1-1-1930

Cream Line Studies of Market Milk

G. Malcolm Trout

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Cream Line Studies of Market Milk

by G. MALCOLM TROUT

Figure 1.—Cream Line on Milk Held (left to right)
at 35° F., 32° F., and 70° F.

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*Cream Line Studies of Market Milk**

by G. MALCOLM TROUT†

MARKET milk is judged by the consumer according to its flavor and to the amount of cream appearing in the neck of the bottle.

The fact that butterfat is lighter than milk serum and rises to the top in the form of a cream layer is common knowledge. It is therefore difficult in the event of a small cream layer to explain to the housewife why not all the fat originally present in the milk has risen to the top of the bottle.

The common practice today in the market milk plants is to pasteurize the milk at 140° to 145°F. and to hold it at that temperature for 30 minutes. Then it is pumped over a surface cooler and cooled to below 50°. Such procedure when followed by a skilled operator rarely has a harmful effect upon the flavor, but often does affect the depth of the cream layer. Any methods of procedure that will restore to milk its natural creaming ability or least retard the natural rising of the cream should be of especial value to the market milk industry.

The growing importance of the market milk industry in West Virginia, together with the introduction of much modern machinery, has prompted a study of the effect of agitation and pumping upon the creaming ability of market milk.

HISTORICAL REVIEW

A number of papers have appeared in recent years on the creaming ability of milk and on the effect of certain milk plant operations on the resulting cream layer of market milk. Some have dealt exclusively with the factor of temperatures used in pasteurization, while others have shown the effect of various methods of pasteurization, agitation, and pumping upon the creaming ability of the milk so treated. Only the papers reporting investigational work on the factors under direct control of the milk plant operator are here considered.

Hammer and Hauser (1914) in their study on the "in-the-bottle" method of pasteurization found that "a high pasteurization temperature was unsatisfactory for the method of final package pasteurization because of the decreased creaming ability and pronounced heated flavor of the milk so treated."

When the milk was exposed for a short time at various temperatures an increased creaming ability of the milk so treated was frequently observed; but with exposures which would satisfy the requirements governing bacterial efficiency, such an increase was not observed.

Hammer (1916) reported that pasteurization can be so carried out that the decrease in the creaming ability will not be very pronounced. He further concluded

*Submitted for publication September, 1928.

†Resigned October, 1928.

that apparently it was impossible to pasteurize milk properly without decreasing the creaming ability. Agitation of milk at ordinary temperatures did not appreciably decrease the creaming ability of the milk; occasionally, in fact, there was a slight increase.

Kilbourne (1916) stated that one of the important factors affecting the volume of cream in bottled milk was the amount of agitation to which the milk was subjected, especially while hot. In those plants where there was most agitation of the milk, and particularly when pumping of the hot milk was practised, the greatest difficulty with the cream line was experienced.

Parker (1917) quoted Professor Peter of the Swiss Dairy School in Berne as stating that the rapidity of formation as well as the depth of the cream line increased up to a pasteurizing temperature of 141.8°F. Beyond this point these factors decreased, but even at 145.4° they were greater than in raw milk. Parker concluded that milk should never be pumped after pasteurization on account of recontamination and because, if the pumping is done while the milk is hot, the volume of cream that will rise on it is greatly reduced.

Judkins and Downs (1918) found during their studies in processing milk that the reduction in the cream line of vat-pasteurized milk cooled in the vat was 2.9 percent and when cooled over the cooler, 1.5 percent. In the case of in-the-bottle pasteurization there was no apparent reduction in the cream line. They noted that the higher the temperature to which the milk was heated, the greater was the reduction in cream line.

Harding (1921) observed that the volume of cream on milk began to decrease measurably when the temperature of pasteurization was raised from 142° to 144°F. As the temperature was increased, the decrease in the volume of cream rapidly become more pronounced; at 145° the decrease amounted to slightly more than 10 percent by volume; at 146° it amounted to 16.6 percent; and at 148° to approximately 40 percent.

Wright (1923) after investigating the effect of pasteurization of market milk in the glass-enameled tank and in the bottle, reported that the glass-enameled tank when used with a surface coil cooler gave very satisfactory results as compared with the in-the-bottle method. The rapid cooling gave a larger volume of cream, and the line of demarcation was very distinct. The milk passing last over the cooler gave a smaller volume than did the milk passing first.

Martin and Combs (1924) made investigations into the effect of milk plant operations on the amount of cream rising on milk. They found that when milk was cooled in the pasteurizer a considerable loss in cream volume occurred, the extent of the loss depending on the type of pasteurizer and on the amount of agitation to which the milk was subjected. Hot milk subjected to agitation showed a gradual loss in creaming ability which was very small for the first two hours, but after that it amounted to from 20 to 65 percent. Pumping milk while cold had little effect on its creaming ability. The average of seven trials in which hot milk was pumped showed but a small loss.

Whittaker and co-workers (1925) found that pasteurization at 145° to 146°F. for 30 minutes reduced the cream volume an average of approximately 8 percent, with considerable variations above and below. As to the agitation of milk during pasteurization they reported that tests conducted to show the effect of agitation during the holding period were not uniform, but that the tendency appeared to be

slightly in favor of holding the milk without agitation during that period. They concluded: "Moderate agitation during the 30-minute holding period apparently had no appreciable effect on the cream volume. Pumping milk at temperatures between 60° and 120° reduced the cream volume to a slight extent in some cases. Pumping raw milk below 60° and pumping pasteurized milk at temperatures between 120° and 140° had practically no effect upon the cream volume. Holding or agitating milk at a temperature of 145° had considerably less effect on the cream volume than at temperatures between 60° and 110°."

PURPOSE OF THE EXPERIMENT, AND METHODS USED

The chief objects in the present experiment were to determine the effect of agitation and pumping of milk upon the resulting cream layer, and to determine the critical temperatures at which pumping had the most harmful effect upon the depth of cream layer appearing at the top of the bottle of milk.

The milk samples used in this experiment were obtained in part from the West Virginia University dairy herd and in part from the commercial milk plant at Morgantown. The University herd at the time of the experiment consisted of the four main dairy breeds; about three-fifths of the herd were Holstein, one-fifth Jersey, and the balance Ayrshire and Guernsey. The herds supplying milk to the local plant were of mixed breeding, the Holstein and Jersey breeds predominating.

The milk received at the West Virginia University dairy was pasteurized in a glass-lined tank at 145°F. for 30 minutes. During pasteurization the milk was agitated by a side paddle-wheel rotating at 431 revolutions per minute. After the pasteurization period was completed, the milk was pumped by a centrifugal pump having a speed of 1,135 revolutions per minute over a tubular surface cooler which cooled the milk to 35°. Precooling the milk in the vat, by circulating water in the jacket surrounding the tank, was begun simultaneously with pumping the milk over the cooler.

Samples were taken of the raw milk after it had been thoroughly mixed; of the pasteurized milk before and after pumping at 145°F.; and of the pasteurized milk pumped at 135°, 125°, 115°, 105°, 90°, and 80°, respectively. Samples were obtained under conditions as nearly comparable to plant practices as possible.

The creaming tests were made in 100 c.c. graduate cylinders of an even diameter. The depth of the column of milk within the cylinders was approximately that of a quart milk bottle. Triplicate samples of each lot of milk were taken, one sample of which was creamed in ice water. Another sample was creamed in the milk cooler at 40°F.; and the third sample was creamed at 70°. Measurements of the depth of the cream layer were recorded in sixteenths of an inch after standing two, four, six, and twenty-four hours.

All fat tests were made by the Babcock butterfat test. Samples of cream for a fat test were obtained by pipetting off the cream layer down to one-fourth inch of the lower limit. Precautions were taken to keep the cylinder in an upright position and free from agitation, thus preserving the distinct cream line. The lower fourth-inch cream layer remaining, together with the upper one-inch of serum, was removed by a suction pump. An absorbent cotton swab was used to remove any cream which may have adhered to the sides of the cylinder. The serum then was shaken vigorously, and a sample taken.

Table 1.—Creaming Efficiency of Raw Milk at Various Temperatures

Trial No.	Percent- age of Fat in Milk	Depth of Cream Layer*			Percentage of Fat in Cream			Percentage of Fat in Skimmilk		
		32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.
1	3.2	17	18	7	19.0	21.0	20.0	.15	.15	1.30
2	3.0	17	17	8	21.0	19.5	21.5	.27	.20	1.20
5	3.3	18	18	7	21.0	19.0	19.0	.40	.40	1.30
8	3.4	16	20	6	22.0	19.0	21.5	.35	.40	1.35
13	3.3	18	18	7	19.5	18.5	19.0	.45	.50	1.40
16	3.6	18	19	6	18.5	18.5	20.5	.45	.45	1.70
18	3.1	16	19	5	22.5	17.5	18.5	.40	.40	1.80
22	3.4	17	19	6	19.0	18.5	23.0	.45	.40	1.90
25	3.0	18	18	7	17.5	18.0	23.0	.40	.40	1.60
28	3.3	17	19	6	20.0	18.0	20.0	.60	.70	1.90
30	3.2	16	17	6	20.0	20.0	19.5	.45	.55	1.60
34	3.6	17	18	5	20.5	20.5	18.0	.50	.55	1.80
37	3.6	15	18	5	22.5	18.0	21.0	.45	.40	1.80
39	3.6	15	17	5	24.0	21.0	25.5	.70	.80	2.20
Av. 39 Trials	3.30	16.85	18.26	5.98	20.54	19.15	21.05	0.47	0.50	1.66
Odds†		very great very great very great			very great very great very great			1:6 very great		

*Measurements recorded in sixteenths of an inch.
†In cases where the odds were greater than 999:1 they have been recorded as "very great."

The samples of milk taken at the commercial plant were obtained from the bulk of the raw milk before and after pumping; after preheating at 85° to 90°F.; after clarification; after pasteurization at 145° for 30 minutes in a coil vat; after pasteurization at 145° for 30 minutes in a glass-lined pasteurizer; and after pumping the pasteurized milk by the use of a single-stage homogenizer without pressure to the cooler.

When photographs were taken, 5 c.c. of a saturated solution of Sudan III in 95 percent alcohol were added to each pint of milk. Sudan III rendered the cream line more distinct and made photography possible by coloring the cream layer a deep orange.

EXPERIMENTAL RESULTS

Effect of Various Temperatures of Creaming Raw Milk upon the Percentage of Fat in the Cream and upon the Completeness of Creaming. To gain an impression of the efficiency of creaming, 39 lots of raw milk of known fat content were creamed at 32°, 40°, and 70°F. Table 1 shows a portion of the data obtained, selected to show the variations encountered as well as the representative results. (Cf. Figure 1, cover page.)

The data obtained from creaming raw milk at different temperatures show cream layers varying from 15 to 18 units (sixteenths of an inch) when creamed at 32°F.; from 16 to 20 units when creamed at 40°; and from 4 to 8 units when creamed at 70°, while the fat content of the raw milk ranged from 3.0 to 3.6 percent.

The percentage of fat found in the cream layer obtained from creaming milk at 32°F. varied from 17.5 to 24.0 percent; that creamed at 40° ranged from 17.5 to 21.0 percent; while that creamed at 70° showed a minimum test of 18.0 percent fat and a maximum of 25.5 percent fat.

The variations encountered were greatest in the fat test of the milk serum. The serum of the milk creamed at 32°F. varied from 0.15 to 0.70 percent fat; at 40°, from 0.15 to 0.80 percent; and at 70°, from 1.20 to 2.20 percent fat.

The average for 39 trials showed a slightly greater depth of cream layer when the milk was creamed in air at 40°F. rather than in ice water at 32°. The creaming efficiency, as determined by the amount of fat remaining in the milk serum, however, is in favor of the ice-water temperature. The results obtained show greater concentration of fat in the cream layer creamed in ice water, as compared to that creamed at 40°. Likewise less fat remained in the milk serum creamed in ice water than in the milk serum creamed at 40°.

Delayed creaming was encountered in creaming milk at 70°F. Not until after several hours was the line of demarcation distinct. A microscopical examination revealed a greater percentage of large fat globules present in the cream obtained by creaming the milk at 70°, as compared to the percentage present in cream obtained by creaming at 32° and at 40°.

Effect of Various Temperatures of Creaming Milk, Pasteurized at 145°F. for Thirty Minutes, upon the Percentage of Fat in the Cream and upon the Completeness of Creaming. In order to learn what effect pasteurization of milk at 145°F. for 30 minutes might have upon its creaming ability, data were obtained on 30 lots of milk so treated. A portion of the data obtained, sufficient to show the variations and representative results, is included in Table 2.

The depth of the cream layer rising on the pasteurized milk creamed in ice water varied from 10 to 16 units. When pasteurized milk was creamed at 40°F. the range in depth of cream layer was from 7 to 14, while that creamed at 70° ranged from 5 to 8. The results of 30 trials showed an average depth of cream layer of 13.77 when creamed at ice-water temperatures as compared to 11.37 at 40°, and 6.00 at 70°. Like raw milk, the creaming efficiency of pasteurized milk was greater when creamed at 32° than at 40°.

The variation of percentage of butterfat found in the cream layer rising on pasteurized milk creamed at 32°F. ranged from 18.0 to 25.0 percent, with an average for 30 trials of 21.07 percent. When the milk was creamed at 40° the variations encountered were from 17.5 to 24 percent, with an average of 19.92 percent. When the milk was creamed at 70° the fat test ranged from 14.5 to 27.0 percent and averaged 21.83 percent.

The percentage of fat remaining in the milk serum ranged from 0.40 to 1.70 percent when creamed at 32°F.; from 0.60 to 2.10 percent at 40°; and from 0.90 to 2.00 percent at 70°. The average fat tests of the milk serum creamed at 32°, 40°, and 70° were 0.84, 1.35, and 1.68 percent, respectively. The fat remaining in the serum of pasteurized milk creamed at 32° and at 40° was more than twice that found in the serum of raw milk creamed under similar conditions. Very little difference, in either the depth of cream layer or the percentage of fat remaining in the milk serum, was encountered in pasteurized milk and raw milk when creamed at 70°.

Effect of Various Temperatures of Creaming upon the Completeness of Creaming and upon the Percentage of Fat in Cream Rising on Milk Pasteurized at 145°F. for Thirty Minutes and Pumped at 145°F. The results obtained from creaming 15 samples of milk pasteurized and pumped at 145°F. in ice water show a variation of from 7 to 12 units in the depth of cream layer. When creamed at 40° the same milk showed a variation of from 7 to 11 units in the depth of cream layer. At 70° the cream layer ranged from 4 to 6 units. The average depth of cream obtained by creaming at 32°, 40°, and 70° was 9.00, 10.27, and 5.40, respectively. (See Table 3.)

The variations encountered in the percentage of fat in cream obtained at 32°F. were from 18.0 to 24.0 percent, with an average of 20.63 percent. The variations at 40° were from 11.0 to 21.0 percent, with an average of 17.40 percent, while those at 70° ranged from 13.5 to 28.5 percent, with an average of 22.57 percent. The percentages of fat found in the various lots of cream compared to the depth of the cream layer on the same samples show that a more efficient creaming of pumped-pasteurized milk is accomplished in ice-water temperatures rather than at 40°. Not only was the depth of cream layer found greater, but the percentage of fat also was found to be higher when the milk was creamed rapidly at the lower temperature. Although the highest fat test was found in the cream obtained by creaming at 70°, the cream layer had little depth and was quite leathery at the surface.

The fat test of the milk serum seemed to give a more satisfactory indication of the efficiency of creaming, since the efficiency of creaming is calculated from the proportion of fat remaining in the milk serum rather than from the depth of cream appearing on the column of milk. At 32°F. the range of fat remaining in the serum was from 0.90 to 2.00 percent; at 40° the range was from 1.20 to 2.20 percent; and at 70° the variations encountered were from

Table 2.—Creaming Efficiency of Milk Pasteurized at 145°F. for 30 Minutes when Creamed at Various Temperatures

Trial No.	Percent- age of Fat in Milk	Depth of Cream Layer*			Percentage of Fat in Cream			Percentage of Fat in Skimmilk		
		32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.
1	3.2	12	10	5	19.0	20.0	20.0	.90	1.20	1.40
2	2.9	10	7	5	23.5	18.5	22.5	1.70	2.10	2.00
4	3.3	15	12	6	21.5	21.5	24.5	.65	1.15	1.45
7	3.6	14	11	6	18.0	17.5	20.0	.65	1.40	1.70
11	3.2	16	12	7	23.5	20.0	23.0	.50	1.20	1.50
14	3.4	16	14	8	20.0	19.0	20.5	.40	0.60	0.90
16	3.0	15	12	7	18.0	22.5	23.0	.80	1.25	1.40
20	3.6	14	11	5	20.5	20.0	14.5	.90	1.40	1.80
23	3.5	15	12	5	18.5	20.5	21.0	.80	1.20	1.70
27	3.4	14	12	6	25.0	18.5	21.0	.80	1.40	1.80
30	3.6	14	12	6	23.0	24.0	27.0	1.00	1.60	2.00
Av. 30 Trials	3.32	13.77	11.37	6.00	21.07	19.92	21.83	0.84	1.35	1.68
Odds		very great			1110:1			very great		
		very great			4999:1			very great		

*Measurements recorded in sixteenths of an inch.

Table 3.—Creaming Efficiency of Pasteurized Milk Pumped at 145°F. when Creamed at Various Temperatures

Trial No.		Percent- age of Fat in Milk	Depth of Cream Layer*			Percentage of Fat in Cream			Percentage of Fat in Skimmilk		
			32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.
1		3.0	12	10	5	18.0	18.9	15.5	1.25	1.75	1.60
2		3.2	9	8	5	20.0	16.0	19.0	1.40	1.80	1.70
3		3.5	12	10	6	20.0	11.0	25.0	0.90	1.20	1.50
4		3.3	12	10	6	20.0	18.0	28.0	1.20	1.20	1.60
5		3.3	9	8	5	20.0	18.5	21.0	1.80	2.00	2.00
6		3.6	10	9	5	23.0	21.0	23.0	1.70	2.00	2.00
7		3.5	8	7	5	18.0	18.0	24.0	1.80	2.20	1.50
8		3.6	7	7	4	21.0	18.0	13.5	2.00	2.20	2.10
9		3.6	11	10	5	19.5	15.0	21.0	1.00	1.30	1.40
10		3.6	12	10	6	22.5	15.0	24.0	1.30	1.70	1.90
11		3.0	12	11	6	24.0	17.0	28.5	1.00	1.60	1.80
12		3.6									
Av. 15 Trials		3.343	9.00	10.27	5.40	20.63	17.40	22.57	1.45	1.73	1.74
Odds			4999:1 very great			587:1 434:1			very great not significant		

*Measurements recorded in sixteenths of an inch.

Table 4.—Comparison of Creaming Efficiency of Raw, Pasteurized, and Pumped-Pasteurized Milk when Creamed at Various Temperatures

Treatment of Samples	Number of Trials	Average Percent Fat	Storage Temperature	Depth of Cream*	Percent of Total Cream	Percent Fat in Cream	Percent Fat in Skimmilk
Raw	39	3.30	32°F. 40°F. 70°F.	16.85 18.26 5.98	100. 108. 35.	20.54 19.15 21.05	0.47 0.50 1.66
Pasteurized at 145°F. for 30 minutes..	30	3.32	32°F. 40°F. 70°F.	13.77 11.37 6.00	82. 67. 36.	21.07 19.92 21.83	0.84 1.35 1.68
Pasteurized at 145°F. for 30 minutes and pumped at 145°F.	15	3.34	32°F. 40°F. 70°F.	10.27 9.00 5.40	61. 53. 32.	20.63 17.40 22.57	1.45 1.73 1.74

*Measurements recorded in sixteenths of an inch.

1.50 to 2.10 percent. The average fat tests in the milk serum of the 32°, 40°, and 70° lots were 1.45, 1.73, and 1.74 percent, respectively.

Comparison of Creaming Efficiency of Raw, Pasteurized, and Pasteurized-pumped Milk at 145°F.

As indicated in Table 4, creaming raw milk at 40°F. gave a greater depth of cream layer after 24 hours than when creamed in ice water for a similar period. However, the percentage of fat in the cream obtained at 40° was less than that in cream obtained at 32°. The efficiency of skimming as shown by the percentage of fat remaining in the milk serum was in favor of creaming at 32°.

Milk which had been pasteurized at 145°F. for 30 minutes gave a greater depth of cream layer at 32° than at 40° and 70°. Not only was the depth of cream greater at this temperature, but the percentage of fat in the cream also was greater by 1.0 percent. When the pasteurized milk was creamed at 32°, approximately one-third less fat remained in the serum than when the milk was creamed at 40°, and one-half less than when the milk was creamed at 70°.

The processing of milk had little effect upon creaming ability when it was creamed at 70°F. The fat test of the milk serum remained practically the same for the various lots, being 1.66, 1.68, and 1.74 percent. A microscopical examination of cream from the various lots obtained at 70° showed a high percentage of large fat globules. Apparently these globules are not prevented from rising to the surface by the practices of processing milk commonly employed in the modern milk plant.

Table 5.—Rate of Creaming and Percentage of Total Cream Rising on Milk Processed Under Various Plant Conditions

Treatment of Samples	Number of Trials	Percent of Fat in Milk	Storage Temperatures °F.	Percentage of Total Cream Rising			
				Held 2 Hrs.	Held 4 Hrs.	Held 6 Hrs.	Held 24 Hrs.
Raw	62	3.72	32	92.2	93.6	100.0	89.3
			40	82.1	84.5	83.1	86.4
			70	30.4	31.0	32.0	35.6
Pasteurized at 145°F. 30 minutes.	62	3.72	32	90.8	92.4	92.3	85.1
			40	79.9	82.4	82.0	84.0
			70	51.3	52.1	53.3	52.0
Pasteurized-pumped at 145°F.	61	3.72	32	91.5	90.2	90.8	83.5
			40	82.8	84.1	81.1	81.7
			70	66.5	61.3	62.0	56.5
Pasteurized-pumped at 135°F.	54	3.72	32	93.9	92.5	91.0	83.3
			40	83.1	84.8	83.3	83.0
			70	64.1	60.6	58.9	54.9
Pasteurized-pumped at 125°F.	58	3.72	32	95.4	93.4	92.4	84.0
			40	85.7	87.4	85.8	83.3
			70	73.5	62.0	60.8	55.5
Pasteurized-pumped at 115°F.	56	3.72	32	97.2	95.5	94.2	82.8
			40	85.7	87.9	87.9	83.6
			70	65.5	65.1	62.4	56.0
Pasteurized-pumped at 105°F.	32	3.72	32	92.9	90.1	90.4	80.9
			40	95.9	93.6	91.1	82.7
			70	73.9	70.4	68.1	59.3
Pasteurized-pumped at 90°F.	4	3.72	32	94.5	93.3	94.5	82.1
			40	68.4	73.4	74.7	75.6
			70	54.7	53.5	52.2	51.0
Pasteurized-pumped at 80°F.	4	3.72	32	95.8	97.1	97.2	79.6
			40	65.9	74.6	75.9	75.9
			70	53.7	46.0	44.8	46.0

Effect of Pasteurizing, Agitating, and Pumping Milk upon the Percentage of Cream Rising on Milk after Two, Four, Six, and Twenty-four Hours, at Storage Temperatures of 32°, 40°, and 70°F. Table 5 gives a summary of the data obtained by creaming various lots of milk at different temperatures. The maximum amount of cream rising on raw milk was taken as a standard of 100 percent, and all calculations were made from that basis.

Sixty-two trials of creaming raw milk at 32°F. resulted in the rising after two hours of 92.2 percent of the total cream; 98.6 percent after four hours; and the maximum, or 100 percent, after six hours. At the end of the 24-hour period this volume of cream shrank back to 89.3 percent, a loss in depth of cream of 10.7 percent. At 40° the creaming of raw milk was somewhat slower, reaching its maximum depth after 24 hours, when the cream layer was 2.9 percent less than the cream volume appearing on raw milk after 24 hours at 32°. Raw milk creamed very slowly at 70°, but similar to creaming at 40° it increased upon standing until a maximum of 35 percent was reached after 24 hours.

The rate of creaming in pasteurized milk was comparable to that of raw milk, although the volume of cream appearing on the top of the milk was somewhat less. At 32°F. the maximum volume of cream appeared after 6 hours, while at 40° the maximum was not reached until after 24 hours' exposure. At 70° the maximum cream volume was reached after six hours' exposure after which the volume of cream shrank slightly.

Pumping pasteurized milk at 145°F. resulted in very little change in the rate of creaming at 32°, the maximum amount of cream appearing after 6 hours. When creamed at 40° the greatest volume of cream appeared after four hours, while at 70° the greatest depth of cream was present after two hours.

The general results obtained from creaming pasteurized milk pumped at temperatures ranging from 105° to 135°F., inclusive, showed the greatest depth of cream layer after two hours with the 32° exposure, after four hours with the 40° exposure, and after two hours at 70°.

Although the number of trials did not warrant a justifiable conclusion, it appeared from the results of the four trials studied that pumping pasteurized milk at 80° and 90°F. retards the rate of creaming. The greatest depth of cream layer was obtained after an exposure of six hours at both 32° and 40°. When creamed at 70° the greatest depth of cream appeared after two-hour exposure. The cream was similar in this respect to the results obtained from creaming milk pumped at the higher temperatures.

In every case there was a decided shrinkage in the volume of cream appearing on milk creamed at 32°F. between the six-hour and the 24-hour periods. (See Figure 2.) In cases where a large volume of cream appeared in a short period of time, the cream was bulky, coarse, and granular. As the exposure lengthened, the cream became more compact and lost its loose rough appearance as a result of the separation of the fat globules from the surface serum, as the globules clumped together. When the milk was creamed at 70° the differences in the depth of the cream layer of the lots of milk for any period of creaming were of little consequence.

Raw milk creamed at 32°F. showed a shrinkage of 10.7 percent in the cream volume between the six-hour and the 24-hour periods. The average shrinkage of milk pasteurized and pasteurized-pumped at temperatures be-

Figure 2.—Chart Showing Percentage of Cream Rising on Milk under Various Plant Conditions When Held at Ice-Water Temperatures for Various Periods of Time

tween 105° and 145° and creamed under the same conditions was only 8.8 percent. The shrinkage encountered when the milk was pasteurized-pumped at 80° to 90°, as shown by the four trials, was 15 percent.

Raw milk creamed at 40°F. showed an increase of 3.3 percent in the depth of cream layer between the six-hour and the 24-hour periods. When pasteurized and pasteurized-pumped at 145° the increase during the same period was slight, whereas there was a slight reduction in the depth of cream layer when the pasteurized milk was pumped at temperatures ranging from 105° to 135° and creamed for 24 hours at 40°.

Effect of Pasteurizing, Agitating, and Pumping upon the Creaming Ability of Milk. In an endeavor to find what effect the processing of milk under modern plant conditions had upon the creaming ability of the milk, a number of samples were taken from the regular lot at the different stages of processing and creamed for 24 hours in ice water, at 40°F., and at 70°. The results of these trials are given in Table 6. All the results were standardized to the equivalent of 4 percent milk.

The depth of cream appearing on raw milk creamed at 32°F. for 24 hours was taken as 100 percent. From this standard all other calculations were made. The results of 92 trials showed that pasteurization at 145° for 30 minutes decreased the depth of cream rising on a column of milk held for 24 hours in ice water by 8.85 percent. Although this reduction in cream layer due to pasteurization is of importance to the milk plant operator, since it challenges higher pasteurization temperatures, it is of little significance to the milk consumer, since, as shown in Figure 3, an 8 percent reduction in cream layer is hardly noticeable.

Table 6.—Depth of Cream Layer Appearing on Milk Processed According to Plant Operations after Twenty-four Hours' Exposure to Various Temperatures

Treatment	Number of Trials	Percent Fat in Milk	Storage Temperatures °F.	Depth of Cream*	Percent of Total Cream
Raw	101	4.0	32	19.50	100.00
			40	19.72	101.10
			70	7.35	37.70
Pasteurized 145°F. 30 min..	92	4.0	32	17.78	91.15
			40	16.63	85.28
			70	9.82	50.37
Pasteurized- pumped 145°F..	70	4.0	32	16.82	86.27
			40	16.34	83.81
			70	11.06	56.71
Pasteurized- pumped 135°F..	55	4.0	32	17.87	91.64
			40	17.70	90.78
			70	11.79	60.41
Pasteurized- pumped 125°F..	58	4.0	32	17.89	91.74
			40	17.74	90.99
			70	11.74	60.18
Pasteurized- pumped 115°F..	57	4.0	32	17.97	92.13
			40	17.80	91.25
			70	12.00	61.55
Pasteurized- pumped 105°F..	32	4.0	32	17.26	88.48
			40	17.61	90.29
			70	12.63	64.77
Pasteurized- pumped 90°F...	4	4.0	32	17.48	89.63
			40	16.95	86.92
			70	10.86	55.68
Pasteurized- pumped 80°F...	4	4.0	32	16.95	86.92
			40	15.92	81.63
			70	9.80	50.25

*Measurements recorded in sixteenths of an inch.

Pumping the pasteurized milk at 145°F. further reduced the cream volume by approximately 5 percent, thereby making a total reduction, due to combined pasteurization and pumping at 145°, of 13.73 percent. This figure represents the greatest loss encountered by pasteurization or by pumping at temperatures ranging from 80° to 145° when the milk was creamed at 32°.

The pumping of pasteurized milk at 135°, 125°, or 115°F. resulted in little change in depth of cream layer from that obtained by pumping pasteurized milk at 145°. Pumping pasteurized milk at these temperatures tends slightly to increase the depth of cream layer. When pasteurized milk was pumped at 105°, 90°, and 80°, respectively, and creamed at 32°, there was a slight reduction in the depth of cream layer but this was not as much as when the pasteurized milk was pumped at 145°.

Figure 3.—Cream Line on Milk Held at 32° F. for 24 Hours under Various Plant Conditions

When samples of the same milk were creamed at 40°F., considerable variations from the results obtained in the ice-water creaming were encountered. Although the cream from raw milk was a little slower in rising at 40° than at 32°, a volume greater by 1 percent was obtained after 24 hours. Pasteurization affected the cream volume by a 15.82 percent reduction, and pumping the pasteurized milk at 145° resulted in a combined loss of 17.29 percent.

A reduction in cream layer averaging 10.3 percent was encountered when milk was pumped at temperatures ranging from 105° to 135°F. and held for 24 hours at 40°. The amount of cream on the milk pumped at these temperatures after 24 hours compared very favorably with that on pasteurized milk creamed at 32° for a similar period. Pumping pasteurized milk at temperatures ranging from 105° to 135° resulted in an average increase of 5.55 percent in the depth of cream layer over that of the pasteurized milk creamed under the same conditions. Pumping pasteurized milk at 80° to 90° and holding at 40° for 24 hours resulted in a reduction of the cream layer of 19.47 and 14.18 percent, respectively. Although these reductions are considerably greater than those encountered when pumping at temperatures between 105° and 135°, they are yet comparable to reductions encountered in pasteurized milk and in pasteurized milk pumped at 145° and creamed at 40°.

When the various lots of milk were creamed at 70°F., the total volume of cream rising on the milk ranged from 37.7 percent in the raw milk to 64.7 percent in the milk pasteurized and pumped at 145°. Pasteurization and pumping of milk increased the creaming ability at room temperatures.

The cream layer is never more than one-third butterfat at best; in fact, the highest percentage of fat encountered in the cream layers studied was but 28.5 percent. The depth of cream layer therefore is determined largely by the amount of non-fat material such as water, milk sugar, or coagulated proteins which the fat globules carry to the surface as they rise through the milk. Heat and agitation tended to render the fat globules free by reducing the viscosity and by making available the non-fat material, principally the proteins, which may readily be carried along with the fat to the surface.

A microscopical examination of the various lots of milk showed significant differences in the size and arrangement of the fat globules. In raw milk the fat globules appeared singly with a preponderance of the larger globules. (See Figure 4.) Pasteurization at 145°F. for 30 minutes did not materially decrease the size of the globules or change their arrangement. (See Figure 5.) There appeared, however, a tendency for the globules to unite.

Figure 4.—Fat Globules of Raw Milk

Pumping pasteurized milk at 145°F. caused a slight clumping of the fat globules. (See Figure 6.) In some cases the number of clumps predominated over the number of single globules. Furthermore, the size of the globules was smaller on account of the breaking up of the individual globules. At the lower temperatures of pumping, clumping was less pronounced, but the proportion of small fat globules to the large globules increased very materially. (See Figure 7.)

The milk was subjected to agitation for an average period of approximately one and one-half hours, depending somewhat upon the amount of milk received for pasteurization. Of this period, from 23 to 26 minutes was required to heat the milk to the pasteurization temperatures; 30 minutes was allowed for the time of pasteurization; and the remainder was required for pumping the milk over the cooler.

When the glass-lined tank was filled with milk the agitation was such that the milk flowed in a steady current about the tank. As the milk was pumped over the cooler, thereby lowering the depth within the tank, the rate

of agitation increased, becoming so violent that considerable splashing and foaming occurred which necessitated turning off the agitator.

Agitation for such a prolonged period of time, together with further agitation through pumping at various temperatures, decreased the cream line never more than 13.73 percent when the milk was creamed at 32°F. Under the same conditions of agitation and pumping, the cream line was decreased 19.47 percent when the creaming temperature was 40°. Of this reduction 15.82 percent is attributed to pasteurization, leaving a loss due to subsequent agitation and pumping of but 3.65 percent. Agitation, as well as pasteurization, increased the creaming ability of milk when the milk was creamed at 70°.

Table 7.—Effect of Preheating, of Clarification, and of Various Types of Pasteurizers upon Depth of Cream Layer

Lot No.	Treatment	No. of Trials	Percent Fat in Milk	Storage Temperature	Depth of Cream*	Percent of Total Cream
1	Raw	23	4.0	32°F.	22.76	100.00
2	Pumped 60-65°F. Preheated 85-90°F....	23	4.0	32°F.	20.84	91.55
3	Lot No. 2 Clarified 85-90°F....	23	4.0	32°F.	20.84	91.53
4	Lot No. 3 pasteurized at 145°F. 30 minutes in glass-lined tank	8	1.0	32°F.	20.55	86.50
5	Lot No. 4 pumped through homogenizer under no pressure...	8	4.0	32°F.	19.72	83.10
6	Lot No. 3 pasteurized at 145°F. 30 minutes in coil vat	23	4.0	32°F.	19.59	86.04

*Measurements recorded in sixteenths of an inch.

Effect of Pumping and Preheating upon the Creaming Ability of Raw Milk.†

In a great many plants the milk is pumped from the receiving room to the pasteurizing room, where it is preheated, clarified, pasteurized, and passed over a cooler to the bottling machine. Several samples of milk were taken of

Figure 5.—Fat Globules of Milk Pasteurized at 145° F. for 30 Minutes

†Experiment conducted at commercial plant.

the several operations in such a plant and creamed in ice water to note their effect upon the cream line. The results of these trials are given in Table 7.

When the milk was pumped at temperatures ranging from 60° to 70° F., preheated to 85° to 90°, and creamed at ice-water temperatures, the reduction in the volume of cream rising to the surface amounted to 9.8 percent.

Effect of Clarification upon the Creaming Ability of Milk. Clarification of the preheated milk had little effect on the creaming ability of milk beyond that incurred by preheating. Although the milk was subjected to severe agitation for a brief period of time during clarification, the injury to the cream line

Figure 6.—Fat Globules of Milk Pasteurized and Pumped at 145° F.

resulting therefrom was not sufficient to counterbalance the desirable results. By breaking up the fibrin, by removing a large portion of the leucocytes, and by eliminating all solid foreign material which may have been in the milk in a finely divided state of suspension, the milk was rendered less viscous, thereby permitting the free passage of the fat globules through the milk and thus tending toward a more efficient creaming.

Effect of Various Types of Pasteurizing Vats upon the Resulting Cream Layer when Creaming Milk for Twenty-four Hours at 32° F. After clarification the milk was divided into two lots, one of which was pasteurized in a 300-gallon coil-vat pasteurizer at 145° F., while the other was pasteurized under the same conditions in a 200-gallon glass-lined tank similar in design to the one previously described.* The results of these trials show little difference in the volume of cream appearing on the milk pasteurized in either the coil-vat type of pasteurizer or the glass-lined tank pasteurizer. The amount of cream rising on the coil-vat pasteurized milk was but 85.04 percent, whereas in the glass-lined tank pasteurized milk the cream volume was 86.5 percent. The difference in the depth of cream layer as encountered in the two methods of pasteurization was very slight. Such a small difference is not appreciable to the

*See page 5.

eye, yet when the cream layer already is reduced materially by pumping, pre-heating, clarifying, and pasteurizing, further reductions, even though slight, make an aggregate which is readily perceptible.

Pumping the glass-lined tank pasteurized milk through the single-stage homogenizer without pressure resulted in a further reduction of the cream volume by 3.4 percent.

SUMMARY OF RESULTS

A greater creaming efficiency resulted when milk, raw, pasteurized, or pumped, was creamed in ice-water temperatures than when creamed at higher temperatures in air. Although the depth of cream layer was usually greater in milk creamed in ice water, the volume gradually shrank upon standing, while that creamed at 40°F. gradually increased in depth. The greatest depth of cream layer on raw milk creamed at ice-water temperatures appeared after six hours, while milk creamed at 40° did not yield the maximum depth of cream layer until after 24 hours.

Figure 7.—Fat Globules of Milk Pasteurized and Pumped at 80° F.

Wide variations existed in the percentage of butterfat present in cream obtained by creaming raw and pasteurized milk at different temperatures, although little variation in the average percentage of fat was found in the cream of the one as compared to that of the other. Cream obtained from gravity-creamed raw milk, pasteurized milk, or pasteurized-pumped milk averaged approximately 20 to 22 percent of fat, irrespective of the depth of the cream layer.

Pasteurizing milk at 145°F. for 30 minutes decreased the creaming ability of milk from 9 to 16 percent, depending upon the temperature of creaming. Pumping pasteurized milk at 145° further decreased the creaming ability of the milk from 2 to 5 percent. When the pasteurized milk was pumped at 80° and 90° the creaming ability of milk was decreased to a point comparable to that of pumping pasteurized milk at 145°. Pumping pasteurized milk at temper-

atures between 115° and 135° increased the creaming ability slightly, thereby recovering part of the loss incurred by pasteurization. Pumping pasteurized milk at temperatures between 105° and 145° increased the rate of creaming irrespective of the temperatures at which the milk was creamed. Excessive agitation at temperatures between 105° and 135° did not materially decrease the creaming ability of milk.

Pumping raw milk at 60°F. and preheating to 85° to 90° decreased the creaming ability of milk about 9 percent. Clarification of preheated raw milk had little effect upon the creaming ability of the milk beyond that resulting from pumping and preheating. Pasteurizing pumped clarified milk in a coil-vat pasteurizer, or in a glass-lined pasteurizer, further decreased the cream volume to an approximate total of 14 percent.

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