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Chemistry of Butter and Butter Making

III. The Relationships Between (1) the Percentage Fat and (2) the Protein Percentages of Cream and the Churning Loss

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SUMMARY AND CONCLUSIONS

1. The relationships among the cream test, the buttermilk test and the percentage of the total fat placed in the churn that is lost in the buttermilk were studied.

2. A similar study was made concerning the percentages of total protein, casein and albumin in the cream and the churning losses.

3. The variations of churning time with cream richness are presented.

4. The churning time variations that were obtained with change in richness of the cream were not such as to make it inadvisable to churn high-fat cream.

5. The results of the Mojonier test of the buttermilk vary relatively little between lots of cream with 20 to 30 percent fat, while the variation with cream from 30 to 40 percent fat is comparatively great.

6. The reverse is true of the percentage of the total fat placed in the churn that is lost in the buttermilk. This value varies widely between 20 and 30 percent fat in the cream, considerably less between 30 and 35 percent cream and but slightly with cream having 35 to 40 percent fat.

7. The necessity of considering the fat test of the cream in calculating the churning loss was stressed.

8. The data presenting the relationship between the fat percentage of the cream and the churning loss are presented in a chart (fig. 7). This is so presented that the creamery operator can calculate his churning losses if the buttermilk and cream tests are available. The chart likewise enables him to determine whether or not his losses compare favorably with those he should obtain with the testing method he is employing.

9. The protein data indicate that casein may play an important part in the colloid-chemical relationships of the churning process.

10. The data indicate that the lowest churning loss that it is likely to attain (37.5 percent cream) is in the vicinity of 1.00 to 1.20 percent of the total fat churned. This represents approximately a 99 percent yield, which is exceptionally good. With 30 percent cream the lowest loss figure will fall between 1.40 and 1.60 percent of the total fat placed in the churn. These figures are based on the Mojonier test of the buttermilk.

Chemistry of Butter and Butter Making¹

III. The Relationships Between (1) the Percentage Fat and (2) the Protein Percentages of Cream and the Churning Loss

BY E. W. BIRD AND H. A. DERBY²

The relationships between the fat in cream and the churning loss have been studied by several investigators. Usually the studies have compared "rich" and "thin" cream. Experimental work has been done with both sweet cream and ripened cream. The method of analysis of the buttermilk has not been stated in all cases. In certain of the experiments concerning churning losses the equipment frequently did not approximate that employed in the industrial process. It was considered, therefore, that a systematic study of the relationship between the percentage of fat in the cream and the churning loss, covering the range of fat percentages likely to be encountered in the Iowa cooperative creameries, should be made. Such a study naturally afforded an opportunity to investigate the relationship between the protein percentages and the churning loss.

The purposes of the study were: (1) To determine how much the churning loss could be reduced by controlling the richness of the cream; (2) to obtain information relative to the effect of some of the more important cream components on the efficiency of churning; (3) to obtain information that might help explain the chemistry of the churning process; (4) to devise a simple method of expressing and calculating churning losses that could be readily employed by the creamery operator, the field man and the extension worker.

LITERATURE REVIEW

Vieth (23), according to Sebelien, stated that the higher the fat test of the cream the greater the fat test of butter-

¹Project 107 of the Iowa Agricultural Experiment Station.

²The authors are indebted to Prof. M. Mortensen, of the Dairy Industry Department, Iowa State College, for having abstracted the Danish articles of Hansen and Langmack; to Mr. Glenn Woods (now of the Des Moines Cooperative Milk Producer's Association) for assistance in running the protein determinations presented in this bulletin; to Mr. D. F. Breazeale, of the Dairy Industry Department, Iowa State College, for assistance rendered in obtaining the data presented in tables 1 and 2; and to Prof. G. W. Snedecor for having selected the statistical methods employed and for having made the statistical calculations presented.

milk. Sebelien also reported that Fjord's data (12) indicate that the churning loss, when calculated as percentage of the total fat churned, is lower the richer the cream. Sebelien (20) presented one series of data for sweet and one for sour cream. With but one exception in each series the percentage total fat lost was lower the richer the cream. Hills (16) likewise reported more exhaustive churning with thick cream than with thin cream. Weigmann (24) studied the skimmilk loss, the butter yield and the buttermilk loss; he considered that there was a relatively greater yield of butter from 30 percent than from 20 percent cream. Hansen and Langmack (15) consider that the higher the fat percentage in the cream and the lower the churning temperature the more exhaustive the churning. High fat percentage in cream together with high churning temperature yielded the highest buttermilk test, while with normal or low churning temperatures the fat test of the buttermilk was affected but little by the richness of the cream. These experiments were conducted with highly ripened cream. Jones (17) treated losses in terms of overrun and stated that "the richer the cream, the less effect loss of fat in the buttermilk has on lowering the overrun owing to the decreased amount of buttermilk." Bouska (4) advocated expressing losses as the ratio of the fat lost to the fat churned; he considered that this ratio appeared lower in rich than in thin cream. Thomsen (21), in a discussion of factors affecting fat losses in churning, stated that increasing the fat percentage of the cream within certain limits (not stated) reduced the churning loss. Udy (22) considers the fact that richer creams are churned (over 40 percent) in New Zealand than in the U. S. accounts for the lower churning losses in the former country.

Burr (5) considered that the churning loss was higher the richer the cream and recommended that cream containing 18 to 25 percent be churned. Douglas (11) likewise considered that the losses were greater with thick than with thin cream.

van Dam and Holwerda have investigated the effect of varying the quantity of casein (9) and soluble proteins (10) on the churning losses of highly ripened cream. They believe that the greater the amount of suspended casein the lower the churning loss. Churning time seemed to decrease with increase in amount of suspended casein up to a certain point and then increased. It was considered that the suspended casein protected the fat clumps, prevented their breaking up and thus either decreased the loss or prevented an increase as the churning temperature rose. The soluble

proteins functioned in reverse order; as the concentration increased the loss rose. No definite explanation for this behavior was offered, although the probability of a possible change in surface tension was considered. Palmer (18) was of the opinion that the increase in protein and decrease in fat particle size, which normally accompany late lactation period, tend to make churning more difficult.

EXPERIMENTAL

METHODS

PROCESSING CREAM

a. Sweet Cream. The cream was pasteurized at 145°F. for 30 minutes then cooled, and a sufficient amount of it was passed through a centrifugal separator so that the fat percentage of the entire mixed cream was greater than 40 percent. The cream and skimmilk were cooled separately to 40° F. The lots of cream of the desired richnesses were then obtained by standardizing portions of the high fat cream with its own skimmilk. These lots of standardized cream were then placed in 10 gallon cans, held in the cooler at a temperature between 35° and 40° F. overnight and were churned the following day.

b. Ripened Cream. The procedure was identical with that in *a.* to the point at which the rich cream and the skimmilk were obtained. At this point the cream and skimmilk were placed in separate vats and an amount of butter culture varying from 5 to 10 percent was added to each. The amount of culture added depended on the initial acidity of the cream and the acidity of the culture. The cream and skimmilk were cooled to 40°F. and held overnight after the desired acidity had been obtained. The ripening of the skimmilk was controlled so that the acidity was somewhat less than the serum acidity of the cream on the following morning. The acidity of the skimmilk was adjusted to that of the cream serum by the addition of a small amount of butter culture. The cream was then standardized to the desired richness, thoroughly mixed and held for at least 1 hour before it was churned.

c. Neutralized Cream. Sweet raw cream was heated to 100°F., and a sufficient amount of it was separated to bring the fat percentage of the resulting lot of mixed cream above 40 percent. The cream and skimmilk were placed in separate vats and were held overnight at such temperatures as to develop an acidity of approximately 0.50 percent. The cream and skimmilk were then separately neutralized with a 15 percent solution of a fused mixture of sodium carbonate and sodium bicarbonate (C.A.S.). The neutralizer was added

from a sprinkling can with the vat coils in motion to obtain as even a distribution and as mild a reaction as possible. The final acidity desired in the cream was approximately 0.2 percent. The cream was neutralized to approximately this point and the skim milk to a value corresponding to the serum acidity of the cream. Both were then pasteurized separately at 145° for 30 minutes and were cooled to 38°F. After 4 hours holding at this temperature the lots of cream were standardized to the desired fat percentages and churned out as in *b*.

d. Holding Time and Temperatures. All lots of cream were held either in the bulk, as has been indicated above, or as separate lots at temperatures that would insure a temperature equilibrium condition of the fat. All lots were cooled to 40°F. or below and were held for at least 4 hours at low temperatures before churning. The temperatures were lower at the end of the holding periods than the desired churning temperatures.

e. Churning Temperatures. The churning temperatures were regulated according to the season in an attempt to obtain approximately a 45-minute churning time for cream containing 30 percent fat. The same conditions throughout were employed for all churnings of the same series.

f. Fullness of Churn. The churns were operated in such fashion that they were approximately one-third full. The churning was stopped at the point at which the butter granules were between wheat and corn kernels in size.

g. Types of Churns Employed. Three churns were employed in this study. Two of these were Cherry single-roll Junior churns, Model 2B; the third was a Creamery Package double-roll Junior churn. There were eight churnings in each run. The churns were designated 1, 2 and 3 and were alternated so that such slight differences as existed among them would be distributed throughout the series of eight churnings at the end of each third run.

h. The Condition of the Butterfat. It has been stated (*d.*) that care was exercised to have the fat in the cream in a proper state of temperature equilibrium. In addition, in order to eliminate as nearly as possible the effects resulting from the changes in composition of fats with season, the churnings were made during the season of "winter fats" (from October to May).

ANALYTICAL METHODS

a. Fat Analysis of Cream. These determinations were run by the official Babcock method (1). A steam centrifuge, operated at the correct speed, was employed.

b. *Fat Analysis of Buttermilk.* The Mojonnier method, as previously described (3), was employed.

c. *Protein Analysis.* Total protein, casein and albumin were determined by the "Official" methods (2); the Gunning modification (with CuSO_4) of the Kjeldahl method was used for the nitrogen determinations.

CHECK ON EXPERIMENTAL PROCEDURE

COMPARISON OF FAT LOSSES AMONG THE CHURNS USED

Table 1 presents a comparison of losses among the three churns and between the two methods of standardizing cream that were employed. A statistical treatment of the data showed that the differences among churns is not significant. Statistically the difference between standardization methods is significant. When these differences are compared with those introduced by different cream samples (table 3) it is

TABLE 1. PERCENTAGE OF TOTAL FAT LOST IN THREE EXPERIMENTAL CHURNS AND IN TWO METHODS OF STANDARDIZING CREAM TO 35 PERCENT FAT.

Churn number	Percentage of total fat lost					
	Run 1 ¹	Run 2 ²	Run 3 ¹	Run 4 ²	Run 5 ¹	Run 6 ²
1	1.27	1.27	1.26	1.31	1.23	1.35
2	1.28	1.29	1.26	1.30	1.22	1.32
3	1.21	1.23	1.28	1.32	1.16	1.38
Average	1.253	1.263	1.267	1.310	1.203	1.350

- 30-34% cream separated to 45-47%, standardized with its own skimmilk and pasteurized.
- 30-34% cream pasteurized, separated to 45-47%, and standardized with its own skimmilk.

Note:—Each of the pairs of runs—1 and 2; 3 and 4; 5 and 6—were from the same original lot of cream, split into two parts and processed as designated.

TABLE 2. COMPARISON OF FAT LOSSES WITH EXPERIMENTAL AND LARGE CHURNS

Run No.	Size of churn	Capacity of churn in pounds of cream	Pounds cream churned	Percentage of fat in cream	Percentage total fat lost	Difference	Difference calculated as percentage error of loss with large churn
1	Large	1600	1560	29.0	1.467	+0.091	6.21
	Small	190	190	29.0	1.376		
2	Large	1600	1638	28.0	1.739	-0.061	3.51
	Small	190	190	28.0	1.799		
3	Large	1600	1370	27.5	1.543	-0.001	0.07
	Small	190	190	27.5	1.544		
4	Large	1600	1619	30.0	1.284	+0.059	4.59
	Small	190	190	30.0	1.225		
5	Large	1600	1595	28.0	1.608	-0.114	7.09
	Small	190	190	28.0	1.722		
Average							4.29

evident that they will not invalidate the comparison of losses with varying fat percentage in the cream.

COMPARISON OF FAT LOSSES WITH EXPERIMENTAL AND LARGE CHURNS

Table 2 contains the data from a series of five runs with a large churn and one of the small experimental churns. The differences between percentages of fat lost in the large and small churns are random in nature and of such magnitudes

TABLE 3. THE MOJONNIER TESTS, PERCENTAGES OF THE TOTAL FAT LOST AND THE CHURNING TIMES OF SWEET CREAM VARYING FROM 20 TO 40 PERCENT FAT. (JAN. 15 TO MAR. 13, 1930).

Percentage fat in cream	20.0	25.0	27.5	30.0	32.5	35.0	37.5	40.0
Run number	A. Mojonnier test of buttermilk (percent fat)							
1	0.589	0.599	0.664	1.139*	0.720	0.705	0.754	0.943
2	0.610	0.590	0.611	0.644	0.693	0.745	0.826	0.889
3	0.650	0.602	0.572	0.635	0.676	0.744	0.798	0.854
4	0.695	0.745*	0.597	0.651	0.719	0.746	0.802	0.919
5	0.678	0.669	0.584	0.653	0.723	0.750	0.815	0.869
6	0.613	0.590	0.604	0.627	0.708	0.733	0.849	0.927
7	0.655	0.604	0.646	0.689	0.724	0.741	0.880	0.924
8	0.602	0.641	0.620	0.653	0.823	0.735	0.806	0.896
9	0.626	0.598	0.618	0.652	0.706	0.833	0.733	0.983
10	0.555	0.544	0.619	0.590	0.670	0.727	0.824	0.885
11	0.610	0.616	0.613	0.664	0.703	0.835	0.792	1.043
Average	0.626	0.605	0.613	0.646	0.715	0.754	0.807	0.921
Run number	B. Percentage of total fat lost in buttermilk							
1	2.23	1.68	1.61	2.25*	1.35	1.16	1.10	1.23
2	2.31	1.64	1.48	1.40	1.30	1.23	1.21	1.15
3	2.46	1.68	1.40	1.35	1.27	1.23	1.17	1.11
4	2.63	2.08*	1.45	1.39	1.35	1.23	1.17	1.19
5	2.56	1.87	1.41	1.37	1.35	1.24	1.25	1.13
6	2.32	1.65	1.46	1.34	1.32	1.21	1.24	1.20
7	2.48	1.68	1.56	1.47	1.35	1.22	1.29	1.20
8	2.28	1.79	1.50	1.39	1.54	1.21	1.18	1.16
9	2.37	1.67	1.49	1.37	1.32	1.37	1.07	1.28
10	2.10	1.52	1.50	1.26	1.23	1.20	1.21	1.15
11	2.31	1.72	1.48	1.42	1.32	1.38	1.16	1.35
Average	2.37	1.69	1.49	1.38	1.34	1.24	1.19	1.20
Run number	C. Churning time in minutes							
1	43	45	33	24*	31	54	59	67
2	50	40	50	67	59	60	63	67
3	35	36	38	43	30	47	32	42
4	40	32*	32	37	40	41	38	60
5	45	33	40	33	43	55	53	80
6	53	41	34	44	41	39	24	28
7	46	38	36	41	41	41	38	41
8	40	35	36	41	30	42	43	38
9	50	40	37	31	38	37	50	55
10	47	36	27	36	40	40	43	46
11	48	33	41	38	42	30	43	32
Average	45	38	37	41	40	44	48	51

* Overchurned, not included in average.

that the positive and negative differences practically equalize each other. Calculated as percentage of the total fat churned these variations range from -0.114 to $+0.091$ percent. The differences calculated as percentage error of the loss with the large churn, range from 0.07 to 7.09 percent; the average is 4.29 percent. The small churns, then, yield results that are representative of the factory procedure.

RESULTS OF SWEET CREAM RUNS

In table 3 the Mojonnier tests, percentages of total fat lost, the churning times and the fat percentages of the cream are presented. The averages of the buttermilk tests reach a minimum near the 25 percent fat level and then gradually rise as the percentage fat in the cream increases to 40 percent. The trends of the average percentages of total fat lost are completely different. These decrease as the fat concentration in the cream increases from 20 to 37.5 percent. They are minimal near the latter point. The average churn-

TABLE 4. THE MOJONNIER TESTS, PERCENTAGES OF THE TOTAL FAT LOST AND THE CHURNING TIMES OF RIPENED CREAM VARYING FROM 20 TO 40 PERCENT FAT (MARCH 20 TO APRIL 10, 1930).

Percentage fat in cream	20.0	25.0	27.5	30.0	32.5	35.0	37.5	40.0
Run number	A. Mojonnier test of buttermilk (percent fat)							
1	0.671	0.653	0.680	0.681	0.780	0.912	0.902	1.013
2	0.672	0.698	0.983*	0.780	0.739	0.783	1.025	0.998
3	0.743	0.633	0.621	0.881	0.757	0.822	0.924	1.066
4	0.678	0.694	0.714	0.710	0.770	0.843	0.938	1.057
5	0.720	0.684	0.672	0.713	0.807	0.823	0.860	1.107
6	0.656	0.588	0.383	0.680	0.729	0.770	0.980	1.161
7	0.766	0.713	0.708	0.819	0.825	0.853	0.967	1.084
Average	0.700	0.667	0.680	0.752	0.772	0.829	0.942	1.069
Run number	B. Percentage of total fat lost in buttermilk							
1	2.54	1.84	1.65	1.43	1.46	1.50	1.29	1.32
2	2.54	1.95	2.39*	1.66	1.38	1.29	1.50	1.30
3	2.88	1.77	1.50	1.88	1.42	1.36	1.36	1.40
4	2.56	1.94	1.73	1.51	1.44	1.39	1.37	1.37
5	2.72	1.89	1.61	1.50	1.51	1.36	1.26	1.44
6	2.48	1.64	1.66	1.45	1.36	1.27	1.44	1.51
7	2.87	1.99	1.71	1.75	1.55	1.41	1.42	1.41
Average	2.66	1.86	1.64	1.60	1.45	1.37	1.38	1.39
Run number	C. Churning time in minutes							
1	47	39	40	33	36	33	40	120
2	45	35	30*	32	40	63	75	85
3	55	38	39	40	43	56	57	55
4	40	36	35	37	44	40	48	50
5	43	32	38	33	35	37	38	45
6	54	42	33	40	34	44	33	37
7	42	34	34	31	33	35	34	32
Average	47	37	37	35	38	44	46	61

* Overchurned, not included in average.

ing time (minutes from the time the churn is started until the glass clears) is higher at both extremes but shows the least variation between 25 and 27.5 percent fat in the cream.

RESULTS OF RIPENED CREAM RUNS

Table 4 indicates that the trend of the averages of the Mojonnier tests of the buttermilk from churned ripened cream is much like that of the averages for sweet cream runs; the minimum again occurs at the 25 percent fat level. The minimum point among the averages of the "percentage total fat lost" values occurs at the 35 percent point rather than at the 37.5 percent. The trend of churning time values is little different from that of the preceding series.

RESULTS OF NEUTRALIZED CREAM RUNS

The results of the neutralized cream runs are presented in table 5. Again the minimum of the Mojonnier test averages occurs with 25 percent cream, and the minimum of the averages of the "percentage total fat lost" values occurs at 37.5 percent fat. These minima are coincident with those of the sweet cream runs. Some difference from previous

TABLE 5. THE MOJONNIER TESTS, PERCENTAGES OF THE TOTAL FAT LOST AND THE CHURNING TIMES OF NEUTRALIZED CREAM VARYING FROM 20 TO 40 PERCENT FAT (APRIL 15 TO MAY 6, 1930).

Percentage fat in cream	20.0	25.0	27.5	30.0	32.5	35.0	37.5	40.0
Run number	A. Mojonnier test of buttermilk (percent fat)							
1	0.535	0.533	0.565	0.592	0.635	0.778	0.831	1.068
2	0.741	0.708	0.717	0.739	0.781	0.894	0.882	1.003
3	0.666	0.645	0.637	0.676	0.753	0.852	0.903	0.997
4	0.725	0.691	0.682	0.724	0.885	0.828	0.975	0.976
5	0.751	0.612	0.644	0.659	0.725	0.869	0.850	0.960
6	0.665	0.602	0.606	0.623	0.658	0.752	0.780	1.019
Average	0.681	0.632	0.642	0.671	0.740	0.829	0.870	1.004
Run number	B. Percentage of total fat lost in buttermilk							
1	2.02	1.49	1.37	1.24	1.19	1.28	1.22	1.39
2	2.80	1.98	1.74	1.58	1.46	1.47	1.29	1.30
3	2.52	1.85	1.54	1.44	1.41	1.41	1.32	1.27
4	2.74	1.93	1.65	1.57	1.66	1.36	1.43	1.27
5	2.84	1.71	1.56	1.38	1.36	1.43	1.25	1.25
6	2.51	1.68	1.47	1.33	1.23	1.24	1.14	1.32
Average	2.57	1.77	1.56	1.42	1.39	1.37	1.28	1.30
Run number	C. Churning time in minutes							
1	55	34	32	30	34	28	30	30
2	52	37	33	32	32	28	33	32
3	44	32	30	33	31	38	30	34
4	36	33	32	32	28	32	30	32
5	35	32	30	32	34	38	40	35
6	44	34	26	27	30	27	28	35
Average	44	34	31	31	32	32	32	33

results in the churning time averages is noted in that there is no marked rise among the richer creams.

RESULTS WITH LARGE CHURNS AND "SUMMER FATS"

In order to determine whether or not the persistently lower values of the percentages of total fat lost with 37.5 percent cream would likewise occur with "summer fats" and large churnings, the data of table 6 were obtained. The averages of the small (tables 3, 4 and 5) and the large churnings agree sufficiently well that the data herein presented can be considered representative of the factory procedure, even in the "flush" of the season.

TABLE 6. PERCENTAGE OF THE TOTAL FAT LOST IN THE BUTTERMILK FROM CREAM TESTING 30.0 AND 37.5 PERCENT FAT WHEN CHURNED IN LARGE CHURNS. (1,500 LB. CHURNINGS; MAY 15 TO JULY 8).

Type of cream	Run number	Percentage Total fat lost (30% cream)	Percentage total fat lost (37.5% cream)
Sweet	1	1.71	1.29
	2	1.44	1.14
	3	1.52	1.19
	4	1.45	1.12
	5	1.45	1.08
	6	1.56	1.14
	Average	1.521	1.16
Ripened	7	1.59	1.16
	8	1.37	1.00
	9	1.34	1.00
	Average	1.433	1.053
Neutralized	10	1.52	1.10
	11	1.45	0.98
	12	1.50	1.00
	Average	1.490	1.027

RESULTS RELATIVE TO THE AMOUNT OF BUTTERMILK OBTAINED

One of the objectives of this study was to develop a simple means of calculating churning losses. In order that this might be done, a reasonably precise method for the estimation of the quantity of buttermilk is necessary. At the inception of this study, Prof. M. Mortensen, head of the Dairy Industry Department, Iowa State College, stated that in his experience this value could be satisfactorily calculated if a 20 percent overrun were assumed at the time the buttermilk was drawn. No data to this effect were available in the literature; therefore, those of table 7 were obtained. As is indicated in the table one set of values is calculated assuming a 20 percent overrun while the other set is calculated on the actual weights of the buttermilk (no wash water included) drawn from the churn. These data show that an assumption of a 20 percent overrun, at the time the

TABLE 7. THE PERCENTAGES OF TOTAL FAT LOST WHEN DETERMINED:
 (1) FROM THE ACTUAL WEIGHT OF BUTTERMILK AND (2) FROM AN
 AMOUNT OF BUTTERMILK CALCULATED ON THE BASIS OF
 A 20 PERCENT OVERRUN AT THE TIME THE
 BUTTERMILK WAS DRAWN.

Percent- age fat in cream	Percentage total fat lost				Average diff. between actual and calc. loss, all churnings
	Run showing most variation		Run showing least variation		
	Calcu- lated	Actual	Calcu- lated	Actual	
A. Sweet cream					
40.0	1.13	1.18	1.20	1.20	0.009
37.5	1.25	1.27	1.29	1.29	0.019
35.0	1.24	1.28	1.22	1.24	0.019
32.5	1.35	1.39	1.35	1.35	0.031
30.0	1.37	1.40	1.47	1.47	0.017
27.5	1.41	1.41	1.56	1.60	0.024
25.0	1.87	1.87	1.68	1.70	0.011
20.0	2.56	2.60	2.48	2.48	0.011
B. Ripened cream					
40.0	1.40	1.37	1.37	1.37	0.011
37.5	1.36	1.32	1.37	1.37	0.009
35.0	1.36	1.34	1.39	1.36	0.013
32.5	1.42	1.40	1.44	1.44	0.010
30.0	1.58	1.85	1.51	1.51	0.016
27.5	1.50	1.49	1.73	1.73	0.016
25.0	1.77	1.77	1.94	1.94	0.006
20.0	2.81	2.81	2.56	2.56	0.023
C. Neutralized cream					
40.0	1.39	1.45	1.27	1.27	0.024
37.5	1.22	1.18	1.32	1.32	0.008
35.0	1.28	1.32	1.41	1.41	0.020
32.5	1.19	1.19	1.41	1.43	0.018
30.0	1.24	1.26	1.44	1.44	0.014
27.5	1.37	1.38	1.54	1.54	0.002
25.0	1.49	1.51	1.85	1.85	0.014
20.0	2.02	2.02	2.52	2.52	0.005

TABLE 8. THE BUTTERMILK TESTS AND PERCENTAGES OF TOTAL FAT
 LOST WHEN DIFFERENT BUTTERMILK TESTING METHODS
 ARE EMPLOYED.

Percent fat in cream churned		20.0	25.0	27.5	30.0	32.5	35.0	37.5	40.0
Mojonnier test	% Fat in buttermilk	0.626	0.611	0.613	0.646	0.715	0.754	0.807	0.921
	Total fat lost	2.37	1.71	1.49	1.38	1.34	1.24	1.19	1.20
Amer. assoc. test	% Fat in buttermilk ¹	0.557	0.542	0.544	0.577	0.648	0.688	0.742	0.859
	Total fat lost	2.117	1.518	1.325	1.231	1.216	1.140	1.094	1.117
Minnesota test	% Fat in buttermilk ¹	0.413	0.397	0.399	0.435	0.509	0.551	0.608	0.731
	Total fat lost	1.569	1.112	0.972	0.928	0.955	0.913	0.892	0.950
Babcock test	% Fat in buttermilk ¹	0.170	0.160	0.162	0.183	0.229	0.255	0.290	0.365
	Total fat lost	0.647	0.448	0.394	0.391	0.430	0.422	0.425	0.474

¹Calculated from Mojonnier test by equations previously presented (8).

buttermilk is drawn, involves considerably less error in the calculation of the percentage total fat lost than exists among churnings with different lots of cream. The proposed method of calculation may be used, therefore, with entire confidence.

COMPARISON OF PERCENTAGES TOTAL FAT LOST WITH DIFFERENT TESTING METHODS

The relationships among certain buttermilk testing methods were presented in the second bulletin of this series (3). From the Mojonnier analyses of lots of sweet cream buttermilk, the buttermilk tests and percentages of total fat lost were calculated for the American Association, the original Minnesota and the Babcock methods. These results are presented in table 8. The fact that the Minnesota values are for the original reagent should be stressed, since, as table 9 shows, the equations presented previously could not apply if the other Minnesota reagents that have appeared subsequently were employed. In fact, the third reagent yields values that are smaller than those of the Babcock test.

TABLE 9. COMPARISON OF FAT TESTS OF THE SAME SAMPLE OF BUTTERMILK WITH THE MINNESOTA (REAGENTS 1, 2 and 3.,)¹ THE BABCOCK TEST AND THE AMERICAN ASSOCIATION METHODS. (AVERAGE MOJONNIER TEST 0.745%.)

Test number	Minnesota test, reagent No.			American association	Babcock
	1	2	3		
1	0.54	0.50	0.26	0.74	0.30
2	0.52	0.40	0.23	0.70	0.20
3	0.52	0.46	0.16	0.78	0.24
4	0.48	0.46	0.16	0.72	0.17
5	0.53	0.47	0.16	0.72	0.25
6	0.49	0.49	0.21	0.74	0.17
7	0.52	0.47	0.17	0.76	0.22
8	0.50	0.48	0.19	0.72	0.30
9	0.55	0.44	0.16	0.76	0.21
10	0.51	0.47	0.18	0.72	0.27
11	0.51	0.46	0.26	0.76	0.27
12	0.47	0.48	0.24	0.75	0.20
Average	0.512	0.465	0.198	0.739	0.233
Value calc. from Mojonnier test ² .	0.541	0.680	0.249

1. Minnesota reagents: 1 see (19) (3, appendix); 2 and 3, from (13).

2. For equations employed in these calculations see (3).

RELATIONSHIPS BETWEEN (1) CASEIN AND (2) ALBUMIN AND THE CHURNING LOSS

Table 10 contains the values for total protein, casein and albumin in buttermilk from cream of the different fat percentages studied. These values were determined on the buttermilk rather than the cream to eliminate difficulties arising from the high fat percentages of the lots of cream. Because of the nature of the methods employed, values could be obtained only with sweet cream buttermilk. The

values presented are the averages of five runs. The values among the eight churnings of each run were always within the limits of error of methods employed, and for this reason not more than the five runs were made. Insofar as these

TABLE 10. THE PROTEINS IN BUTTERMILK AND CREAM AND THE PERCENTAGE OF FAT IN THE CREAM.

Item determined or calculated	Fat percentage in the cream*							
	20.0 ³	25.0	27.5	30.0	32.5	35.0	37.5	40.0
1. Percentage total protein in buttermilk	3.23	3.23	3.19	3.23	3.20	3.12	3.13	3.08
2. Percentage casein in buttermilk	2.14	2.14	2.23	2.29	2.32	2.29	2.22	2.32
3. Percentage albumin in buttermilk	0.28	0.28	0.28	0.32	0.29	0.25	0.28	0.30
4. Pounds total protein in 1000 pounds cream ¹	25.84	24.22	23.12	22.61	21.60	20.29	19.57	18.49
5. Pounds casein in 1000 pounds cream ¹	17.12	16.06	16.17	16.04	15.66	14.89	13.87	13.93
6. Pounds albumin in 1000 pounds cream ¹	2.24	2.16	2.03	2.24	1.96	1.63	1.75	1.80
7. Difference 4. less (5+6)	6.48	6.06	4.92	4.33	3.98	3.77	3.95	2.76
8. $\frac{\text{lb. total protein}}{\text{lb. fat}} \times 10^2$ (cream) ²	12.92	9.68	8.41	7.54	6.65	5.80	5.22	4.62
9. $\frac{\text{lb. casein}}{\text{lb. fat}} \times 10^2$ (cream) ²	8.56	6.42	5.88	5.34	4.82	4.26	3.70	3.48
10. $\frac{\text{lb. albumin}}{\text{lb. fat}} \times 10^3$ (cream) ²	11.20	8.40	7.38	7.47	6.03	4.66	4.67	4.50
11. $4 - (5 + 6) \times 10^3$ lb. fat in cream	32.38	24.24	17.98	14.43	12.24	10.77	10.54	6.90

1. Calculated on assumption that cream serum and buttermilk have same composition.

2. Based on 1,000 pounds cream.

3. Not analyzed—assumed same as for 25.0 percent cream for columns 1., 2., and 3.

*Average figures for 5 churnings.

analyses are indicative, the sera of the lots of cream are alike within the limits of error of the analytical methods employed.

The protein values for the lots of cream are calculated from those of the lots of buttermilk. One striking feature of these results is that the total protein less the sum of the casein and albumin (horizontal column 7) is greater, the lower the fat percentage of the cream. It was rather anticipated that the reverse would be true if the assumption that proteins not like those of the serum form the so-called membrane around the fat particles.

DISCUSSION OF RESULTS

CHECK ON EXPERIMENTAL PROCEDURE

Two questions naturally confronted the authors of this bulletin, viz., were the results obtained with the three churns sufficiently different to invalidate the data, and were the data obtained representative of those that would have been obtained had larger or factory-size churns been used?

The preliminary runs (table 1) show that the results among the churns agreed very well. Tables 2 and 6 show that the results with the experimental churns are representative of those with the larger churns.

THE RELATIONSHIPS AMONG THE FAT TEST OF THE CREAM,
THE PERCENTAGE OF THE TOTAL FAT LOST AND THE
MOJONNIER TEST OF THE BUTTERMILK

Figure 1 summarizes the averages of the loss data for the sweet, ripened and neutralized cream runs. The figure was prepared by first plotting the lines that show the relationship between the percentage of the total fat lost and the Mojonnier test of the buttermilk. The equation of these curves is presented in the figure and will be discussed later. Next, the points representing the loss data were plotted in such fashion that each point was determined by three quantities—the percentage of the total fat churned that was lost in the buttermilk, the Mojonnier fat test of the buttermilk

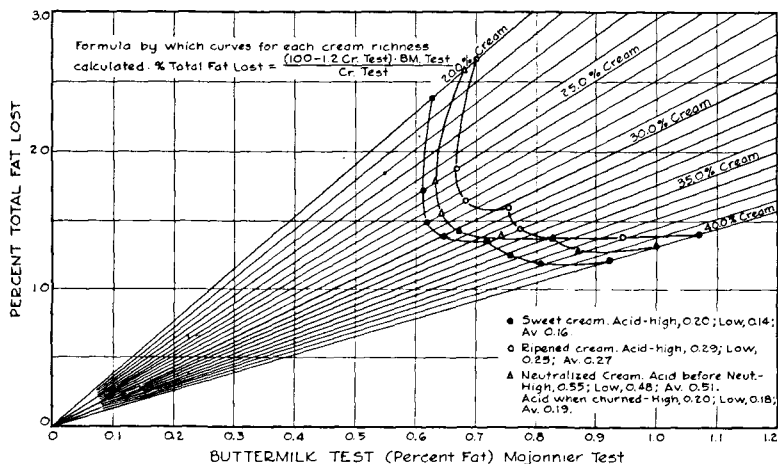


Fig. 1. The relationship between the percentage total fat lost and the fat test of the cream.

and the fat percentage of the cream. The result of this treatment is a quasi-tridimensional figure that lucidly pictures the relationships among the three quantities.

With cream testing 20 to 30 percent fat, the Mojonnier test of the buttermilk is relatively constant. From 30 to 35 percent fat in the cream the rate of change of the Mojonnier test of the buttermilk is more rapid than the rate of change of the percentage of the total fat lost, although the latter changes several tenths of 1 percent. From 35 to 40 percent (in fact from nearly 30 to 40 percent) the Mojonnier

test changes so much more rapidly than the percentage of the total fat lost that the curves have a tendency to parallel the abscissa. This is in marked contrast to the first portion of these curves, in which portion the rate of change of the percentage total fat lost is so much greater than the rate of change of the Mojonnier test of the buttermilk that the curves tend to parallel the ordinate.

This figure shows in a very striking manner the inadvisability of churning cream the fat content of which is below 30 percent *at the time it is placed in the churn*. It should be remembered that the cream churned in these experiments was standardized so that the fat percentages recorded were as of the time of churning.

One other factor, which fig. 1 emphasizes, is that whenever churning losses are compared, the fat test of the cream must be considered. A comparison of the fat tests of the buttermilk without due consideration of the cream richness would indicate like losses for lots of cream of 20 to 30 percent, whereas they would show alarming discrepancies were the cream richness above 30 percent. In both cases the indication from the buttermilk test alone is erroneous because great differences in actual loss do occur with variation in fat percentage in the cream below 30 percent; the actual loss variations are small in comparison when the cream richness is greater than 30 percent. The total variation in loss between 20 and 30 percent fat in the cream is approximately 1 percent of the total fat placed in the churn; the maximum difference between 30 and 40 percent fat in the cream is less than 0.5 percent of the total fat churned, and between the 35 and 40 percent fat levels in cream the loss is in the neighborhood of 0.2 percent of the total fat churned.

Figure 1 indicates that a change in function occurs in the fat loss curves. For further consideration of the possibility of such change of function the sweet cream data were treated in two ways in fig. 2. A comparison of the percentage fat in the cream and the percentage of the total fat lost is presented in the upper graph. The authors interpret the curves as discontinuous and represent the discontinuity by the dotted line. In the lower graph of fig. 2 the pounds of fat lost in the buttermilk from 1,000 pounds of cream are plotted against the pounds of fat in 1,000 pounds of cream. Here the loss is not weighed by the fat in the cream, as was done when the percentage of total fat lost in the buttermilk was considered as the dependent variable. The lower graph emphasizes markedly the change in function at a point between 30 and 35 percent fat in the cream. At present it is considered that this change results from some change in the

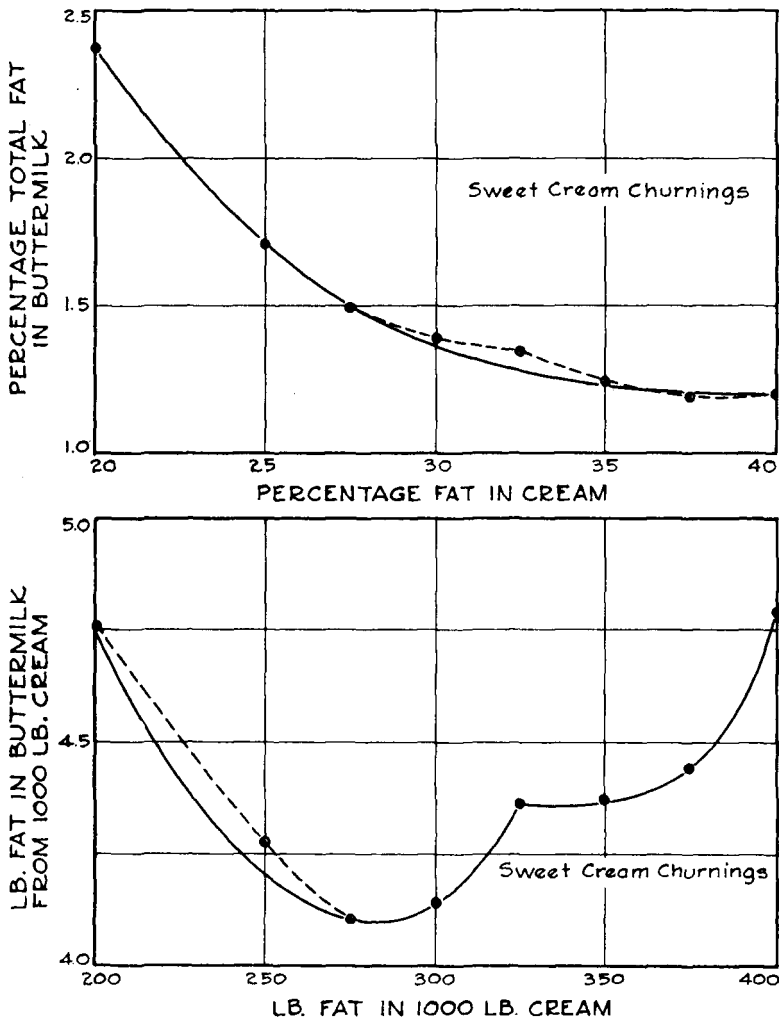


Fig. 2. A treatment of the sweet cream data to consider the possibility of the apparent discontinuity of function in the fat loss curves.

phase relationships among the colloidal systems of cream. Until data are available to confirm or refute this statement, it must be taken as an unsupported hypothesis.

THE RELATIONSHIP BETWEEN THE PERCENTAGE FAT AND THE CHURNING TIME OF THE CREAM

Figure 3 presents the average churning time of the different lots of cream as a function of their richness. The curve for sweet cream drops from 45 minutes at 20 percent cream,

to 37 minutes at 25 percent cream and then rises gradually to 51 minutes at 40 percent. With the possible exception of the 40 percent cream, none could be criticized as having too long a churning time. The ripened cream churnings show a minimum of 35 minutes at the 30 percent cream point, having dropped from 47 minutes with 20 percent cream; the time increases at a greater rate from the minimum to the 37.5 percent fat level than did the sweet cream. The churning time for 37.5 percent ripened cream is 46 minutes. A steep rise in the curve occurs to 61 minutes with 40 percent cream. Attention should be called to the churning time figures presented in table 4. These indicate that the marked rise to 61 minutes results largely from two values of 120 and 85 minutes, respectively. Without these values the slope of the curve beyond 35 percent would have been considerably less. The graph for the neutralized cream values lies below either of the other two and does not present any appreciable rise as the cream richness increases from 27.5 to 40 percent fat. The characteristic drop occurs in churning time with increase in fat percentages from 20 to between 25 and 30 percent fat in the cream.

These curves (fig. 3) when compared with the loss data (fig. 1) show that the relationship between the churning time and the fat losses is not particularly important. The loss curves (fig. 1) indicate that the losses from neutralized cream lie more closely toward those of the sweet creams than do those from ripened cream, whereas the churning time curves of the sweet and ripened cream approximate each other rather closely. It has been considered generally that extremely long or extremely short churning times indicate high losses in the buttermilk. These data indicate that when the fat has been properly cooled and the churning temperatures are satisfactory such a correlation does not exist.

THE RELATIONSHIPS AMONG THE CHURNING LOSSES AND THE AMOUNTS OF THE DIFFERENT PROTEINS IN THE CREAM

The data on the effect of the quantities of the different proteins were considered only for the sweet cream churnings for reasons previously stated. The results from this section of the study are considered representative of American sweet cream churning conditions. In the trade the only logical, legal variation of proteins results from a change in the richness of the cream. Properly processed cream should have the fat in equilibrium with respect to its physical characteristics and the other constituents (including the pro-

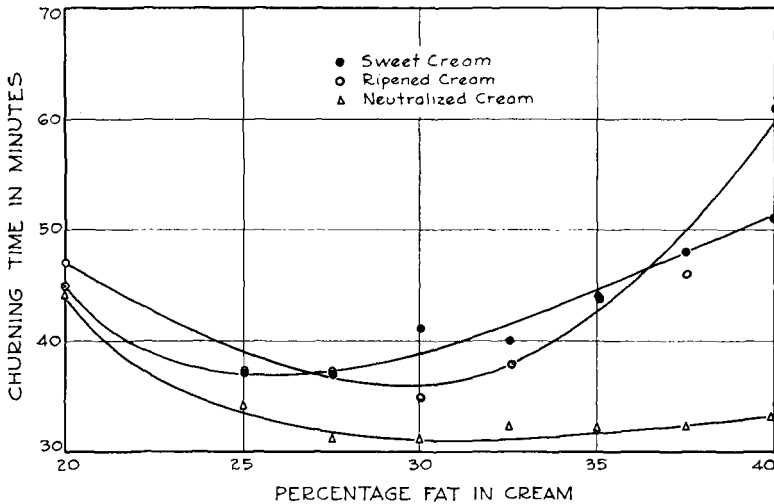


Fig. 3. The relationship between the percentage fat in the cream and the churning time of the cream.

teins) of the cream. This should have been accomplished by the methods of processing employed.

The data have been treated in figs. 4, 5 and 6. Three possibilities seemed likely to be encountered among these results, viz., that the fat would exert so great an influence on the loss that it would out-weigh any effect that the protein might show and thereby make it impossible to detect differences in loss resulting from variation in amounts of protein; that the changes might be functions of the quantity of the proteins present and finally that any possible correlations might show as relationships between the protein: fat ratios of the buttermilk and the similar ratios of the cream.

In fig. 4 the upper graph compares the percentage total fat lost with the protein : fat ratio of the cream ; the lower graph compares the pounds of fat in the buttermilk from 1,000 pounds of cream with the protein : fat ratio. In the upper graph the total protein curve presents to a large degree the same general type of curve as the upper graph in fig. 2. The casein curve is very similar, while the albumin curve does not show the change of function characteristic of the other two curves. In the lower curve (fig. 4) two points of change of function are indicated in the curves for total protein and casein, while but one appears in the albumin curve. In the lower graph (fig. 2) the dotted line indicates a nearly linear function for the three lowest fat percentages ; the same three points present a linear section in the curves of

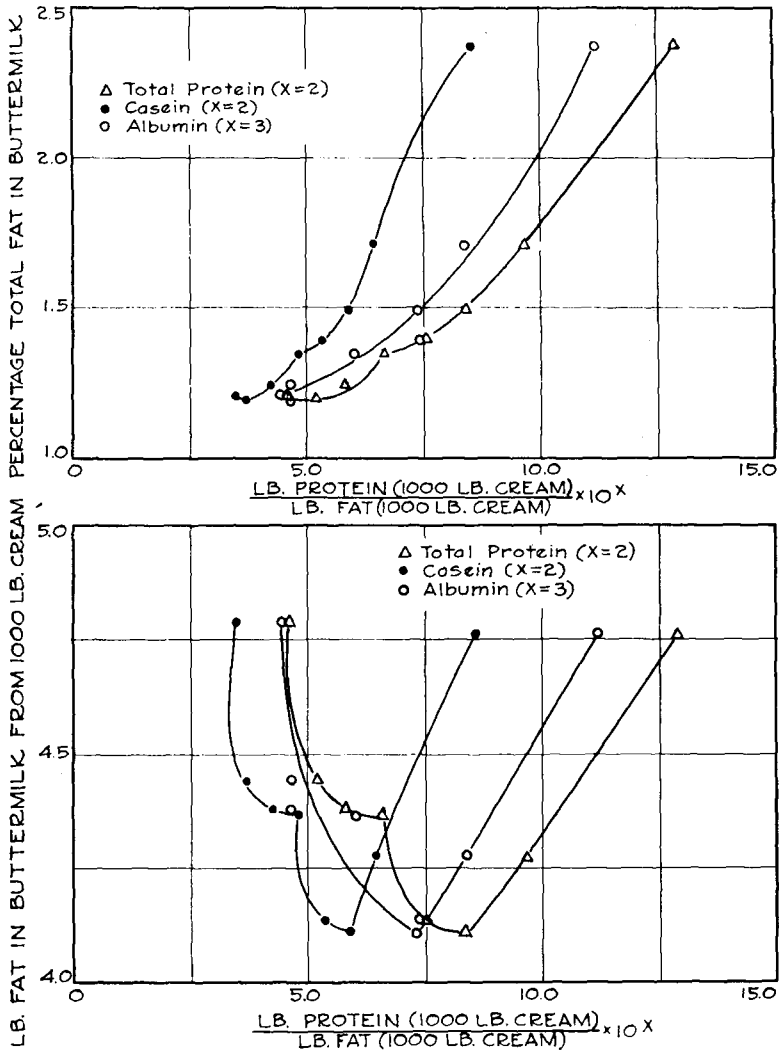


Fig. 4. The relationship between the churning loss and the protein : fat ratios of the cream.

the lower graph of fig. 4. Whether or not this is merely a coincidence or whether these two points represent changes in the phase relationships among the colloidal systems in cream cannot be stated, although these graphs seem to indicate such changes. The portion of the curves of fig. 1 which present a nearly linear appearance with a slope approximating infinity involves the same group of three points

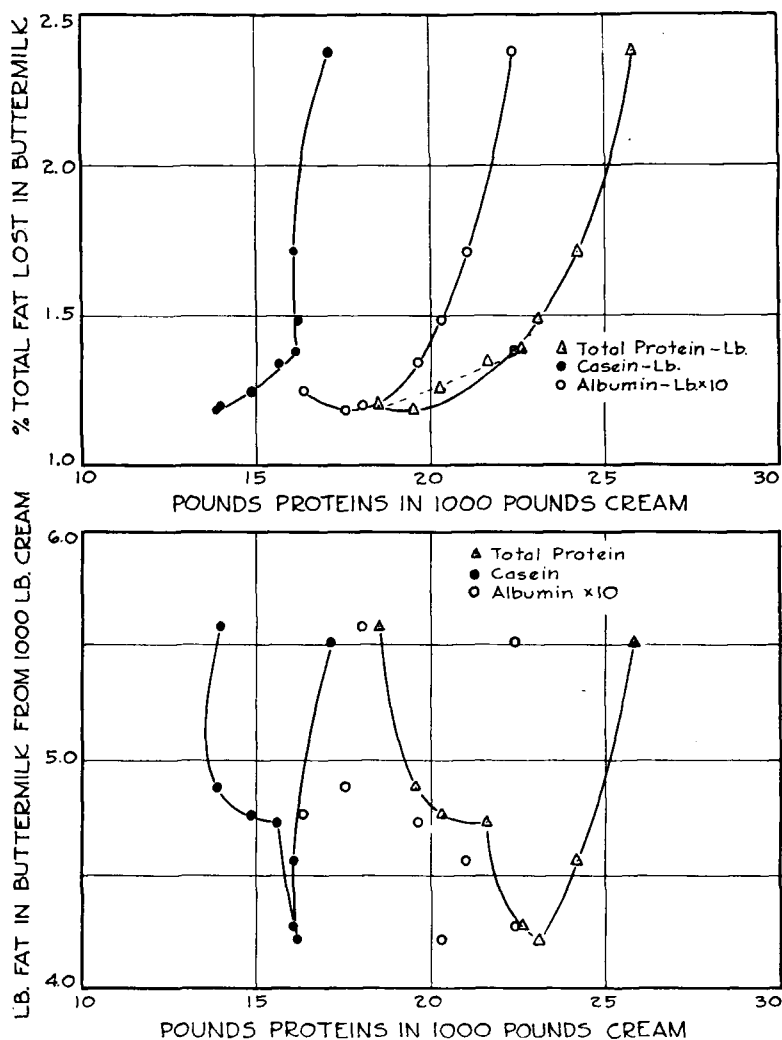


Fig. 5. The relationship between the churning loss and the weight of certain proteins in the cream.

(20.0, 25.0 and 27.5 percent cream) as the linear portions of the curves of the lower graph of fig. 4. A second comparison of the total protein and casein curves of fig. 4 with the sweet cream curve of fig. 1 indicates that the points involving 32.5, 35.0, 37.5 and 40.0 percent cream are included in the sections of all three curves that appear to be a distinct and independent function of the protein : fat ratio

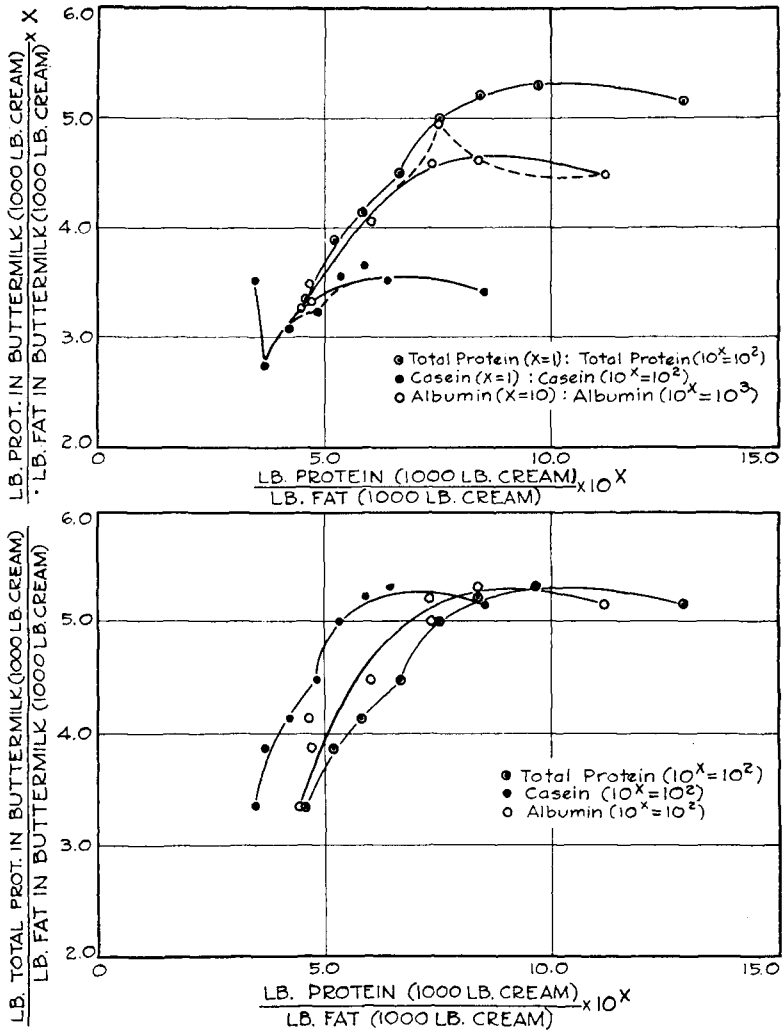


Fig. 6. The relationship between the protein : fat ratios of the buttermilk and the protein : fat ratios of the cream.

(fig. 4) or the buttermilk test (fig. 1) when these sections are compared with the other portions of the same curves.

The upper graph in fig. 5 presents a definite change in function in the casein curve and a strongly suggested one in the total protein curve. Except for the fact that five rather than four cream concentrations seem to be involved the curves are like those of the upper graph of fig. 4, in that one change of function occurs. Whether or not four or five

points are involved in this high fat section of the curve or whether the change in function falls between the fourth and fifth point cannot be stated. It would appear, however, that when the fat lost is weighted (in a percentage) by the fat of the cream, a single point of inflection seems to occur [figs. 1, 2, 4 (upper graph) and 5 (upper graph)]. When, however, the pounds of fat in the buttermilk from 1,000 pounds of cream are plotted either against the weights of casein or total protein per 1,000 pounds of cream, the total protein : fat or casein : fat ratios [figs. 4 (lower graph) and 5 (lower graph)], two points of inflection seem to occur.

When the total protein : fat ratio for buttermilk is plotted against the protein : fat ratios for cream (fig. 6) single points of inflection very like those previously mentioned appear in the lower graph for the total protein and casein curves. A similar single point of inflection occurs in the total protein : fat curves in the upper graph of fig. 6. The casein : fat and albumin : fat ratio curves in the upper graph of fig. 6 are not apparently in agreement with any of the curves previously discussed.

A comparison of the upper and lower graphs of figs. 4 and 5 indicate that when the percentage of the total fat in the cream that is lost in the buttermilk is compared with either the pounds of casein, of total protein, or with the protein (total or casein) : fat ratios, the weighting effect of the cream fat is very pronounced, whereas when the pounds of fat in the buttermilk from 1,000 pounds of cream are compared with these values the weighting effect of the cream fat seems either to be absent or greatly altered. It seems more nearly logical to assume that it has been minimized rather than eliminated.

In general the curves in figs. 4, 5 and 6 for total protein and for casein present much more convincing correlations than the plotted values for albumin. It would seem, moreover, that the curves involving casein present just as good correlations as those for total protein with the exception of the ratios of casein : fat in the upper graph of fig. 6. In one instance (upper graph, fig. 5) the casein curve is more definite than the total protein curve. Whether or not it can be concluded that casein seems to have a definite influence on the churning loss and that albumin exerts a less definite or secondary influence would be difficult to say. The albumin data may be criticized from the standpoint that inasmuch as the percentage of albumin is small, analytical errors tend to give random results that seem to be characteristic of the albumin curves. The casein curves and those for the total protein appear to be very definite and correlate very well

with the loss data (figs. 1 and 2). The data, therefore, seem to indicate that casein plays an important function in the colloidal system, cream, in connection with the churning process.

If any conclusions can be drawn relative to the effect of casein and albumin on the churning loss it seems, from these data, that casein may be a fairly important factor and albumin of minor importance. As the pounds of protein in the cream decrease (fig. 5, upper graph) the percentage total fat lost decreases. At first glance this indicates that the lower the protein percentages in the cream the lower the fat loss. The percentage of the total fat churned which is lost in the buttermilk is very heavily weighted by the fat percentage of the cream. For this reason the curves referred to undoubtedly do not present a true picture of the influence of the proteins on the churning loss.

When the lower graph of fig. 5 is considered it appears that the pounds of fat lost per 1,000 pounds cream decrease as the pounds of protein in 1,000 pounds of cream decrease (cream with 20 to 27.5 percent fat). A sharp rise in the pounds of fat per 1,000 pounds cream occurs as the protein (casein and total protein) continues to decrease (cream of 27.5 to 32.5 percent fat). The rate of increase in pounds of fat lost per 1,000 pounds cream changes at 32.5 percent cream and seems to increase more or less logarithmically as the protein decreases from this point (from 32.5 to 40.0 percent cream).

These figures indicate that the percentage of total fat lost is more nearly a function of the fat test of the cream, while the test of the buttermilk is more nearly a function of the protein percentage or of the protein : fat ratio of the cream. A better way of stating the relationships may be to say: When the percentage of the total fat churned that is lost in the buttermilk is considered, the fat percentage of the cream seems to determine the values obtained more than do the total protein and casein percentages; but if the percentage fat in the buttermilk is considered then the proteins in the cream seem to have the greater influence.

These results need not necessarily be considered at variance with those of van Dam and Holwerda (9, 10) since here only such variations, as naturally occur when the cream richness varies, were considered and, in addition, these results were for sweet cream in which both the fat globules and the protein particles would have negative charges. Those of van Dam and Holwerda were obtained with cream on the acid side of the isoelectric point of casein. It may be that in highly acid creams the "curdled" casein particles

may no longer act in the same way as protective colloids as they may at higher pH's; they may even tend to reverse the charges of some of the fat particles thus leaving some positively, some negatively charged. An increase in the casein content may, therefore, cause greater ease of grouping of the fat globules and, as a result, lower churning losses.

CONSIDERATION OF THE NUMBER OF VARIABLES IN THE SYSTEMS STUDIED

A number of factors have been recognized as having an influence on the churning loss. The chief ones that it might have been necessary to have guarded against in this study are the composition of the fat, the physical condition of the fat at the time of churning, the churning temperature, and the fullness of the churn.

The fat composition was controlled as nearly as was possible by employing gathered cream from a large group of patrons and by conducting the investigation during the winter months when the variations in fat compositions are very slight.

Burr (6), and particularly van Dam (7, 8), have emphasized the necessity of solidifying the fat before it was churned. van Dam's studies are very inclusive and indicate that a holding period of at least 4 hours at a temperature at least 10°C. below the churning temperature is necessary. These conditions were met in the experimental work that has been presented.

The churning temperature was regulated so that it was correct for the season of the year, and the churns were operated with loads such that they were filled to approximately one-third their cubical capacity.

It is considered, therefore, that all variables except the protein and fat percentages of the cream were controlled to as great an extent as was possible with the natural system, cream, under factory conditions.

PRACTICAL APPLICATION OF THE DATA PRESENTED

Among the workers who have either conducted experimental work or presented discussions with regard to churning losses, Bouska (4) has suggested expressing fat losses as the ratio of the fat in the buttermilk to that in the cream. Sebelien (20) as early as 1888 advocated expressing losses as the percentage of the total fat in the cream churned, and he expressed his data in this fashion. Hansen and Langmack (14, 15) advocated and utilized the same method of expressing churning loss data. Despite these suggestions and usages neither the creamery operator, the field worker

nor the majority of the experimental workers have adopted this method.

The reasons for not adopting this method of calculation may be that the calculation of the losses have been more or less cumbersome and time consuming, that no method of precisely evaluating the quantity of buttermilk was available or that with a diversity of buttermilk testing methods, the lack of standardization or adoption of any one testing method would have rendered the expression of losses as percentages of the total fat churned as meaningless as the values of the tests themselves.

It is considered by the authors of this bulletin that the relationships among the tests that have received the most attention in this country have been satisfactorily worked out (3). Moreover, it is the opinion here that the Mojonner method is the one that is best suited for use in controlled experimental work.

The data presented in table 7 show that the objection to expressing losses as percentages of the total fat lost, on the grounds that the amount of buttermilk cannot be estimated, is not valid. These data show that the quantity of buttermilk can be satisfactorily estimated if a 20 percent overrun is assumed at the time the buttermilk is drawn. The calculated percentages of the total fat that is lost are not appreciably affected either by the richness of the cream from 20 to 40 percent fat, or by the acidity of the cream from sweet cream to cream having been ripened to acidities of 0.27 percent (table 7).

The fundamental equation for the calculation of fat losses as percentage of the total fat churned is:

$$1. \% \text{ T.F.L.} = \frac{\text{lb. buttermilk} \times \text{buttermilk test} \times 100}{\text{lb. fat in the cream (at the time of churning)}}$$

The pounds of buttermilk and the pounds of fat in the cream may be represented as:

$$2. \text{ lb. buttermilk} = \text{lb. cream} - \left(\text{lb. fat in cream} \times \frac{120}{100} \right)$$

$$3. \text{ lb. fat in cream} = \text{lb. cream} \times \frac{\text{cream test}}{100}$$

In equation 2. a 20 percent overrun is assumed.

When the values from 2. and 3. are substituted into 1. and the resulting equation is simplified algebraically, the following simple equation for the calculation of the percentage of the total fat lost in the buttermilk is obtained:

$$4. \% \text{ T.F.L.} = \frac{(100 - 1.2 \times \text{cream test}) \cdot \text{buttermilk test}}{\text{cream test}}$$

This equation is valid regardless of the amount of cream employed and eliminates the necessity of knowing the pounds of cream placed in the churn. In order to use the equation it is necessary to know only the fat test of the buttermilk and the fat test of the cream *at the time when the churning is started.*

Figure 7 was prepared by the use of (a) equation 4., (b) the average fat loss values for the sweet cream churnings and (c) the equations (3) showing the relationships among the buttermilk testing methods. This is a quasi-tridimensional figure as was fig. 1. In it are shown the relationships among the percentage total fat lost in the buttermilk, the cream test and the buttermilk tests by the American Association, Babcock, original Minnesota and Mojonier methods.

The presentation of a chart, such as fig. 7, eliminates the necessity for all calculation in the evaluation of churning losses and, because only the cream test and the test of the undiluted buttermilk are required, removes all reason for not checking churning efficiency in the creamery.

The Babcock test is not a desirable method for determining the buttermilk fat test because the magnitude of the values obtained are small and for that reason variations are difficult to catch. If the original Minnesota or the American Association (butyl alcohol) methods are employed, the operator can, by comparing his loss figures on the chart with the graph for the test he is using, determine whether or not his churning is efficiently done.

The question relative to the determination of the so-called "true fat" value of buttermilk has received considerable attention during the past 10 years. It is the opinion of the authors that the knowledge by the buttermaker of the quantity of "true fat" that passes out in the buttermilk is not essential. It has been pointed out that, in the light of the results presented in the literature for milk and cream testing, the estimation of fat in buttermilk by the Mojonier test should present loss data comparable to fat purchases of milk or cream on the basis of the Babcock test (3). Regardless of the above facts the most important thing for the creamery operator to know is whether or not his churning losses approximate those which have been obtained under such conditions as would make them minimal. Figure 7 enables him to make such a comparison rapidly and conveniently. The chart, likewise, eliminates the possibility of drawing erroneous conclusions if two operators who are employing different buttermilk testing methods attempt to compare their results.

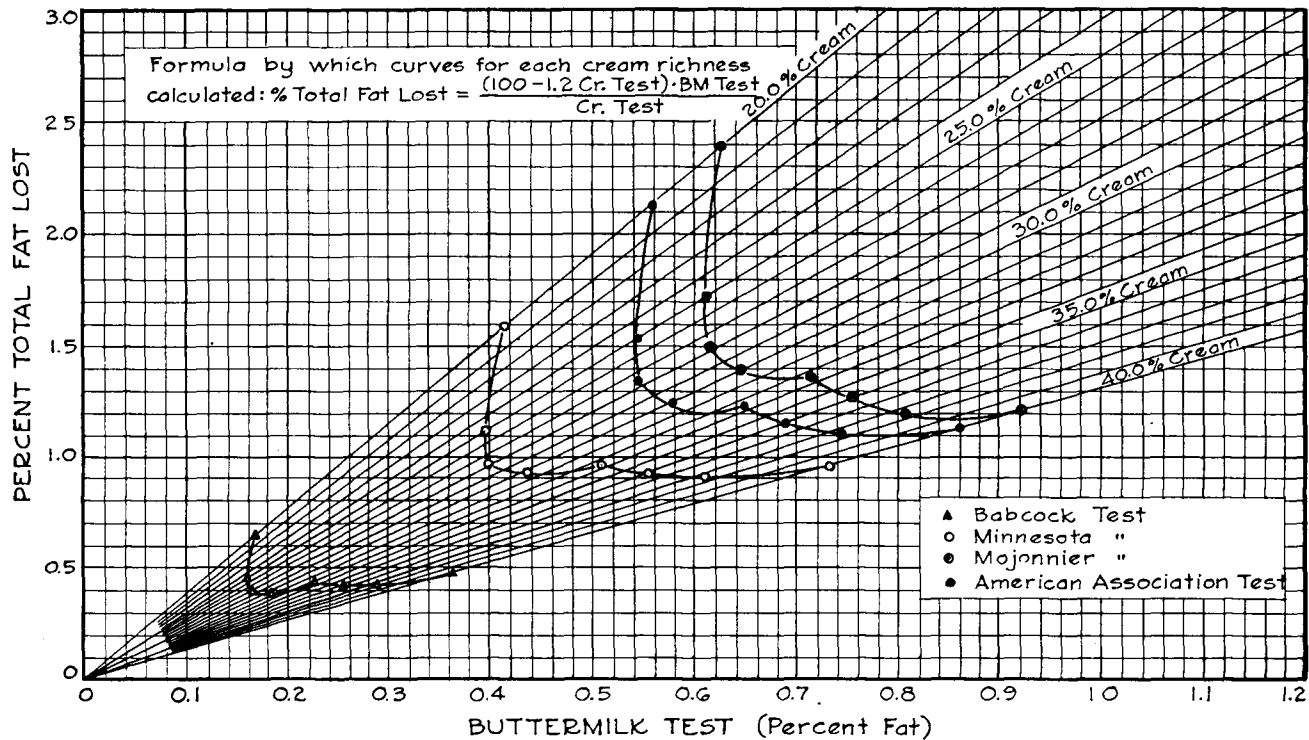


Fig. 7. The relationships among the cream test, the buttermilk tests by several analytical methods and the percentage total fat lost in the buttermilk.

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as much as 40 per cent. was reckoned to be the outcome of the combined effects of systematic burning of heather and of drainage.¹

Although the main object of burning heather is to promote young growth it may be desirable to reduce the heather acreage and increase the acreage of grass land. Conversely heather may be made to replace bracken by systematic cutting of the latter plant, mat grass by restricted grazing, and deer's hair grass by adequate draining.

Balanced Grazing.—The importance of ensuring that grazings should be so managed as to regulate the dominance of any particular species of plants can scarcely be over-estimated. On lowland pastures control of the grazing may be brought about by the kind of animal grazing the pastures, by rest periods and by the use of the mower. On hill grazings control is less easy but by mixing cattle with sheep good results are usually obtained. Cattle tend to eat the taller growing herbage like white or blow bent which sheep avoid after a certain period in the spring. Largely through mixing cattle with sheep on their hill grazing at Boghall,² the East of Scotland College have been able to graze 20 Galloway cows with their calves in summer without displacing a single sheep. Moreover, since the cattle were put on to this grazing, which extends to 300 acres, the quality of the lambs has improved. It should be noted that other measures of improvement, drainage and irrigation, have contributed to the result. Somewhat similar results have been obtained by W. H. Hamilton³ of Cairns, Midlothian.

The most striking evidence of the benefits to be derived from grazing cattle with sheep was obtained at Cockle Park. For every pound of live weight increase gained by sheep grazing alone on a given acreage of land two pounds of total increase were obtained when sheep were grazed along with cattle.

Other Measures of Improvement.—It is difficult to measure the improvement effected by such means as the burning of blow bent in the spring, bracken-cutting, drainage, irrigation, etc., since such measures of improvement are seldom adopted by themselves. They are, however, self-evident to sheep farmers and shepherds.

Grazing Patches.—Stapledon has in his book, *The Land Now and To-morrow*, emphasised the attraction for sheep of certain patches in moorland areas. During the summer it is not uncommon to see many of the sheep on a grazing congregated on a narrow fringe on either side of a roadway. This has led many people to suppose that the crushed road material, which has been either

¹ *Trans. High. and Agric. Soc.*, 5th Ser., Vol. XX. (1908).

² Wilson in *Scot. Jour. Agric.*, Vol. XIX. (1936).

³ *Scot. Jour. Agric.*, Vol. XXI. (1938).