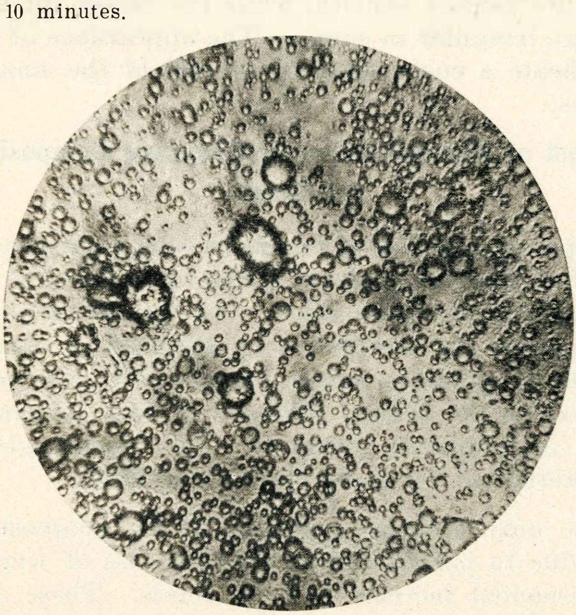

Fig. 6.—Fat globules in cream pasteurized at 180 degrees F. and cooled immediately.

In Table No. 6 there will be noted a great irregularity of results in the different experiments. This difference is partly due, no doubt, to the difficulty in obtaining accurately the average diameter of globules in any one field.

These studies were also made at intervals, and it is quite probable that the season and lactation period caused some variation.

The results in the accompanying table show a very small decrease in the average size of the fat globules due to pasteurization. The important fact is the difference in the appearance of the fat globules in cream before and after pasteurization (pp. 541-542). In raw cream the fat globules are smooth and more regular of shape and uniform in size. In pasteurized cream, the fat globules are less uniform, varying in size from .001 millimeters to .035 millimeters in diameter. (The latter size is unusual). The smallest fat globules in the pasteurized cream are usually smooth, while the larger fat globules are more irregular in shape. The appearance of the latter indicate a coalescense of several of the smaller fat globules.

Effect of Pasteurization on Chemical Composition of Cream.

Separate samples of cream in each experiment were taken for chemical analysis at the same time the bacteriological samples were taken. No preservatives were used because the samples were analyzed at once. The percentages of water, solids, protein and sugar were determined by the Official Methods of the Association of Official Agricultural Chemists. The percentage of fat was determined by Roese-Gottlieb method.

The only noticeable change in the composition of cream due to pasteurization was the loss of water, and the consequent increase in total solids. These changes were most marked when the higher pasteurization temperatures were used.

TABLE NO. 7.

EFFECT OF PASTEURIZATION UPON CHEMICAL COMPOSITION OF CREAM.

No. of series	No. of experiments in each series	Composition of Raw and Pasteurized Cream												differ-ence
		% water		% fat		% protein		% lactose		% ash		% acid		
		Raw	Past.	Raw	Past.	Raw	Past.	Raw	Past.	Raw	Past.	Raw	Past.	
Pasteurized at 140 degrees F. for 25 minutes														
1	5	63.03	62.35	31.69	32.13	2.12	2.12	2.13	2.37	0.51	0.52	0.476	0.458	-0.018
2	7	64.54	63.89	29.81	30.26	2.21	2.26	2.44	2.59	0.49	0.51	0.515	0.492	-0.023
3	4	66.02	65.47	28.26	28.73	2.29	2.33	2.89	2.92	0.54	0.55	0.572	0.562	-0.010
4	3	66.61	66.24	27.30	27.97	2.31	2.37	3.60	3.66	0.52	0.52	0.490	0.476	-0.014
Average		65.05	64.48	29.26	29.77	2.23	2.27	2.76	2.87	0.51	0.52	0.513	0.497	-0.016
Pasteurized at 160 degrees F. for 10 minutes														
1	5	62.92	61.83	31.44	32.38	2.21	2.15	2.39	2.58	0.51	0.54	0.472	0.456	-0.016
2	7	63.60	62.80	30.85	31.56	2.15	2.17	2.39	2.45	0.48	0.50	0.525	0.499	-0.025
3	4	66.29	65.47	27.84	28.55	2.32	2.38	3.01	3.05	0.55	0.56	0.475	0.467	-0.008
4	4	64.39	62.91	29.90	30.82	2.19	2.29	3.15	3.15	0.48	0.51	0.525	0.528	*0.003
Average		64.30	63.25	30.00	30.82	2.21	2.24	2.73	2.80	0.50	0.52	0.499	0.487	-0.011
Pasteurized at 180 degrees F., and cooled immediately														
1	5	65.35	63.50	29.06	30.73	2.16	2.24	2.37	2.49	0.53	0.53	0.492	0.470	-0.022
2	7	63.67	62.31	30.54	31.56	2.23	2.30	2.57	2.83	0.50	0.52	0.483	0.477	-0.006
3	4	66.39	64.97	27.61	28.83	2.32	2.42	3.14	3.23	0.54	0.56	0.455	0.437	-0.018
4	3	66.76	64.48	28.40	29.72	2.56	2.56	3.30	3.80	0.49	0.53	0.486	0.533	*0.047
Average		65.54	63.81	28.90	30.21	2.24	2.38	3.09	3.08	0.51	0.52	0.479	0.479	0.000

Analysis and Quality of Butter.

In order to find the effect of different pasteurization temperatures on the keeping quality, a five pound jar of butter was packed from each experiment. The butter was scored and analyzed the day after churning. The acidity and score of the butter were obtained each month for three consecutive months. In many cases the butter became so rancid at the end of the third month that it was considered useless to give a score on its quality.

The acidity of the butter was determined by the following method: Ten grams of butter from a well mixed sample were weighed, then melted at a low temperature, 25 cc. of neutral alcohol and 25 cc. of neutral ether added. One-half cubic centimeter of phenolphthalein was added and the mixture titrated with tenth normal sodium hydroxide.

TABLE NO. 8.

CHEMICAL ANALYSIS AND SCORE OF BUTTER.

No. of series	No. of experiments in each series	Average analysis of butter				Average acidity and score of butter							
						Fresh		1 month old		2 months old		3 months old	
		% Water	% Fat	% Curd	% Ash	Acid	Score	Acid	Score	Acid	Score	Acid	Score
Pasteurized at 140 degrees F. for 25 minutes													
1	5	12.79	83.54	1.12	2.55	......	92.8	......	91.1	......	89.9	......	.....
2	7	12.89	84.58	0.72	1.80	1.51	93.1	1.77	91.0	2.20	89.8	2.58	83.2
3	4	14.11	83.86	0.76	1.28	1.53	91.6	2.13	86.0	2.66	85.6	4.40	......
4	3	14.77	83.20	0.63	1.65	1.66	92.0	2.03	88.8	2.28	82.0	2.53	.....
Average		13.84	83.79	0.80	1.82	1.56	92.3	1.97	89.2	2.38	86.8	3.17	83.2
Pasteurized at 160 degrees F. for 10 minutes													
1	5	12.82	83.30	1.10	2.78	......	92.4	......	90.2	......	89.1	......	......
2	7	14.25	82.78	0.72	2.25	1.43	92.7	1.53	90.1	1.88	89.5	2.12	88.6
3	4	14.04	83.39	0.73	1.83	1.38	92.3	1.56	90.0	2.25	88.8	2.65	......
4	3	14.30	83.18	0.72	1.70	1.46	91.7	1.93	88.3	2.06	82.0	1.95	......
Average		13.85	83.16	0.81	2.14	1.41	92.2	1.67	89.6	2.06	87.3	2.24	88.6
Pasteurized at 180 degrees F., and cooled immediately													
1	5	12.69	83.20	1.04	3.07	......	92.8	......	89.2	......	90.1	......	......
2	7	14.02	83.16	0.73	2.09	1.36	93.2	1.37	92.5	1.40	91.7	1.61	89.0
3	4	13.79	83.75	0.75	1.71	1.17	92.0	1.28	89.6	1.83	87.6	2.58	......
4	4	14.84	83.19	0.68	1.61	1.48	92.0	1.45	88.1	1.43	85.0	1.81	84.0
Average		13.83	83.30	0.80	2.12	1.33	92.5	1.36	89.8	1.55	88.6	2.00	86.0

The acidity is expressed by the number of cubic centimeters of tenth normal alkali required to neutralize the acid in ten grams of butter dissolved in ether-alcohol mixture.

Table No. 8 shows that the butter from the different experiments was quite uniform in composition. The lowest moisture content was 12.69 per cent, and the highest was 14.84 per cent, with an average of 13.84 per cent. The butterfat and curd content of the butter was also about the same in each series of experiments. The different temperatures and methods of pasteurization of the cream apparently had no effect upon the percentage of butterfat and curd in the butter. The ash content which represents mainly the salt in the butter, shows a wider variation than any of the other constituents. The lowest average percentage of ash in any one series was 1.28, and the highest percentage was 3.07. The average for the three series was 2.02 per cent. By the above analysis it is shown that the chemical composition of the butter is not noticeably affected by the different temperatures, and methods of pasteurization.

TABLE NO. 9.

EFFECT OF PASTEURIZATION TEMPERATURE UPON ACIDITY OF BUTTER AT DIFFERENT AGES.

Cream Pasteurized	Butter Fresh	Butter 1 month old	Butter 2 months old	Butter 3 months old
140 degrees F. held 25 minutes	1.56	1.97	2.38	3.17
160 degrees F. held 10 minutes	1.41	1.67	2.06	2.24
180 degrees F. cooled immediately	1.33	1.36	1.55	2.00

The score of butter from cream at different pasteurization temperatures after storage of one and two months shows a slight variation in quality. The butter from cream pasteurized at 140 degrees F. was inferior in quality to the butter made from cream pasteurized at either 160 or 180 degrees F. In the accompanying Table No. 9 there is noted a lower development of acid in butter made from cream pasteurized at 160 degrees and 180 degrees F. than in cream pasteurized at 140 degrees F.

SUMMARY.

1. It was found that in pasteurization of cream at different temperatures; namely, 140 degrees F. for 25 minutes, 160 degrees F. for 10 minutes and 180 degrees F., with immediate cooling, the temperature of 160 degrees F. for 10 minutes was the most effective in destroying total micro-organisms.

2. Pasteurization of cream at 160 degrees F., or 180 degrees F. proved more efficient in killing molds and non-acid forming organisms than pasteurization at 140 degrees F.

3. The only noticeable change in composition of cream due to paseurization was a slight decrease in percentage of water, and a consequent increase in percentage of total solids.

4. There was a slight decrease in acidity of the cream after pasteurization at temperatures of 140 degrees F. and 160 degrees F. Cream pasteurized at 180 degrees F. showed on the average less decrease in per cent acid. This is probably due to the fact that the decrease in acidity by volatilization of acids just about offsets the increase in acidity through evaporation of water from the cream.

5. The numerous microscopical examinations of fat globules in raw and pasteurized cream show that at the higher temperatures (160 and 180 degrees F.) the fat globules tend to coalesce or unite. This is probably due to the higher heat, together with the greater agitation of the cream by the coil.

6. In no instance was it noticed that the high pasteurization temperatures unfavorably affected the body of the butter.

7. Butter made from cream pasteurized at 180 degrees F. retained its keeping qualities the best.

8. The different temperatures of pasteurization did not have any important effect on the chemical composition of the butter.

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109. Rusts of Cereals and other Plants.
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114. Digestion Coefficients of Grains and Fodders for South Dakota.
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157. Rape Pasture for Pigs in Corn Field. Kaoliang for Pigs.
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