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REDUCING THE LOSS OF FAT DURING CHURNING

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FOREWORD

THIS bulletin presents the findings of an investigation conducted by the Oregon Agricultural Experiment Station to determine the amount of fat lost in buttermilk during churning and to devise methods of reducing the loss.

On the basis of the present annual production of butter in Oregon an excess loss in the buttermilk of only 0.5 per cent of the total fat churned would create a loss of $44,000, if fat is valued at 35 cents a pound.

WM. A. SCHOENFELD
Dean and Director

TABLE OF CONTENTS

RECOMMENDATIONS

In this study of the churning of 2,141 lots of cream over a period of 6 years it was found that when the fat test of the cream was controlled, and when proper care was exercised in pasteurizing, cooling, holding, and churning cream, the amount of fat lost in the buttermilk could be kept to a minimum.

On the basis of the findings, the following factors are most important for maintaining a low fat loss.

1. Cool the pasteurized cream to from 40° to 45° F. This applies to spring and summer conditions.
   (A minimum temperature of 50° F. may be required during the winter when difficulty is experienced with crumbly or sticky body.)
2. Hold the cream at the low temperature until churning, preferably overnight, but if the cream is to be churned the same day, hold it for at least 3 hours before it is churned.
3. Do not overload the churn. Using a normal amount of cream makes it possible to employ a low churning temperature. The fat loss will be less than when an excessive amount of cream is churned at a high temperature.
4. Avoid dilution of the cream with water at all points during the manufacturing process. In order to eliminate water dilution of the cream, collect and separate all vat rinsings, etc., and add the cream obtained to the next lot of cream to be pasteurized.
5. Churn cream of a relatively high fat content. The test of the cream should preferably range from 36 to 40 per cent.
6. Use a churning temperature low enough to give an exhaustive churning. The churning period should be at least 45 minutes.
7. For every churning, make a test of the cream in the churn and of the buttermilk; then calculate the per cent of the total fat churned that is lost in the buttermilk. This will aid in checking the churning efficiency and will be a warning if abnormal conditions develop.

Reducing the Loss of Fat During Churning*

By
G. H. WILSTER, R. P. ROBICHAUX, R. E. STOUT, and R. W. STEIN

EFFICIENCY in the churning of cream is of considerable economic importance. The Oregon creameries manufactured in 1939 a total of 31,000,000 pounds of butter. Approximately 75,000,000 pounds of 33 per cent cream that contained 25,000,000 pounds of fat were used in the manufacture of this butter. If approximately 50,000,000 pounds of buttermilk were obtained and this contained the equivalent of 1 per cent of the total fat used in churning, the loss would be 250,000 pounds of fat. If the buttermilk contained 1.5 per cent of the total fat used, the loss would be 375,000 pounds of fat. The additional loss of 125,000 pounds of fat at a value of 35 cents a pound would reduce the net returns to the creameries and in turn to the dairy farmers by $43,750.

METHOD USED FOR DETERMINING THE FAT CONTENT OF THE BUTTERMILK

It was decided to use a method for determining the fat content of the buttermilk obtained in the investigation that is familiar to buttermakers throughout Oregon as well as to the buttermakers in other states. The Babcock-butyl alcohol method was therefore used except for certain studies when the Mojonnier method was used. This method has been found by the Oregon Agricultural Experiment Station to give results† that check very closely with the ether extraction (Mojonnier) method. This test has been used by creameries in the United States since 1921. The Babcock-butyl alcohol method was found satisfactory by Bird, Breazeale, and Sands.‡. Recently Bird§ compared the results obtained from the testing of buttermilk by several different methods. He found that the Babcock-butyl alcohol method gave results that checked very closely with those obtained by the Mojonnier method. The following average fat percentages were obtained by him:

	Average 12 samples Per cent fat
Babcock-Minnesota modification (original Minnesota-Babcock reagent formula)	0.512
Babcock-Minnesota modification (modified reagent)‖	.465
Babcock-Minnesota modification (present commercial reagent)	.198
Babcock-sulphuric acid method	.233
Babcock-butyl alcohol-sulphuric acid method	.739
Mojonnier method	.745

* ACKNOWLEDGMENT: The cooperation of the management and personnel of six Oregon creameries in connection with this study has been greatly appreciated by the Agricultural Experiment Station.

† Unpublished data.

‡ Bird, E. W., Breazeale, D. F., and Sands, G. C., *Chemistry of Butter and Buttermaking. II. The Nature of the Fatty Material in Buttermilk and the Significance of Certain Buttermilk Testing Methods.* Iowa Agricultural Res. Bul. No. 175. 1935.

§ Bird, E. W., "A Discussion of Buttermilk Testing Methods," *Canadian Dairy and Ice Cream Journal,* October 1940.

‖ Sommer, H. H., *The Theory and Practice of Ice Cream Making,* page 159. Published by the author at Madison, Wisconsin, 1932.

A similar comparison was made at the Oregon Agricultural Experiment Station. Twelve samples of buttermilk were tested in quintuplicate by the use of four different modifications of the Babcock method. An 8.8 cc. pipette was used for transferring the buttermilk to the test bottle.

The following results were obtained:

	Average 12 samples Per cent fat
Babcock-Minnesota modification (original Minnesota-Babcock reagent formula)	0.51
Babcock-Minnesota modification (modified reagent)*	.45
Babcock-Minnesota modification (present commercial reagent)	.29
Babcock-butyl alcohol-sulphuric acid method	.78

With reference to the method of determining the fat content of buttermilk, Hunziker† has recently pointed out that, "If the testing of the buttermilk is to fulfill its intended purpose of enhancing the factory operating efficiency, the method of testing used must:

"1. Provide a fat test of buttermilk that is representative of and comparable with the fat test of the cream,
"2. Be sufficiently sensitive to be suitable as a basis for determining the churning efficiency,
"3. Be sufficiently dependable to yield duplicates that check,
"4. Be confined to simple and reasonably inexpensive equipment,
"5. Be simple and rapid to operate."

Hunziker concluded as follows:

"On the basis of the close check of the Mojonnier test with the Babcock test for cream, it would appear that the American Association test showing the close agreement with the buttermilk values given by the Mojonnier test gives a somewhat more representative test for buttermilk than does the Minnesota test. Likewise the American Association test is somewhat simpler of operation as it requires no preliminary heating in a water bath." The American Association test, also known as the butyl alcohol test, was developed by G. L. McKay and J. W. Mitchell of the American Association of Creamery Butter Manufacturers.

DETERMINATION OF FAT BY THE BABCOCK-BUTYL ALCOHOL METHOD

The procedure followed in this study by Oregon Agricultural Experiment Station was as follows:

Prior to measuring, the samples of buttermilk were tempered in a water bath to a temperature of 68° F. Mixing of the sample was done by pouring from one container to another a total of six times. The pipette used for transferring the sample was graduated to hold 8.8 cc. The pipette resembled a Babcock milk pipette, but contained only one-half the amount, or $\frac{17.6}{2} = 8.8$ cc. A 9 cc. capacity pipette is suggested in several books in which the test is described. Hunziker‡ listed an 8.8 cc. capacity pipette. A sample of the well-

* Sommer, H. H., *The Theory and Practice of Ice Cream Making*, page 159. Published by the author at Madison, Wisconsin. 1932.
† Hunziker, O. F., *The Butter Industry*, 3d edition, published by the author at La Grange, Illinois, 1940.
‡ Hunziker, O. F., *The Butter Industry*, 2d edition, published by the author at La Grange, Illinois, 1927.

mixed buttermilk was transferred to an 18-gram capacity latest type double-neck skim milk test bottle. The graduated neck represented 0.50 per cent fat. The smallest graduation represented 0.01 per cent fat. The 8.8 cc. pipette was found to deliver approximately 9 grams buttermilk. The milk in the test bottle was tempered to 60° F. by placing the bottle in a water bath for 5 to 10 minutes. Two cc. of normal butyl alcohol were added to the test bottle and mixed with the milk. This was followed by the addition of approximately 8 cc. of sulphuric acid of a specific gravity approximately 1.825 and with the acid at a temperature of 60° F.

Centrifuging was done in an electrically operated tester for three periods of 6, 2, and 2 minutes. The air in the centrifuge was maintained at a temperature of from 140° to 150° F. Distilled water was used for adding to the test bottles. The temperature of this water was maintained at from 140° to 150° F. The finished tests were kept in a water bath maintained at a temperature of 138° F. for 5 minutes before measuring.

The fat column was measured by means of a pair of needle-pointed calipers employing a specially constructed lamp equipped with a magnifying lens. The reading was multiplied by two in order to obtain the per cent of fat in the buttermilk.

Only double-neck bottles of correct capacity of the graduated portion of the neck were used.

CALCULATING THE PERCENTAGE OF THE FAT CHURNED THAT IS LOST IN THE BUTTERMILK

The fat test of the buttermilk alone is not a criterion for measuring the efficiency of churning. *The only accurate method is to determine the percentage of the total fat churned that is lost in the buttermilk.*

This is illustrated by the following examples, where it is assumed that the fat test of the buttermilk is 0.52 per cent.

1. High-testing cream

2,500 pounds 40 per cent cream contain 1,000 pounds fat.
Approximate amount of butter before salting $1,000 + (1,000 \times \frac{1}{5}) = 1,200$ pounds.
Buttermilk $2,500 - 1,200 = 1,300$ pounds.
Fat test of buttermilk = 0.52 per cent.
Total fat lost in buttermilk $1,300 \times 0.0052 = 6.8$.

$$\text{Percentage of total fat churned lost in buttermilk} = \frac{6.8 \times 100}{1,000} = 0.68.$$

2. Medium-testing cream

2,500 pounds 32 per cent cream in a churn contain 800 pounds fat.
Approximate amount of butter before salting $800 + (800 \times \frac{1}{5}) = 960$ pounds.
Buttermilk $2,500 - 960 = 1,540$ pounds.
Fat test of buttermilk = 0.52 per cent.
Total fat lost in buttermilk $1,540 \times 0.0052 = 8$ pounds fat.

$$\text{Percentage of total fat churned lost in buttermilk} = \frac{8 \times 100}{800} = 1.00.$$

3. **Low-testing cream**

2,500 pounds 24 per cent cream in a churn contain 600 pounds fat.
Approximate amount of butter before salting $600 + (600 \times \frac{1}{5}) =$ 720 pounds.
Buttermilk $2,500 - 720 = 1,780$ pounds.
Fat test of buttermilk = 0.52 per cent.
Total fat lost in buttermilk $1,780 \times 0.0052 = 9.3$ pounds fat.

$$\text{Percentage of total fat churned lost in buttermilk} = \frac{9.3 \times 100}{600} = 1.55.$$

Summary. When churning high-testing cream 0.68 per cent of the total fat churned is lost. When churning medium-testing cream 1 per cent of the total fat churned is lost. When churning low-testing cream 1.55 per cent of the total fat churned is lost.

From the point of view of efficiency of churning, therefore, these theoretical calculations show that to obtain the highest efficiency it is advantageous to churn the higher-testing cream.

When calculating the per cent of the total fat that is lost in the buttermilk Wiley* suggested using a factor.

The factor for 23 per cent cream was obtained as follows:

$$\frac{100 - (\text{Per cent fat in cream churned} \times 1.2)}{\text{Per cent fat in cream churned}};$$

If the fat percentage of the cream is 23 the equation would be:

$$\frac{100 - (23 \times 1.2)}{23}, \text{ which when solved equals } 3.15.$$

Therefore the factor for 23 per cent cream would be 3.15.

Similarly, the factor for 30 per cent cream was obtained as follows:

$$\frac{100 - (30 \times 1.2)}{30} = 2.13$$

The only calculation the buttermaker would make is as follows:

When the fat test of cream churned is 23.0 per cent,
With factor 3.15,
When the fat test of buttermilk is 0.80 per cent,
The per cent of total fat churned lost in the buttermilk is:
$3.15 \times 0.80 = 2.5$

In other words, simply multiply the factor for the respective cream percentage with the test of the buttermilk.

For example:

Test of cream	*Factor*		*Test of buttermilk*	
(23.0)	(3.15	×	0.80)	= 2.5 per cent of total fat churned lost in buttermilk
(25.0)	(2.80	×	.80)	= 2.2 per cent of total fat churned lost in buttermilk
(30.0)	(2.13	×	.80)	= 1.7 per cent of total fat churned lost in buttermilk
(35.0)	(1.66	×	.80)	= 1.3 per cent of total fat churned lost in buttermilk
(40.0)	(1.30	×	.80)	= 1.0 per cent of total fat churned lost in buttermilk
(44.5)	(1.05	×	.80)	= .8 per cent of total fat churned lost in buttermilk

Wiley prepared a table that shows the factors for cream testing 23.0 to 44.5 per cent fat (Table 1).

* Wiley, W. J., Council for Scientific and Industrial Research, Melbourne, Australia, in "New Zealand Dairyman," August 1939.

Table 1. FACTORS TO USE WHEN CALCULATING PER CENT OF TOTAL FAT CHURNED THAT IS LOST IN THE BUTTERMILK

Fat test of cream	Factor	Fat test of cream	Factor
Per cent		*Per cent*	
23.0	3.15	34.0	1.74
23.5	3.05	34.5	1.70
24.0	2.97	35.0	1.66
24.5	2.88	35.5	1.62
25.0	2.80	36.0	1.58
25.5	2.72	36.5	1.54
26.0	2.65	37.0	1.50
26.5	2.57	37.5	1.47
27.0	2.50	38.0	1.43
27.5	2.44	38.5	1.40
28.0	2.37	39.0	1.36
28.5	2.31	39.5	1.33
29.0	2.25	40.0	1.30
29.5	2.19	40.5	1.27
30.0	2.13	41.0	1.24
30.5	2.08	41.5	1.21
31.0	2.03	42.0	1.18
31.5	1.97	42.5	1.15
32.0	1.93	43.0	1.13
32.5	1.88	43.5	1.10
33.0	1.83	44.0	1.07
33.5	1.79	44.5	1.05

For the convenience of buttermakers we have prepared a table that gives the fat losses for cream and buttermilk of various fat contents. This shows at a glance the per cent of the total fat churned that is lost in the buttermilk. No calculations are necessary (Table 2). Reprints of this table suitable for placing on a testing room wall may be obtained free from the Experiment Station.

Table 2. Per Cent of Total Fat Churned That Is Lost in Buttermilk

Table shows per cent of the total fat churned that is lost in the buttermilk for any churning in which the test of cream ranges from 23.0 per cent to 44.5 per cent, and the buttermilk test ranges from 0.40 per cent to 1.20 per cent. The extreme left column shows the fat test of the cream churned. The fat test of the buttermilk is given at the top of each column.

How to use the table: Read the test of the cream at the left and follow that line across the table to the column which represents the test of the buttermilk. Example: Cream test 30 per cent; buttermilk test 0.7 per cent fat. Answer: 1.49 per cent of total fat churned lost in the buttermilk.

To calculate the per cent of total fat churned lost in the buttermilk when the buttermilk test is greater or less than the figures on this table, multiply the fat test of the buttermilk by the factor (second column from left) that corresponds with the test of the cream.

Oregon Agricultural Experiment Station

Per cent fat in cream churned	Factor	Per cent fat in buttermilk																			
		0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.72	0.74	0.76	0.78
23.0	3.15	1.26	1.32	1.38	1.45	1.51	1.58	1.64	1.70	1.76	1.83	1.89	1.95	2.02	2.08	2.14	2.21	2.27	2.33	2.39	2.46
23.5	3.05	1.22	1.28	1.34	1.40	1.46	1.53	1.59	1.65	1.71	1.78	1.83	1.89	1.95	2.01	2.07	2.14	2.20	2.26	2.32	2.38
24.0	2.97	1.19	1.25	1.31	1.37	1.43	1.49	1.54	1.60	1.66	1.72	1.78	1.84	1.90	1.96	2.02	2.08	2.14	2.20	2.26	2.32
24.5	2.88	1.15	1.21	1.27	1.32	1.38	1.44	1.50	1.56	1.61	1.67	1.73	1.79	1.84	1.90	1.96	2.02	2.07	2.13	2.19	2.25
25.0	2.80	1.12	1.18	1.23	1.29	1.34	1.40	1.46	1.51	1.57	1.62	1.68	1.74	1.79	1.85	1.90	1.96	2.02	2.07	2.13	2.18
25.5	2.72	1.09	1.14	1.20	1.25	1.31	1.36	1.41	1.47	1.52	1.58	1.63	1.69	1.74	1.80	1.85	1.90	1.96	2.01	2.07	2.12
26.0	2.65	1.06	1.11	1.17	1.22	1.27	1.33	1.38	1.43	1.48	1.54	1.59	1.64	1.70	1.75	1.80	1.86	1.91	1.96	2.01	2.07
26.5	2.57	1.03	1.08	1.13	1.18	1.23	1.29	1.34	1.39	1.44	1.49	1.54	1.59	1.64	1.70	1.75	1.80	1.85	1.90	1.95	2.00
27.0	2.50	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95
27.5	2.44	.98	1.02	1.07	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.46	1.51	1.56	1.61	1.66	1.71	1.76	1.81	1.85	1.90
28.0	2.37	.95	.99	1.04	1.09	1.14	1.19	1.23	1.28	1.33	1.37	1.42	1.47	1.52	1.56	1.61	1.66	1.71	1.75	1.80	1.85
28.5	2.31	.92	.97	1.02	1.06	1.11	1.16	1.20	1.25	1.29	1.34	1.39	1.43	1.48	1.52	1.57	1.62	1.66	1.71	1.76	1.80
29.0	2.25	.90	.95	.99	1.04	1.08	1.13	1.17	1.22	1.26	1.31	1.35	1.40	1.44	1.49	1.53	1.58	1.62	1.67	1.71	1.76
29.5	2.19	.88	.92	.96	1.01	1.05	1.10	1.14	1.18	1.23	1.27	1.31	1.36	1.40	1.45	1.49	1.53	1.58	1.62	1.66	1.71
30.0	2.13	.85	.89	.94	.98	1.02	1.07	1.11	1.15	1.19	1.24	1.28	1.32	1.36	1.41	1.45	1.49	1.53	1.58	1.62	1.66
30.5	2.08	.83	.87	.92	.96	1.00	1.04	1.08	1.12	1.16	1.21	1.25	1.29	1.33	1.37	1.41	1.46	1.50	1.54	1.58	1.62
31.0	2.03	.81	.85	.89	.93	.97	1.02	1.06	1.10	1.14	1.18	1.22	1.26	1.30	1.34	1.38	1.42	1.46	1.50	1.54	1.58
31.5	1.97	.79	.83	.87	.91	.95	.99	1.02	1.06	1.10	1.14	1.18	1.22	1.26	1.30	1.34	1.38	1.42	1.46	1.50	1.54
32.0	1.93	.77	.81	.85	.89	.93	.97	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.27	1.31	1.35	1.39	1.43	1.47	1.51
32.5	1.88	.75	.79	.83	.86	.90	.94	.98	1.02	1.05	1.09	1.13	1.16	1.20	1.24	1.28	1.32	1.35	1.39	1.43	1.47
33.0	1.83	.73	.77	.80	.84	.88	.92	.95	.99	1.02	1.06	1.10	1.13	1.17	1.21	1.24	1.28	1.32	1.35	1.39	1.43
33.5	1.79	.72	.75	.79	.82	.86	.90	.93	.97	1.00	1.04	1.07	1.11	1.15	1.18	1.22	1.25	1.29	1.32	1.36	1.40
34.0	1.74	.70	.73	.77	.80	.84	.87	.90	.94	.97	1.01	1.04	1.08	1.11	1.15	1.18	1.22	1.25	1.29	1.32	1.36
34.5	1.70	.68	.71	.75	.78	.82	.85	.88	.92	.95	.99	1.02	1.05	1.09	1.12	1.16	1.19	1.22	1.26	1.29	1.33
35.0	1.66	.66	.70	.73	.76	.80	.83	.86	.90	.93	.96	1.00	1.03	1.06	1.10	1.13	1.16	1.20	1.23	1.26	1.29
35.5	1.62	.65	.68	.71	.75	.78	.81	.84	.87	.91	.94	.97	1.00	1.04	1.07	1.10	1.13	1.17	1.20	1.23	1.26
36.0	1.58	.63	.66	.70	.73	.76	.79	.82	.85	.88	.92	.95	.98	1.01	1.04	1.07	1.11	1.14	1.17	1.20	1.23
36.5	1.54	.62	.65	.68	.71	.74	.77	.80	.83	.86	.89	.92	.95	.99	1.02	1.05	1.08	1.11	1.14	1.17	1.20
37.0	1.50	.60	.63	.66	.69	.72	.75	.78	.81	.84	.87	.90	.93	.96	.99	1.02	1.05	1.08	1.11	1.14	1.17
37.5	1.47	.59	.62	.65	.68	.71	.74	.76	.79	.82	.85	.88	.91	.94	.97	1.00	1.03	1.06	1.09	1.12	1.15
38.0	1.43	.57	.60	.63	.66	.69	.72	.74	.77	.80	.83	.86	.89	.92	.94	.97	1.00	1.03	1.06	1.09	1.12
38.5	1.40	.56	.59	.62	.64	.67	.70	.73	.76	.78	.81	.84	.87	.90	.92	.95	.98	1.01	1.04	1.06	1.09
39.0	1.36	.54	.57	.60	.63	.65	.68	.71	.73	.76	.79	.82	.84	.87	.90	.92	.95	.98	1.01	1.03	1.06
39.5	1.33	.53	.56	.59	.61	.64	.67	.69	.72	.74	.77	.80	.82	.85	.88	.90	.93	.96	.98	1.01	1.04
40.0	1.30	.52	.55	.57	.60	.62	.65	.68	.70	.73	.75	.78	.81	.83	.86	.88	.91	.94	.96	.99	1.01
40.5	1.27	.51	.53	.56	.58	.61	.64	.66	.69	.71	.74	.76	.79	.81	.84	.86	.89	.91	.94	.97	.99
41.0	1.24	.50	.52	.55	.57	.60	.62	.64	.67	.69	.72	.74	.77	.79	.82	.84	.87	.89	.92	.94	.97
41.5	1.21	.48	.51	.53	.56	.58	.61	.63	.65	.68	.70	.73	.75	.77	.80	.82	.85	.87	.90	.92	.94
42.0	1.18	.47	.50	.52	.54	.57	.59	.61	.64	.66	.68	.71	.73	.76	.78	.80	.83	.85	.87	.90	.92
42.5	1.15	.46	.48	.51	.53	.55	.58	.60	.62	.64	.67	.69	.71	.74	.76	.78	.81	.83	.85	.87	.90
43.0	1.13	.45	.47	.50	.52	.54	.57	.59	.61	.63	.66	.68	.70	.72	.75	.77	.79	.81	.84	.86	.88
43.5	1.10	.44	.46	.48	.50	.53	.55	.57	.59	.62	.64	.66	.68	.70	.73	.75	.77	.79	.81	.84	.86
44.0	1.07	.43	.45	.47	.49	.51	.54	.56	.58	.60	.62	.64	.66	.68	.71	.73	.75	.77	.79	.81	.83
44.5	1.05	.42	.44	.46	.48	.50	.53	.55	.57	.59	.61	.63	.65	.67	.69	.71	.74	.76	.78	.80	.82

Table 2. PER CENT OF TOTAL FAT CHURNED THAT IS LOST IN BUTTERMILK—*Continued*

Per cent fat in cream churned	Factor	Per cent fat in buttermilk																			
		0.80	0.82	0.84	0.86	0.88	0.90	0.92	0.94	0.96	0.98	1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20
23.0	3.15	2.52	2.58	2.65	2.71	2.77	2.84	2.90	2.96	3.02	3.09	3.15	3.21	3.28	3.34	3.40	3.47	3.53	3.59	3.65	3.72	3.78
23.5	3.05	2.44	2.50	2.56	2.62	2.68	2.75	2.81	2.87	2.93	2.99	3.05	3.11	3.17	3.23	3.29	3.36	3.42	3.48	3.54	3.60	3.66
24.0	2.97	2.38	2.44	2.49	2.55	2.61	2.67	2.73	2.79	2.85	2.91	2.97	3.03	3.09	3.15	3.21	3.27	3.33	3.39	3.45	3.50	3.56
24.5	2.88	2.30	2.36	2.42	2.48	2.53	2.59	2.65	2.71	2.76	2.82	2.88	2.94	3.00	3.05	3.11	3.17	3.23	3.28	3.34	3.40	3.46
25.0	2.80	2.24	2.30	2.35	2.41	2.46	2.52	2.58	2.63	2.69	2.74	2.80	2.86	2.91	2.97	3.02	3.08	3.14	3.19	3.25	3.30	3.36
25.5	2.72	2.18	2.23	2.28	2.34	2.39	2.45	2.50	2.56	2.61	2.67	2.72	2.77	2.83	2.88	2.94	2.99	3.05	3.10	3.16	3.21	3.26
26.0	2.65	2.12	2.17	2.23	2.28	2.33	2.39	2.44	2.49	2.54	2.60	2.65	2.70	2.76	2.81	2.86	2.92	2.97	3.02	3.07	3.13	3.18
26.5	2.57	2.06	2.11	2.16	2.21	2.26	2.31	2.36	2.42	2.47	2.52	2.57	2.62	2.67	2.72	2.78	2.83	2.88	2.93	2.98	3.03	3.08
27.0	2.50	2.00	2.05	2.10	2.15	2.20	2.25	2.30	2.35	2.40	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85	2.90	2.95	3.00
27.5	2.44	1.95	2.00	2.05	2.10	2.15	2.20	2.24	2.29	2.34	2.39	2.44	2.49	2.54	2.59	2.64	2.68	2.73	2.78	2.83	2.88	2.93
28.0	2.37	1.90	1.94	1.99	2.04	2.09	2.13	2.18	2.23	2.28	2.32	2.37	2.42	2.46	2.51	2.56	2.61	2.65	2.70	2.75	2.80	2.84
28.5	2.31	1.85	1.89	1.94	1.99	2.03	2.08	2.13	2.17	2.22	2.26	2.31	2.36	2.40	2.45	2.49	2.54	2.59	2.63	2.68	2.73	2.77
29.0	2.25	1.80	1.85	1.89	1.94	1.98	2.03	2.07	2.12	2.16	2.21	2.25	2.30	2.34	2.39	2.43	2.48	2.52	2.57	2.61	2.66	2.70
29.5	2.19	1.75	1.80	1.84	1.88	1.93	1.97	2.01	2.06	2.10	2.15	2.19	2.23	2.28	2.32	2.37	2.41	2.45	2.50	2.54	2.58	2.63
30.0	2.13	1.70	1.75	1.79	1.83	1.87	1.92	1.96	2.00	2.04	2.09	2.13	2.17	2.22	2.26	2.30	2.34	2.39	2.43	2.47	2.51	2.56
30.5	2.08	1.66	1.71	1.75	1.79	1.83	1.87	1.91	1.96	2.00	2.04	2.08	2.12	2.16	2.20	2.25	2.29	2.33	2.37	2.41	2.45	2.50
31.0	2.03	1.62	1.66	1.71	1.75	1.79	1.83	1.87	1.91	1.95	1.99	2.03	2.07	2.11	2.15	2.19	2.23	2.27	2.31	2.35	2.40	2.44
31.5	1.97	1.58	1.62	1.65	1.69	1.73	1.77	1.81	1.85	1.89	1.93	1.97	2.01	2.05	2.09	2.13	2.17	2.21	2.25	2.29	2.32	2.36
32.0	1.93	1.54	1.58	1.62	1.66	1.70	1.74	1.78	1.81	1.85	1.89	1.93	1.97	2.01	2.05	2.08	2.12	2.16	2.20	2.24	2.28	2.32
32.5	1.88	1.50	1.54	1.58	1.62	1.65	1.69	1.73	1.77	1.80	1.84	1.88	1.92	1.96	1.99	2.03	2.07	2.11	2.14	2.18	2.22	2.26
33.0	1.83	1.46	1.50	1.54	1.57	1.61	1.65	1.68	1.72	1.76	1.79	1.83	1.87	1.90	1.94	1.98	2.01	2.05	2.09	2.12	2.16	2.20
33.5	1.79	1.43	1.47	1.50	1.54	1.58	1.61	1.65	1.68	1.72	1.75	1.79	1.83	1.86	1.90	1.93	1.97	2.00	2.04	2.08	2.11	2.15
34.0	1.74	1.39	1.43	1.46	1.50	1.53	1.57	1.60	1.64	1.67	1.71	1.74	1.77	1.81	1.84	1.88	1.91	1.95	1.98	2.02	2.05	2.09
34.5	1.70	1.36	1.39	1.43	1.46	1.50	1.53	1.56	1.60	1.63	1.67	1.70	1.73	1.77	1.80	1.84	1.87	1.90	1.94	1.97	2.01	2.04
35.0	1.66	1.33	1.36	1.39	1.43	1.46	1.49	1.53	1.56	1.59	1.63	1.66	1.69	1.73	1.76	1.79	1.83	1.86	1.89	1.93	1.96	1.99
35.5	1.62	1.30	1.33	1.36	1.39	1.43	1.46	1.49	1.52	1.56	1.59	1.62	1.65	1.68	1.72	1.75	1.78	1.81	1.85	1.88	1.91	1.94
36.0	1.58	1.26	1.30	1.33	1.36	1.39	1.42	1.45	1.49	1.52	1.55	1.58	1.61	1.64	1.67	1.71	1.74	1.77	1.80	1.83	1.86	1.90
36.5	1.54	1.23	1.26	1.29	1.32	1.36	1.39	1.42	1.45	1.48	1.51	1.54	1.57	1.60	1.63	1.66	1.69	1.72	1.76	1.79	1.82	1.85
37.0	1.50	1.20	1.23	1.26	1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.68	1.71	1.74	1.77	1.80
37.5	1.47	1.18	1.21	1.23	1.26	1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.50	1.53	1.56	1.59	1.62	1.65	1.68	1.71	1.73	1.76
38.0	1.43	1.14	1.17	1.20	1.23	1.26	1.29	1.32	1.34	1.37	1.40	1.43	1.46	1.49	1.52	1.54	1.57	1.60	1.63	1.66	1.69	1.72
38.5	1.40	1.12	1.15	1.18	1.20	1.23	1.26	1.29	1.32	1.34	1.37	1.40	1.43	1.46	1.48	1.51	1.54	1.57	1.60	1.62	1.65	1.68
39.0	1.36	1.09	1.12	1.14	1.17	1.20	1.22	1.25	1.28	1.31	1.33	1.36	1.39	1.41	1.44	1.47	1.50	1.52	1.55	1.58	1.60	1.63
39.5	1.33	1.06	1.09	1.12	1.14	1.17	1.20	1.22	1.25	1.28	1.30	1.33	1.36	1.38	1.41	1.44	1.46	1.49	1.52	1.54	1.57	1.60
40.0	1.30	1.04	1.07	1.09	1.12	1.14	1.17	1.20	1.22	1.25	1.27	1.30	1.33	1.35	1.38	1.40	1.43	1.46	1.48	1.51	1.53	1.56
40.5	1.27	1.01	1.04	1.07	1.09	1.12	1.14	1.17	1.19	1.22	1.24	1.27	1.30	1.32	1.35	1.37	1.40	1.42	1.45	1.47	1.50	1.52
41.0	1.24	.99	1.02	1.04	1.07	1.09	1.12	1.14	1.17	1.19	1.22	1.24	1.26	1.29	1.31	1.34	1.36	1.39	1.41	1.44	1.46	1.49
41.5	1.21	.97	.99	1.02	1.04	1.06	1.09	1.11	1.14	1.16	1.19	1.21	1.23	1.26	1.28	1.31	1.33	1.36	1.38	1.40	1.43	1.45
42.0	1.18	.94	.97	.99	1.01	1.04	1.06	1.09	1.11	1.13	1.16	1.18	1.20	1.23	1.25	1.27	1.30	1.32	1.35	1.37	1.39	1.42
42.5	1.15	.92	.94	.97	.99	1.01	1.04	1.06	1.08	1.10	1.13	1.15	1.17	1.20	1.22	1.24	1.26	1.29	1.31	1.33	1.36	1.38
43.0	1.13	.90	.93	.95	.97	.99	1.02	1.04	1.06	1.08	1.11	1.13	1.15	1.18	1.20	1.22	1.24	1.27	1.29	1.31	1.33	1.36
43.5	1.10	.88	.90	.92	.95	.97	.99	1.01	1.03	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.23	1.25	1.28	1.30	1.32
44.0	1.07	.87	.88	.90	.92	.94	.96	.98	1.01	1.03	1.05	1.07	1.09	1.11	1.13	1.16	1.18	1.20	1.22	1.24	1.26	1.28
44.5	1.05	.84	.86	.88	.90	.92	.95	.97	.99	1.01	1.03	1.05	1.07	1.09	1.11	1.13	1.16	1.18	1.20	1.22	1.24	1.26

REVIEW OF PREVIOUS STUDIES

Bird and Derby,* at the Iowa Agricultural Experiment Station, churned cream that tested 37.5 per cent fat and 30 per cent fat. Their data indicated that, "The lowest churning loss that is likely to attain (37.5 per cent cream) is in the vicinity of 1.0 to 1.2 per cent of the total fat churned. This represents approximately a 99-per-cent yield, which is exceptionally good. With 30 per cent cream the lowest loss figure will fall between 1.4 and 1.6 per cent of the total fat placed in a churn. These figures are based on the Mojonnier test of the buttermilk."

Later Bird, Breazeale and Bartle† reported that when cream testing 37.5 per cent fat was churned, the per cent of the total fat lost in the buttermilk ranged from 1.10 to 1.28, and for 30 per cent cream it ranged from 1.23 to 1.42. The buttermilk was tested by the Mojonnier method.

From the study of the fat losses in commercial butter manufacture over a period of years, Hunziker‡ found that "the buttermilk tests in vat-pasteurizing plants (145° to 150° F. for 30 minutes) ranged from 0.30 per cent to 0.65 per cent, averaging approximately 0.45 per cent fat, while in flash-pasteurizing plants (standard flash pasteurizer with steam jacket and revolving wing agitator, temperature 180° to 185° F.) the buttermilk tests ranged from 0.50 to 1.15 per cent, averaging approximately 0.65 to 0.70 per cent."

Under normally efficient conditions of operation the loss of fat in the buttermilk, in accordance with Hunziker, is approximately 1.25 per cent of the total fat churned. He calculated that when applied to the total amount of butterfat churned annually in the United States, the total buttermilk fat loss is equivalent to approximately 20,000,000 pounds butter.

The Danish Dairy Experiment Station in 1918 suggested expressing the per cent of the total fat churned that is lost in the buttermilk as the "Churning Efficiency Number," or as the "Fat Loss Number."

A large number of samples of buttermilk from Danish creameries have been analyzed and the churning efficiencies calculated by the Danish Agricultural and Dairy School at Ladelund.§

Year	*Number of samples of buttermilk*	*Per cent fat*	*Average churning efficiency number*‖
1936	1,249	0.56	1.70
1937	1,164	.54	1.69
1938	1,219	.57	1.73
1939	1,354	.55	1.67
1940	1,180	.56	1.66

* Bird, E. W., and Derby, H. A., *Chemistry of Butter and Butter Making. III.* The relationship between (1) the percentage fat and (2) the protein percentages of cream and the churning loss. Iowa Agri. Exp. Sta. Res. Bul. 214, 1937.

† Bird, E. W., Breazeale, D. F., and Bartle, E. R., *Chemistry of Butter and Butter Making. IV.* The relationships among the cream acidity, the churning loss, and the churning time. Iowa Agr. Res. Bul. 227, 1937.

‡ Hunziker, O. F., *The Butter Industry.* 3d edition. Published by the author at La Grange, Illinois, 1940.

§ Petersen, Jorgen, Excerpt from Report by Ladelund Agricultural and Dairy School's Chemical Laboratory. Maelkeritidende, Vol. 54, Nos. 10 and 11, 1941.

‖ Per cent of total fat churned lost in the buttermilk.

The report calls attention to the opportunity for many creameries to increase their efficiency. This is emphasized by the frequency distribution of the 1,180 churnings for 1940:

	Number of samples	*Per cent of all samples*
1.0 efficiency number or less	261	22.1
1.1 to 2.0 efficiency number	670	56.7
2.1 to 3.0 efficiency number	188	16.0
Above 3.0 efficiency number	61	5.2
Total	1,180	100.0

It was pointed out that only one-half of the churnings showed an efficiency number of 1.4 or less.

The influence of the fat content of the cream on the per cent of total fat lost during churning was investigated by the Danish Dairy Experiment Station during 1918-1921.*

	Per cent fat in cream	*Efficiency churning number*
Rich cream	31	1.60
Medium-rich cream	24	1.72
Low-fat cream	18	2.67

(When calculating the pounds butter in the churn before salting the formula: fat × 1 1/16 was used.)

RESULTS FROM THE STUDIES BY THE OREGON AGRICULTURAL EXPERIMENT STATION

1. **Loss of fat in buttermilk in the Agricultural Experiment Station Dairy Products Laboratory—1937.** The loss of fat during the churning of cream in the Oregon Agricultural Experiment Station Dairy Products Laboratory for the period January 2, 1937, to December 31, 1937, was studied. A total of 148 churnings was made. An average of 534 pounds fat was used for each churning. The fat content of the cream was determined by removing a sample of the cream from the churn after it had revolved a few revolutions and testing the cream in the usual manner by the Babcock method. The Babcock-butyl alcohol method was used for determining the fat content of the buttermilk. The results obtained are shown in Table 3. The weighted average per cent of fat was 1.22. The weighted average per cent of fat is obtained by dividing the total pounds of fat lost in the different lots by the total pounds of fat and multiplying by one hundred. This gives the true average per cent of fat churned lost in the buttermilk.

Table 3. FAT LOST IN THE BUTTERMILK IN 148 CHURNINGS IN THE DAIRY PRODUCTS LABORATORY.

Vat method of pasteurization.

January 2, 1937, to December 13, 1937

	Range	Average
	Per cent	*Per cent*
Fat content of cream	22.0 to 32.6	.....
Fat content of buttermilk	0.2 to 0.96	.....
Percentage of total fat churned lost in buttermilk	0.5 to 3.2	1.22
	Pounds	
Total pounds fat lost during period	965	.....

* Hansen, O. S., and Jensen, H. M., *Mejerilaere*, 3d ed. Published by Andelsbogtrykkeriet, Odense, Denmark, 1939.

2. **Loss of fat in buttermilk at the Dairy Cooperative Association during 1936-1937.** An analysis was made of the churning data at the Dairy Cooperative Association creamery at Portland. The determinations for fat in the buttermilk were made by J. N. Reynolds, who has charge of the laboratory maintained by the association. He used the Babcock-butyl alcohol method for determining the fat.

In Table 4 are shown the fat tests of the buttermilk and the percentage of the total fat churned that was lost in the buttermilk during three different periods. It will be noted that there was little difference between the percentages of fat lost during the two winter periods, but the amount of fat lost per 100 pounds of fat churned was considerably higher during the summer period. The weighted average per cent total fat lost for the 354 churnings was 1.162.

Table 4. FAT LOST DURING THE CHURNING OF 354 LOTS OF CREAM.
Vat method of pasteurization (Dairy Cooperative Association).

Date	Number of churnings	Pounds fat in cream	Average fat content of buttermilk, butyl alcohol	Percentage of total fat churned lost in buttermilk	Total fat lost
		Pounds	*Per cent*	*Per cent*	*Pounds*
1936:					
December 1 to 31....	126	109,843.43	0.4400	1.010	1,109.89
1937:					
January 1 to 15.....	64	55,716.56	.4800	1.068	594.96
June 16 to July 15	164	140,863.04	.6264	1.319	1,858.71

The tests of the cream churned ranged from 19.5 to 37. A segregation of the churnings of cream that contained less than 28 per cent fat and of churnings of cream that contained 35 per cent fat and above showed that the per cent of the total fat lost for the low-testing cream (105 churnings) ranged from 0.877 to 3.13 and averaged 1.37 (weighted). For the high-testing cream (11 churnings) the loss varied from 0.62 per cent to 1.49 per cent and averaged 0.75 per cent (weighted). The difference in the per cent fat lost was 0.62. On 1,000,000 pounds of fat this would amount to 6,200 pounds of fat. With fat at 30 cents a pound this would have a value of $1,860. This shows the economic advantage of churning the higher-testing cream.

3. **Loss of fat in buttermilk at Dairy Cooperative Association, 1939-1940.** Complete churning data for all churnings made in the Dairy Cooperative Association creamery for 4 months each in 1939 and 1940 were examined. The per cent of total fat churned that was lost in the buttermilk ranged from 0.44 to 2.71 and averaged 1.06. The weighted average per cent of total fat churned that was lost in the buttermilk for each month is shown in Table 5. An increase in the fat loss is noted during the months of June and September of each year.

It was noted that the weighted average per cent of the total fat churned that was lost in the buttermilk was higher in December 1940 than in December 1939. A further study of the churning data for December 1940 was made to determine if standard flash pasteurization of part of the churnings would account for this higher fat loss.

Table 6 shows the higher fat losses that resulted when standard flash pasteurization to 190° F. was used when compared with the vat-holding method of 160° F. for 30 minutes.

Table 5. Fat Losses During the Churning of 1,119 Lots of Cream
Vat Method of Pasteurization
Dairy Cooperative Association

Date	Churnings	Cream	Weighted average per cent fat in cream	Fat in cream	Weighted average per cent fat in buttermilk, butyl alcohol	Weighted average per cent of total fat churned lost in buttermilk	Fat lost
	Number	*Pounds*	*Per cent*	*Pounds*	*Per cent*	*Per cent*	*Pounds*
1939							
March 1 to 31	116	390,993	30.7	120,415	0.47	0.97	1,168.0
June 1 to 30	193	660,019	32.0	211,810	.56	1.08	2,287.5
September 1 to 30	103	330,252	30.5	103,408	.56	1.16	1,199.5
December 1 to 31	115	371,829	31.8	118,260	.51	.99	1,289.0
1940							
March 1 to 31	173	567,168	32.6	184,684	.49	.92	1,699.1
June 1 to 30	180	601,711	32.5	195,511	.58	1.09	2,131.1
September 1 to 30	115	357,866	32.4	115,758	.58	1.09	1,261.8
*December 1 to 31	124	384,660	30.5	117,419	.55	1.14	1,338.6
Total	1,119	.....	.....	1,167,265	.....	1.06 (weighted)	12,374.6

* December 1940: Sixty-six churnings (53.2 per cent of the churnings for December 1940) were standard flash pasteurized to 190° F.

Table 6. FAT LOSSES IN BUTTERMILK IN CHURNINGS PASTEURIZED BY FLASH (190° F.) AND BY VAT (160° F.) METHODS

Dairy Cooperative Association
December 1940

Number of churnings	Cream	Weighted average per cent fat in cream	Fat in cream	Weighted average per cent fat in butter-milk	Weighted average per cent total fat churned lost in butter-milk	Fat lost in butter-milk
	Pounds	*Per cent*	*Pounds*	*Per cent*	*Per cent*	*Pounds*
66 (Standard flash pasteurization 190° F.)	206,761	29.8	61,670	0.62	1.32	814.0
58 (Vat pasteurization 160° F. for 30 minutes)	177,899	31.3	55,749	.47	.92	512.9
Total, 124	384,660	30.5	117,419	.55	1.13	1,326.9

4. Effect of the richness of the cream on the fat lost in buttermilk. In order to study the influence of the richness of the cream on the amount of fat lost in the buttermilk under controlled conditions, arrangements were made to investigate this in a creamery that was able to control the fat content of the cream used in churning. The cream and buttermilk from a total of 60 churnings were analyzed and the percentage of total fat churned that was lost in the buttermilk was calculated. Of the 60 churnings, 27 were from cream that had a fat content that ranged from 35 per cent to 44 per cent, and 33 were from lots of cream that contained from 26 per cent to 34.5 per cent fat. The samples were obtained directly from the churn after it had revolved a few revolutions.

The results obtained are shown in Table 7. The data definitely show that greater efficiency was obtained when cream of the higher fat content was churned. It should be pointed out that it was possible to churn the vacreated cream testing 40 per cent or above without difficulty.

Table 7. EFFECT OF RICHNESS OF CREAM ON FAT LOST IN BUTTERMILK
(Vacreator-Pasteurized)
Spring 1940

	Per cent fat in cream	
	35.0 per cent and above	Below 35.0 per cent
Number of churnings	27	33
	Per cent	*Per cent*
Fat content of cream in churn (Babcock):		
Average	38.6	31.1
Range	35 to 44	26.0 to 34.5
Fat content of buttermilk (Mojonnier):		
Average	0.80	0.77
Range	0.64 to 1.00	0.65 to 1.00
Per cent of total fat churned lost in buttermilk:		
Average	1.11	1.56
Range	0.88 to 1.62	1.17 to 1.98

These findings are further substantiated by the results from the churning of low-testing and high-testing cream at the Dairy Cooperative Association.

Table 8. Influence of Per Cent Fat in the Cream on the Fat Lost in the Buttermilk
Dairy Cooperative Association June 1-30, 1940

Number of churnings	Average pounds cream	Range in the per cent fat in cream	Weighted average per cent fat in cream	Average pounds fat	Weighted average per cent fat in buttermilk, butyl alcohol	Weighted average per cent total fat churned lost in buttermilk	Average pounds of fat lost in buttermilk
	Pounds	*Per cent*	*Per cent*	*Pounds*	*Per cent*	*Per cent*	*Pounds*
24	3,744	36.0 to 40.0	37.6	1,407	0.48	0.71	10.0
14	3,689	27.5 to 29.5	29.3	1,082	.65	1.43	15.5

During the month of June 1940, all the churnings of cream testing 36 per cent fat and above, and all the churnings of cream testing less than 30 per cent fat, with a total weight of the cream in each churning between 3,500 pounds and 4,000 pounds were included in the study. The results are shown in Table 8. The 24 churnings testing over 36 per cent fat in the cream showed 0.71 weighted average per cent of the total fat churned lost in the buttermilk, while the 14 churnings testing less than 30 per cent showed 1.43 weighted average per cent of the total fat churned lost in the buttermilk, or just twice the loss of the higher-testing cream. This shows the economy of churning higher-testing cream.

5. **The effect of dilution of the cream with water on the amount of fat lost in the buttermilk.** As the study has clearly shown the economic importance of churning cream of the higher-fat contents, an investigation was made in the Experiment Station dairy products laboratory to find out what effect the use of water for rinsing cream remnants from vats, pipes, pumps, etc., had in lowering the fat content of the cream churned and in increasing the amount of fat lost in the buttermilk.

Without calling this matter to the attention of the operator in the laboratory, samples of cream and buttermilk were obtained over a period of 2 months.

It was found that the fat content of the cream in the churn averaged 5.3 per cent less than that of the cream in the vat before this had been transferred to the churn. It was calculated that the additional fat loss in the buttermilk on account of the addition of the rinse water averaged 2.4 pounds per churning.

Steps were taken to eliminate the rinsings. Instead of allowing the rinsings to be pumped into the churn, they were collected in cans. The rinsings were then run through a separator and the cream obtained was added to the raw cream received that day.

In connection with the churning of 38 lots of cream during the following 3 months this procedure resulted in a reduction of the percentage of the total fat lost in the buttermilk by approximately 0.50. This method was therefore adopted as standard in the dairy products laboratory.

In order to study this problem under commercial operating conditions, observations were made on the churning of 30 lots of cream in a commercial creamery. All of the 30 lots of cream represented were held overnight before churning. Each storage vat held enough cream for two churnings. It was the practice to pump one-half of the cream into one churn and the other half into the other churn. Throughout the period all the samples were taken from these split churnings. The cream for the first churning did not contain any of the vat rinsings, while the second one did.

Throughout the study no changes were made from the usual method of manufacture in the plant methods as it was desired to determine the normal churning efficiency that was obtained.

As indicated above, one-half of the 60 churnings did not contain any of the vat rinsings, while the other half did. Table 9 shows the effect of the water dilution on the fat lost in the buttermilk. It must be pointed out that the dilutions were normal and no effort was made either to increase or reduce them.

Although the buttermilk tests were slightly lower for the churnings that contained the vat rinsings, the per cent of the total fat churned that was lost was greater. This was due to the increased amount of buttermilk. To illustrate: with a churning containing 3,000 pounds cream having a water dilution of 8.4 per cent, approximately 250 pounds more buttermilk would be obtained.

Table 9. EFFECT OF WATER DILUTION ON THE AMOUNT OF FAT LOST IN BUTTERMILK.

	Dilution of cream with water between vat and churn	
	No water dilution	Normal dilution
Number of churnings	30	30
	Per cent	*Per cent*
Fat content of cream in vat (Babcock):		
Average	35.9	35.9
Range	31.0 to 44.0	31.0 to 44.0
Fat content of cream in churn (Babcock):		
Average	35.9	33.1
Range	31.0 to 44.0	26.0 to 40.0
Fat content of buttermilk (Mojonnier):		
Average	0.81	0.76
Range	0.68 to 1.00	0.63 to 1.00
Per cent total fat used lost in buttermilk:		
Average	1.30	1.38
Range	0.88 to 1.74	0.93 to 1.98
Amount of water dilution:		
Average	0.0	8.4
Range	....	2.6 to 20.6

The saving effected by avoiding dilution was somewhat less than that obtained in the dairy products laboratory. This was because more cream was used per churning and perhaps because the cream had a higher initial fat content.

FIELD STUDY IN FIVE OREGON CREAMERIES

With the adoption during 1939-1940 of the vacuum-pasteurization (vacreation) method of pasteurizing cream by three Oregon creameries, which collectively manufacture over 5 million pounds of butter per year, the study was extended to include these plants and also two creameries that used the conventional vat method of pasteurization.

Two periods were spent during the summer of 1940 at each of the first-mentioned plants. During the first visit complete records were kept on the manufacturing procedure. Recommendations based on the observations were made for the purpose of increasing the churning efficiencies. The second visit made at a later date was primarily for the purpose of studying the effect of putting the previously made recommendations into use.

The general procedure followed at each plant during the field study included:

1. To study in detail the method used for pasteurizing and cooling the cream.
2. To determine accurately the pounds of fat present in each lot of cream used for churning.
3. To calculate the per cent dilution with water for each churning.
4. To observe the following:
   Time cream held after cooling,
   Temperature of cream at churning time,
   Volume of cream in relation to capacity of churn, type of churn, amount of water dilution, acidity of cream, size of butter granules, and other miscellaneous factors.

5. To determine the per cent fat present in the buttermilk, using the butyl alcohol method, and to calculate the per cent of the total fat lost in the buttermilk.

Plant 1. The summarized data of 12 churnings made at Plant 1 during the first period of the field investigation are shown in Table 10. Most of the churnings were made before any recommendations for improved efficiency were put into effect. In this group of churnings there were four sets of split churnings. The cream in each lot for two churnings was taken from the same holding vat and churned in two different roll-less churns, both of the same manufacture and capacity. The split churnings are indicated in the table as Nos. 24 and 25, 27 and 28, 30 and 31, 33 and 34.

The procedure for handling churnings Nos. 24 and 25 was identical except that the vat rinsings were pumped into churning No. 25 after the cream had been equally divided between the two churns. The added water lowered the per cent fat of churning No. 25 from 37.5 to 35.5 per cent and was equivalent to a 5.6 per cent dilution. Although the fat test of the buttermilk was the same in each case (0.92 per cent) the per cent of the total pounds of fat churned that was lost in the buttermilk was 0.14 greater for churning No. 25, which contained the added water, than for churning No. 24, with which no water had been used.

The vat rinsings were held out with churnings Nos. 27 and 28, and no dilution occurred for either churning. The results (churnings Nos. 27 and 28) show that the fat test of the cream, the test of the buttermilk, and the per cent of the total fat churned that was lost in the buttermilk were identical.

Churnings Nos. 33 and 34 were made to determine the effect of a high churning temperature on the fat lost in the buttermilk. It was found that a churning temperature of 5° F. higher than was considered most desirable under the conditions of the test, had a very noticeable effect in increasing the fat loss. The buttermilk test was increased 0.17 and the per cent of the total fat lost was increased 0.20.

Recommendations. After completing the first part of the study at Plant 1, the following recommendations were made:

1. Cool the cream in the plate cooler to between 50° and 55° F.
2. Complete the cooling to 40° F. or below in the holding vat.
3. Use churning temperatures that will give firm butter granules in from 45 to 60 minutes.
4. Reduce dilution of the cream with water to a minimum.
5. Collect and separate all rinsings from vats.
6. When separating milk, adjust the separator to deliver cream of such test that the cream before churning will contain approximately 40 per cent fat.

Effect of changes in manufacturing methods. Table 11 contains the manufacturing data for 18 churnings made after some of the suggested changes had been made. The main change made was cooling the cream more thoroughly after vacreation. The cream left the plate cooler at a temperature about 5° F. lower than previously. Faster additional cooling in the vats was accomplished than in the past, and a lower holding temperature of the cream before churning was obtained. The average water dilution was 3.0 per cent. The data show that no significant decrease in the amount of fat lost in the buttermilk was effected. In considering the fat contents of the cream, churn-

Table 10. SUMMARY OF DATA ON CHURNING AT PLANT 1 BEFORE MAKING SUGGESTED CHANGES

Vacreator of a capacity of 5,000 pounds cream per hour used

Churning number	Cream in vat	Fat test	Acid in cream	Pasteurizing temperature	Temperature after cooling	Temperature cooled in vat	Time held	Churning temperature	Final acidity	Fat test, vat	Fat test, churn	Total dilution	Churning time	Buttermilk temperature	Buttermilk test, butyl alcohol	Total fat churned lost in buttermilk
	Pounds	*Per cent*	*Per cent*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Hours*	*Degrees F.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Degrees F.*	*Per cent*	*Per cent*
Split { 24	3,050	37.5	....	193	55–60	44	16	48	0.09	37.5	37.5	0.0	40	53	0.92	1.35
Split { 25	3,050	37.5	....	193	55–60	44	16	48	.09	37.5	35.5	5.6	38	54	.92	1.49
26	3,800	30.0	0.52	193	55–60	44	14	57	.16	30.0	27.0	11.1	32	60	.80	2.00
Split { 27	3,040	36.0	.11	193	55–60	44	16	48	.11	36.0	36.0	.0	46	54	.77	1.22
Split { 28	3,040	36.0	.11	193	55–60	44	16	48	.11	36.0	36.0	.0	44	54	.77	1.22
29	3,300	30.0	.50	195	55–60	42	16	55	.16	30.0	26.5	13.2	42	60	.68	1.75
Split { 30	3,800	37.0	.15	193	55–60	44	16	51	.12	37.0	37.0	.0	55	54	.80	1.20
Split { 31	2,240	37.0	.15	193	55–60	44	16	46	.12	37.0	37.0	.0	46	53	.81	1.22
32	3,050	27.5	.50	195	55–60	44	17	55	.16	27.5	24.0	14.6	40	60	.65	1.93
Split { 33	2,500	43.0	....	194	55–60	40	16	46	.11	43.0	43.0	.0	55	53	.83	.93
Split { 34	2,500	43.0	....	194	55–60	40	16	51	.11	43.0	43.0	.0	35	56	1.00	1.13
35	3,250	30.5	.51	194	55–60	44	18	56	.18	27.5	26.0	5.8	33	60	.86	2.28
WEIGHTED AVERAGE	.....	.....	....	.....	.....	....	....	....	....	34.7	33.2	4.5	....	....	0.80	1.45

Table 11. Summary of Data on Churnings at Plant 1 After Complying with Some of the Suggestions to Increase Churning Efficiency

Churning number	Cream in vat	Fat test	Acidity of cream	Pasteurizing temperature	Temperature after cooling	Temperature cooled in vat	Time held	Churning temperature	Final acidity	Fat test, vat	Fat test, churn	Total dilution	Churning time	Buttermilk temperature	Buttermilk test, butyl alcohol	Total fat churned lost in buttermilk
	Pounds	*Per cent*	*Per cent*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Hours*	*Degrees F.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Degrees F.*	*Per cent*	*Per cent*
44	2,815	37.0	0.12	194	50–55	43	15	48	0.13	37.0	37.0	0.0	42	54	0.76	1.14
45	2,815	37.0	.12	194	50–55	43	15	48	.13	37.0	36.0	2.8	48	54	.84	1.33
46	4,075	28.0	.51	195	50–55	44	18	58	.18	28.0	27.0	3.7	50	60	.70	1.75
47	2,900	37.0	.12	194	50–55	41	15	48	.13	37.0	37.0	.0	50	54	.72	1.08
48	2,900	37.0	.12	194	50–55	41	15	48	.13	37.0	36.0	2.8	57	54	.64	1.01
49	2,700	29.0	.47	196	50–55	42	18	56	.18	29.0	27.0	7.4	43	61	.62	1.55
50	2,750	38.0	.13	194	50–55	41	15	48	.14	38.0	38.5	.0	42	54	.68	.95
51	2,750	38.0	.13	194	50–55	41	15	48	.14	38.0	37.0	2.7	47	55	.66	.99
52	3,040	26.5	.50	196	50–55	42	18	57	.18	26.5	25.0	6.0	35	60	.62	1.74
53	2,750	39.0	.12	194	50–55	41	15	48	.13	39.0	39.0	.0	44	54	.72	.98
54	2,750	39.0	.12	194	50–55	41	15	48	.13	39.0	35.0	11.4	50	55	.70	1.16
55	2,550	27.0	.50	196	50–55	40	18	55	.18	27.0	27.0	.0	32	60	.74	1.85
56	3,150	35.0	.12	194	50–55	42	15	49	.13	35.0	35.0	.0	60	54	.74	1.23
57	3,150	35.0	.12	194	50–55	42	15	49	.13	35.0	34.0	2.9	70	55	.74	1.29
58	1,850	28.0	.50	196	50–55	44	17	54	.19	28.0	26.5	5.7	35	58	.60	1.54
59	1,900	31.5	.40	195	50–55	40	18	54	.22	28.5	26.0	9.6	50	60	.64	1.70
60	3,075	36.5	.15	193	50–55	42	15	51	.15	36.5	36.5	.0	40	55	.80	1.23
61	3,075	36.5	.15	193	50–55	42	15	51	.15	36.5	35.0	4.3	44	55	.78	1.29
Weighted Average	.....	.....	....	.....	.....	....	....	....	....	34.1	33.1	3.0	....	....	0.71	1.29

ings of the same fat contents showed some improvement in the efficiency. The per cent of the fat churned that was lost in the buttermilk ranged from 0.95 to 1.85 per cent. It appears that the per cent of the total fat churned that was lost in the buttermilk could be lowered still further.

Since the conclusion of the field study at this creamery, the buttermaker has kept careful records of the manufacturing data. An analysis of these for 127 churnings shows that with the majority of the churnings the amount of fat lost in the buttermilk was fairly well controlled. With some churnings, however, the loss was excessive.

The summarized data in Table 12 indicate that the following conditions were associated with the highest total fat loss:

(a) Churning low-testing cream,

(b) Churning at a high temperature,

(c) Overloading the churn.

By controlling these factors it appears possible to maintain a loss in the buttermilk of 1 per cent of the total fat churned. This should be considered very efficient.

Duplicate churnings made in this creamery show the effect of adding hot water to the cream when the butter would not break as a result of too low churning temperature. Each churning contained 2,776 pounds of 48 per cent cream that had been pasteurized to 160° F. in a vat and held for 30 minutes. The cream was cooled to 45° F. and held. The churning temperature on the first churning was 45° F. This resulted in prolonged churning. Hot water was added to cause the butter to "break." The buttermilk tested 1.4 per cent fat. The second churning churned in normal time without the addition of hot water. The first churning had a loss of 16.4 pounds of fat in the buttermilk, while the second churning had a loss of only 4.7 pounds.

Plant 2. All cream processed at this plant was obtained from whole milk, and it was not necessary to neutralize the cream. The churns were of the two-worker-roll type and had a capacity of 1,000 pounds of butter each.

The general procedure at this plant was as follows: The milk was preheated to approximately 110° F. and separated. Two separators delivering about 2,500 pounds of 40 per cent cream per hour were used. The cream left the separators at about 105° F. and entered a 100-gallon holding vat. This vat was connected with the feed pump of the Vacreator and the cream was pasteurized at a rate of 2,500 pounds an hour. The pasteurized cream was cooled over a surface cooler and was then pumped into holding vats for further cooling. The cream at this plant was handled in a continuous manner. The runs were from 4 to 6 hours in duration, depending on the volume of cream at different times. Only part of the cream was used for churning; the remainder was used in the manufacture of ice cream.

Previous to this study, and at the request of the plant manager, the Experiment Station had made several recommendations in order to improve the efficiency in churning. It was found that at least two of the suggestions were carried out; namely, to churn cream of a higher fat content, about 40 per cent, and to eliminate the water dilution by separating all rinsings.

General observations. In Table 13 are recorded the manufacturing data for 12 churnings of butter made during the first visit to Plant 2. The average fat content of the cream was satisfactory and dilution was nil.

Table 12. MANUFACTURING DATA FOR 127 CHURNINGS IN PLANT 1.

March 1 to April 18, 1941

Number of churnings	Average pounds cream	Weighted average cream test	Average churning temperature	Weighted average buttermilk test (butyl alcohol)	Weighted per cent fat lost in buttermilk of total fat churned	Average pounds fat lost in buttermilk per churning
	Pounds	*Per cent*	*Degrees F.*	*Per cent*	*Per cent*	*Pounds*
Overload						
9	3,587	30.14	54.7	0.84	1.78	19.27
4	3,436	40.04	46.7	.81	1.05	14.44
Moderate load						
12	3,155	31.02	53.7	.86	1.73	17.16
19	3,238	37.61	48.2	.93	1.36	16.59
20	3,111	40.69	47.9	.92	1.16	14.98
6	3,131	43.05	47.7	.90	1.01	12.98
Medium load						
6	2,687	28.80	53.7	.71	1.61	12.51
5	2,768	30.31	52.4	.70	1.47	12.33
6	2,920	36.60	47.3	.67	1.03	11.00
12	2,846	40.62	47.1	.76	.96	11.21
6	2,877	43.65	46.3	.98	1.07	12.89
Small load						
9	2,226	31.26	51.2	.67	1.35	9.52
3	2,171	35.65	47.3	.64	1.02	7.91
10	2,243	40.57	46.6	.63	.80	7.42
Average	.....	36.7 (weighted)	.....	.82 (weighted)	1.25 (weighted)	13.61 (weighted)

Table 13. SUMMARY OF DATA ON CHURNINGS AT PLANT 2 BEFORE MAKING SUGGESTED CHANGES

Vacreator with a capacity of 2,500 pounds of cream per hour used

Churning number	Cream in vat	Fat test	Acidity of cream	Pasteurizing temperature	Temperature after cooling	Temperature cooled in vat	Time held	Churning temperature	Final acidity	Fat test, vat	Fat test, churn	Total dilution	Churning time	Buttermilk temperature	Buttermilk test, butyl alcohol	Total fat churned lost in buttermilk
	Pounds	*Per cent*	*Per cent*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Hours*	*Degrees F.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Degrees F.*	*Per cent*	*Per cent*
1	2,000	37.5	0.15	195	60	45	12	51	0.12	37.5	37.5	0.0	38	55	0.82	1.21
2	2,400	39.0	.12	195	60	45	1	46	.11	39.0	39.0	.0	35	52	.92	1.25
3	2,300	43.5	.12	194	54–60	40	15	51	.11	43.5	43.5	.0	45	54	1.00	1.10
4	2,300	42.5	.12	194	48–50	46	1	46	.11	42.5	42.5	.0	48	51	.90	1.04
5	2,300	40.5	.11	194	50	40	2	49	.10	40.5	40.5	.0	38	54	.92	1.17
6	2,300	43.0	.10	194	60	48	17	49	.11	43.0	43.0	.0	47	54	1.00	1.13
7	2,300	38.5	.12	194	55–60	47	12	47	.12	38.5	38.5	.0	42	52	1.00	1.40
8	2,300	38.0	.11	194	56	41	17	50	.11	38.0	38.0	.0	58	56	.90	1.29
9	2,300	47.0	.11	194	60	38	15	47	.11	47.0	47.0	.0	47	54	1.18	1.09
10	2,300	42.0	.11	195	60	48	18	48	.11	42.0	42.0	.0	46	55	1.14	1.35
11	2,300	43.0	.11	195	50	39	15	50	.11	43.0	43.5	.0	40	55	.96	1.06
12	2,300	40.5	.12	195	50	40	15	49	.11	40.5	40.5	.0	42	54	1.06	1.35
WEIGHTED AVERAGE	.....	.....	.....	....	.....	....	....	....	....	....	41.3	41.3	0.0	....	....	0.97	1.18

Table 14. SUMMARY OF DATA ON CHURNINGS AT PLANT 2 AFTER MAKING SOME OF THE SUGGESTED CHANGES

Churning number	Cream in vat	Fat test	Acidity of cream	Pasteurizing temperature	Temperature after cooling	Temperature cooled in vat	Time held	Churning temperature	Final acidity	Fat test, vat	Fat test, churn	Total dilution	Churning time	Buttermilk temperature	Buttermilk test, butyl alcohol	Total fat churned lost in buttermilk
	Pounds	*Per cent*	*Per cent*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Hours*	*Degrees F.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Degrees F.*	*Per cent*	*Per cent*
1	2,300	42.5	.....	195	41	41	18	49	.....	42.5	42.5	0.0	49	54	0.88	1.01
2	2,300	43.5	.....	195	44	40	17	49	.....	43.5	43.5	.0	47	54	.90	.99
3	2,300	44.0	.....	195	42	42	20	49	.....	44.0	44.0	.0	41	55	.94	1.01
4	2,300	36.0	.....	195	41	40	17	50	.12	36.0	36.0	.0	45	55	.90	1.42
5	2,300	38.5	.....	195	41	41	1	47	.11	38.5	38.5	.0	51	55	.78	1.09
6	2,300	36.0	.....	195	40	40	18	50	.11	36.0	36.0	.0	49	54	.80	1.26
7	2,300	40.5	0.09	194	42–44	40	18	50	.10	40.5	40.5	.0	46	55	.99	1.25
8	2,300	44.0	.....	194	40	40	18	49	.10	44.0	44.0	.0	41	55	1.00	1.07
9	2,300	38.5	.12	194	40	40	18	50	.11	38.5	38.5	.0	42	55	.92	1.29
10	2,300	44.5	.....	196	46	46	⅔	47	.09	44.5	44.5	.0	41	54	.96	1.01
11	2,300	41.5	.....	196	40	40	⅔	47	.09	41.5	41.5	.0	42	53	.92	1.11
12	2,300	42.0	.....	196	42	40	18	49	.10	42.0	42.0	.0	49	54	.96	1.13
13	2,300	41.5	.....	196	40	40	18	49	.11	41.5	41.5	.0	46	55	.96	1.16
WEIGHTED AVERAGE	.....	.....	.....	.....	....	....	....	....	....	41.0	41.0	0.0	....	....	0.91	1.13

The surface cooler was not capable of lowering the temperature of the cream sufficiently, and the cream was not cooled in the vats to below 45° F. for holding. The churns were being somewhat overloaded.

With 12 churnings it was found that the Babcock-butyl alcohol test of the buttermilk ranged from 0.82 to 1.18 per cent. The per cent of the total fat churned that was lost in the buttermilk ranged from 1.04 to 1.40.

Recommendations. In order to improve the efficiency, the following recommendations were made:

1. Cool the cream to a lower temperature over the surface cooler.
2. Complete cooling in the holding vat to 40° F. or below.
3. Avoid overloading the churn in order to bring about more exhaustive churning of the high-testing cream.
4. Use a slightly lower churning temperature in order to lengthen the churning time to between 45 and 60 minutes.

Results obtained. In Table 14 are compiled the data for 13 churnings made at Plant 2 several weeks after the first study. Some of the changes that had been suggested had been made. The temperature of the cream was reduced on the surface cooler to approximately 42° F. and the cream was generally cooled to 40° F. in the vats. These changes resulted in reducing the percentage of the total fat churned that was lost in the buttermilk. It was felt that the loss could be lowered still further.

The average buttermilk fat test was relatively high at this plant when compared with the average per cent of the total fat lost, which was relatively low. There was a smaller amount of buttermilk, however, from this high-testing cream. The only accurate way to compare fat losses in buttermilk in different plants is to express the loss in terms of *the per cent of the total fat churned.*

Plant 3. Approximately one-fourth of the cream was obtained from whole milk separated in the plant, while the remainder was gathered from the farms in the territory. Single-roll churns of 1,000-pound capacity were used. The procedure in handling the cream was as follows: Four receiving vats were used for the cream of different grades. Neutralization was done without preheating the cream in the vats before vacreating. The cream of each respective quality was pumped to the Vacreator by means of a variable speed pump. The cream was cooled over a two-section water and direct-expansion surface cooler, and flowed by gravity into cylindrical coil-less holding vats, where it was held without agitation or further cooling until churned. Usually the cream was held overnight, but several lots were usually churned the same day that it was pasteurized.

General observations. A summary of the manufacturing data for 25 churnings made at Plant 3 during the first visit to the plant is presented in Table 15. A study of these data shows that:

1. As no further cooling was done in the holding vats, the cream was not cooled sufficiently over the surface cooler.
2. There were no facilities for tempering the cream before churning, and the churning temperatures in most cases were too high.
3. The churns were being overloaded.
4. The cream was being diluted with an excessive amount of water.
5. The percentage of the total fat churned that was lost in the buttermilk was found to be excessive.

Table 15. Summary of Data on Churnings at Plant 3 Before Making Suggested Changes

Vacreator of a capacity of 15,000 pounds cream per hour used

Churning number	Cream in vat	Fat test	Acidity of cream	Pasteurizing temperature	Temperature after cooling	Temperature cooled in vat	Time held	Churning temperature	Final acidity	Fat test, vat	Fat test, churn	Total dilution	Churning time	Buttermilk temperature	Buttermilk test, butyl alcohol	Total fat churned lost in buttermilk
	Pounds	*Per cent*	*Per cent*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Hours*	*Degrees F.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Degrees F.*	*Per cent*	*Per cent*
1	2,700	30.0	0.48	195	42	42	13	52	0.09	30.0	29.0	3.4	50	57	0.84	1.89
2	2,700	28.5	.50	195	46	46	14	53	.11	28.5	28.5	.0	45	58	.66	1.52
3	2,700	28.0	.50	198	48	48	12	56	.06	28.0	28.0	.0	39	60	1.12	2.65
4	2,700	29.0	.50	197	46	46	17	53	.24	29.0	28.0	3.4	55	58	.68	1.61
5	2,700	29.0	.50	197	44	44	17	53	.12	29.0	27.5	5.4	31	58	.66	1.61
6	2,700	28.5	.52	196	44	44	19	54	.19	28.5	25.5	11.7	43	58	.66	1.80
7	2,700	28.0	Sweet	194	46	46	18	56	.23	28.0	28.0	.0	30	58	.76	1.80
8	2,700	34.0	Sweet	194	45	45	17	55	.13	34.0	33.0	3.0	45	59	.86	1.57
9	2,700	30.0	Sweet	195	45	45	14	56	.20	30.0	29.0	3.3	20	58	.80	1.80
10	2,700	29.0	Sweet	194	44	44	14	60	.18	29.0	28.0	3.5	15	61	1.28	3.03
11	2,700	29.0	Sweet	194	44	44	14	52	.18	29.0	28.0	3.4	55	58	.62	1.47
12	2,700	29.5	.52	194	44	44	14	54	.16	29.5	27.0	9.3	54	58	.54	1.35
13	2,700	34.0	.14	194	44	44	0	46	.13	34.0	34.0	.0	35	48	1.24	2.16
14	2,700	.....	.55	198	43	43	13	52	.15	26.5	26.0	1.9	50	57	.66	1.75
15	2,700	.....	Sweet	195	44	44	13	54	.15	32.0	30.5	5.0	50	57	.62	1.29
16	2,700	.....	.52	197	44	44	13	54	.24	28.5	28.0	1.8	50	58	.74	1.75
17	2,700	.....	Sweet	195	45	45	15	56	.18	32.0	30.0	6.6	35	58	.74	1.58
18	2,700	.....	Sweet	195	44	44	17	54	.15	33.0	31.0	6.0	39	57	.68	1.38
19	2,700	.....	.48	197	43	43	17	52	.23	31.0	30.5	1.6	68	57	.66	1.37
20	2,700	.....	Sweet	195	43	43	17	52	.20	30.0	30.0	.0	75	57	.70	1.49
21	2,700	.....	Sweet	197	43	43	13	52	.20	33.0	30.5	8.2	47	57	.60	1.25
22	2,700	.....	.32	195	42	42	13	50	.12	29.5	27.0	9.2	120	55	.64	1.60
23	2,700	.....	.50	197	42	42	13	51	.23	29.0	27.0	7.4	120	56	.52	1.30
24	2,700	.....	Sweet	194	43	43	15	52	.19	33.5	32.5	3.0	58	57	.62	1.16
25	2,700	.....	.58	197	42	42	17	51	.18	29.5	28.0	5.4	90	56	.56	1.33
Weighted Average	.....	.....	.....	.....	....	....	....	....	....	30.2	29.0	4.1	....	....	0.73	1.64

Table 16. Summary of Data on 30 Consecutive Churnings at Plant 3 After Making Suggested Changes

Churning number	Cream in vat	Fat test	Pasteurizing temperature	Temperature after cooling	Temperature cooled in vat	Churning temperature	Fat test, vat	Fat test, churn	Total dilution	Churning time	Buttermilk test, butyl alcohol	Total fat churned lost in buttermilk
	Pounds	*Per cent*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Per cent*	*Per cent*
1	2,600	34	195	42	42	50	34	34	0.0	50	0.54	0.94
2	2,600	31	195	42	42	50	31	31	.0	60	.50	1.02
3	2,600	31	195	44	44	52	31	31	.0	31	.88	1.79
4	2,600	28	194	44	44	53	28	28	.0	28	.56	1.33
5	2,600	31	195	43	43	52	31	31	.0	34	.60	1.22
6	2,600	33	195	44	44	53	33	33	.0	42	.72	1.39
7	2,600	30	195	42	42	49	30	30	.0	33	.54	1.15
8	2,600	31	194	42	42	48	31	31	.0	47	.70	1.42
9	2,600	30	195	44	44	52	30	30	.0	40	.52	1.11
10	2,600	32	195	44	44	53	32	32	.0	36	.60	1.16
11	2,600	31	194	43	43	52	31	31	.0	39	.54	1.10
12	2,600	33	195	43	43	53	33	33	.0	36	.54	.99
13	2,600	31	195	44	44	54	31	31	.0	33	.50	1.02
14	2,600	31	195	42	42	47	31	31	.0	48	.50	1.02
15	2,600	31	195	42	42	49	31	31	.0	30	.56	1.14
16	2,600	33	194	44	44	50	33	33	.0	25	.72	1.32
17	2,600	30	195	43	43	49	30	30	.0	37	.54	1.15
18	2,600	40	195	43	43	53	40	40	.0	32	.88	1.14
19	2,600	42	195	43	43	50	42	42	.0	39	.84	.99
20	2,600	33	195	42	42	44	33	33	.0	51	.66	1.21
21	2,600	31	195	42	42	46	31	31	.0	50	.59	1.20
22	2,600	34	195	40	40	48	34	34	.0	48	.48	.84
23	2,600	35	195	40	40	47	35	35	.0	49	.52	.86
24	2,600	30	195	42	42	50	30	30	.0	46	.50	1.07
25	2,600	32	194	40	40	52	32	32	.0	34	.54	1.04
26	2,600	30	195	40	40	52	30	30	.0	38	.48	1.02
27	2,600	31	195	40	40	51	31	31	.0	44	.42	.85
28	2,600	35	195	40	40	54	35	35	.0	30	.54	.90
29	2,600	31	195	42	42	51	31	31	.0	47	.60	1.22
30	2,600	35	195	42	42	49	35	35	.0	43	.60	1.00
Weighted Average	.....	....	.....	....	....	....	32.2	32.2	0.0	....	0.59	1.12

Recommendations. After making the above observations, the following changes were recommended:

1. Cool the vacreated cream to as low a temperature as possible over the surface cooler.
2. Maintain as low a temperature of the cream as possible in the holding vats.
3. Use less cream in the churn, thereby making it possible to use lower churning temperatures without increasing the churning time above normal.
4. Reduce the dilution of cream with water.
5. Separate higher-testing cream so as to raise the average test at churning as much as possible.
6. Forewarm the cream to 110° F. before vacreating.

Results obtained. The recommendations that were made were immediately put into effect by the plant superintendent. A revisit to the plant was made after 2 weeks. The results obtained from putting the recommendations into effect were remarkable. In Table 16 are given the manufacturing data obtained for 30 consecutive churnings that represented approximately 30,000 pounds of butter.

The changes that had been put into effect were:

1. The dilution of the cream with water had been eliminated.
2. The average test of the cream churned had been increased from 29.0 to 32.2 per cent.
3. The cream was being cooled on the cooler to a lower temperature than formerly and was being held at a lower temperature until churned.
4. Each churn load had been reduced by approximately 100 pounds of cream.

These changes had a pronounced effect on reducing the amount of the fat lost in the buttermilk. The buttermilk test ranged from 0.42 to 0.88. The per cent of the total fat churned that was lost in the buttermilk ranged from 0.84 to 1.79. The weighted average fat loss was 1.12.

With the volume of cream handled at this particular plant, the reduction in the amount of fat lost resulted in a saving of more than $20 per day or approximately $600 per month. *A most important fact is that the change to this new efficiency was accomplished with practically no added cost or inconvenience.*

Frequency distribution and summary of the fat-loss percentages. A frequency distribution and summary of the fat-loss percentages for the three creameries obtained during the two surveys are shown in Table 17. The summary shows very clearly that:

A slight improvement was effected in Plant 1;

A considerable improvement was made in Plant 2;

A remarkable improvement was made in Plant 3.

It is of particular interest to note that during the second survey 76.9 per cent of churnings in Plant 2 and 83.4 per cent of the churnings in Plant 3

showed fat losses of 1.25 per cent or less, which is a very good accomplishment. Perhaps by employing still further technical control it would be possible to reduce the loss still further.

Although the reduction of the loss in Plant 1 showed only a slight improvement the reduction should have been greater had all the recommendations been adopted and dilution with water eliminated.

Table 17. FREQUENCY DISTRIBUTION AND SUMMARY OF FAT-LOSS PERCENTAGES IN PLANTS 1, 2, AND 3. 110 CHURNINGS.

Range in per cent fat lost in buttermilk of total fat churned	First survey		Second survey	
	Churnings	Percentage of churnings	Churnings	Percentage of churnings
	Number	*Per cent*	*Number*	*Per cent*
Plant 1				
Below 1.00	1	8.3	3	16.7
1.00 to 1.25	5	41.7	6	33.3
1.26 to 1.50	2	16.7	3	16.7
1.51 to 1.75	1	8.3	5	27.8
1.76 to 2.00	2	16.7	1	5.5
2.01 to 2.25	....	.....	....	.....
2.26 to 2.50	1	8.3	....	.....
Total	12	100.0	18	100.0
Plant 2				
Below 1.00	....	.....	1	7.7
1.00 to 1.25	7	58.3	9	69.2
1.26 to 1.50	5	41.7	3	23.1
Total	12	100.0	13	100.0
Plant 3				
Below 1.00	0	0.0	7	23.4
1.00 to 1.25	2	8.0	18	60.0
1.26 to 1.50	8	32.0	4	13.3
1.51 to 1.75	8	32.0	0	0.0
1.76 to 2.00	4	16.0	1	3.3
2.01 to 2.25	1	4.0	....	.....
2.26 to 2.50	....	.....	....	.....
2.51 to 2.75	1	4.0	....	.....
2.76 to 3.00	....	.....	....	.....
3.01 to 3.25	1	4.0	....	.....
Total	25	100.0	30	100.0

Plants 4 and 5. Vat method of pasteurization. Two representative plants that used vat pasteurization were selected. Plant 4 used a single-roll 1,000-pound butter capacity churn, while Plant 5 used a roll-less 1,000-pound butter capacity churn. Plant 4 used a pasteurizing temperature of 155° F. for 30 minutes, while Plant 5 used a temperature of 180° F. but cooled the cream immediately in the vat without holding.

In Table 18 are shown the data for a previously made study on 145 churnings in Plants 4 and 5 during the spring of 1940. Because of normally higher fat losses during the summer months, it was thought advisable to make a further study during the present investigation so as to have comparable results with those obtained at the other plants.

Table 18. SUMMARY OF DATA ON 145 CHURNINGS MADE AT PLANTS 4 AND 5 DURING THE PERIOD MARCH 9 TO MAY 16, 1940.

Vat method of pasteurization

Plant number	Churnings	Average vat test	Average test in churn	Average dilution from vat to churn	Average fat test of buttermilk, butyl alcohol
	Number	*Per cent*	*Per cent*	*Per cent*	*Per cent*
4	61	31.5	27.7	13.7	0.55
5	84	29.7	27.4	8.4	.43

Percentage of total fat churned lost in buttermilk	Percentage of churnings	
	Plant 4	Plant 5
	Per cent	*Per cent*
Less than 0.90 per cent	9.8	15.5
0.90 to 0.99 per cent	18.0	14.3
1.00 to 1.09 per cent	19.7	32.1
1.10 to 1.19 per cent	34.4	19.0
1.20 to 1.29 per cent	8.2	14.3
1.30 to 1.39 per cent	3.3	3.6
1.40 to 1.49 per cent	3.3	1.2
1.50 per cent and above	3.3	.0
Range in percentage of total fat lost	Plant 4 0.77 to 1.73	Plant 5 0.76 to 1.42

The summarized data for eight churnings made during a 3-day study at Plants 4 and 5 are presented in Table 19.

The data in Table 19 show that variations in the percentage of the total fat churned that was lost in the buttermilk occurred between the plants that used vat pasteurization and also between the churnings in the same plant. Although the results were obtained on a limited number of churnings, the data presented show some of the variations that do occur in practical plant operation. The buttermilk test ranged from 0.30 per cent to 1.14 per cent, while the per cent of the total fat churned that was lost in the buttermilk ranged from 0.71 to 2.85.

Table 19. Summary of Data on Churnings at Plants 4 and 5

July 30 to August 1, 1940

Vat method of pasteurization

Churning date	Cream in vat	Fat test	Acidity of cream	Pasteurizing temperature	Method	Temperature cooled in vat	Time held	Churning temperature	Final acidity	Fat test, vat	Fat test, churn	Total dilution	Churning time	Buttermilk temperature	Buttermilk test, butyl alcohol	Total fat churned lost in buttermilk
	Pounds	*Per cent*	*Per cent*	*Degrees F.*		*Degrees F.*	*Hours*	*Degrees F.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Degrees F.*	*Per cent*	*Per cent*
Plant 4—vat pasteurization single-roll churn																
7/30	1,375	28.5	0.52	155	Vat	46	12	48	0.20	28.5	29.0	0.0	50	61	0.57	1.28
7/31	2,412	31.5	.48	155	Vat	46	12	54	.20	31.5	28.5	10.5	38	59	.44	1.02
8/1	2,500	29.0	.75	155	Vat	48	12	54	.25	29.0	27.0	7.4	25	60	1.14	2.85
Plant 5—vat pasteurization rollless churn																
7/30	1,600	27.0	.60	180	Vat	45	12	50	.20	27.0	27.0	0.0	40	58	.52	1.30
7/30	2,000	30.0	.65	180	Vat	41	2½	52	.20	30.0	27.0	10.0	40	56	.40	1.00
7/31	2,300	30.0	.49	180	Vat	51	14	51	.13	30.0	28.0	7.1	55	55	.30	.71
8/1	1,900	.....	.42	180	Vat	40	12	50	.25	24.0	19.0	26.3	90	56	.38	1.54
8/1	1,800	.....	.70	180	Vat	40	12	50	.17	26.0	26.0	.0	60	58	.60	1.59

Range of fat loss percentages—0.71 to 2.85.

SUMMARY

1. The investigation to determine the amount of fat lost in the buttermilk during churning included actual field observations in several creameries as well as laboratory studies. The amount of fat lost in the buttermilk from the churning of 2,141 lots of cream was determined.
2. The Babcock-butyl alcohol method for determining the fat content of buttermilk was found to be satisfactory to use. *The per cent of total fat churned lost in the buttermilk was found to be the only practical way of comparing the fat losses in buttermilk.*
3. Using the vat method of pasteurization the per cent of the total fat lost in the buttermilk during the churning of 148 lots of cream in the Experiment Station Dairy Products Laboratory during the year 1937 ranged from 0.5 to 3.2. The weighted average loss was 1.22 per cent.
4. The per cent of the total fat churned that was lost in the buttermilk at a creamery that used the vat method of pasteurization in 354 churnings during 1936 and 1937 ranged from 0.55 to 3.13. The weighted average loss for all the churnings was 1.162 per cent. The loss for 2 summer months averaged approximately 0.3 in the percentage higher than for 2 winter months.

   During 1939 and 1940 the per cent of the total fat lost in the buttermilk when churning 1,119 lots of cream in the same creamery ranged from 0.44 to 2.71 and averaged 1.06 (weighted).

   Of the 1,119 churnings, 1,053 were from vat-pasteurized cream and 66 were from standard flash-pasteurized cream. The weighted average per cent fat lost in the buttermilk of the total fat churned for the 66 churnings of the flash-pasteurized cream was 1.32, and for 58 churnings of vat-pasteurized cream made during the same month the weighted average per cent fat loss was 0.92.
5. It was found that less total fat was lost in the buttermilk when high-testing cream was churned. In 60 churnings the per cent of the total fat churned that was lost in the buttermilk from cream that averaged 38.6 per cent was 1.11, and from cream that averaged 31.1 per cent the loss was 1.56, a difference of 0.45.
6. The exclusion of rinse water from the cream churned was found to cause a reduction in the fat lost in the buttermilk. An effective way to avoid diluting the cream to be churned with water was to collect and combine all rinsings and separate them. The cream thus obtained was included with the next day's batch of raw cream. By this method it was possible thoroughly to rinse all vats, pipe lines, etc., and not dilute the cream to be churned.
7. A summary of records compiled on 145 churnings of vat-pasteurized cream in two creameries during several spring months showed that the percentage of the fat churned that was lost in the buttermilk ranged from 0.76 to 1.73 and averaged approximately 1.10.
8. The data obtained on eight churnings of vat-pasteurized cream in two creameries during a summer month showed that the total percentage of fat churned that was lost in the buttermilk ranged from 0.71 to 2.85.
9. Churning one of two equally divided portions of the same vat of cream at 5° F. above the correct temperature and the other portion at the correct temperature showed that 0.20 per cent more of the total fat was lost in the buttermilk from the cream churned at the higher temperature.

10. In three creameries that vacuum-pasteurized the cream the average per cent of the total fat churned that was lost in the buttermilk at the beginning of the study was 1.45 per cent, 1.18 per cent, and 1.64 per cent respectively. After putting certain suggestions for improvement in the methods of handling and churning the cream into effect the average percentages were 1.29, 1.13, and 1.12 for the three plants.
11. Quick cooling of the cream after leaving the Vacreator to at least 50° F. and a final lowering of the temperature of the cream to from 40° to 45° F. proved to be very important in maintaining a low fat loss in buttermilk during the summer months.
12. It was demonstrated that it was possible significantly to lower the per cent of the total fat churned that was lost in the buttermilk from vacreated cream of average fat content (32 per cent) when:
    (1) Dilution with water was eliminated;
    (2) The cream was thoroughly cooled;
    (3) The churning temperature was correctly adjusted;
    (4) The churn was not overloaded.
13. In one creamery a daily saving of $20 because of improved efficiency in the handling of the cream and in churning was effected. This change to the new efficiency was accomplished with practically no added cost or inconvenience.
14. A loss of fat in the buttermilk of from 1.00 to 1.25, expressed as the per cent of the total fat churned, would appear to indicate efficient control.

Appendix

BABCOCK-BUTYL ALCOHOL METHOD FOR TESTING BUTTERMILK

Equipment needed in addition to standard Babcock milk-testing equipment:

8.8 cc. buttermilk pipette, total length 250 mm., outside diameter of suction tube 8 mm., length of delivery tube 75 mm., outside diameter of delivery tube 5 mm.

2.0 cc. pipette for measuring butyl alcohol,

Double-neck skim milk test bottle with a total graduation representing 0.5 per cent fat and the smallest graduation representing 0.01 per cent fat.

Determination:

1. Adjust temperature of buttermilk to from 60° to 70° F.,
2. Carefully mix sample by pouring from one container to the other,
3. Measure 8.8 cc. of buttermilk by pipette and transfer to the test bottle,
4. Add 2 cc. normal butyl alcohol to test bottle,
5. Mix buttermilk and butyl alcohol,
6. Add 7 to 8 cc. sulphuric acid at 60° F. (sp. gr. 1.825 at 60° F.); the amount of acid used may be varied to give a clear test,
7. Mix well by giving bottle a gentle rotary motion. Care must be taken not to let the contents of the bottle rise up into the graduated portion of the bottle,
8. Whirl for 6 minutes in a heated centrifuge,
9. Add water (140° F.) to bottom of the neck of the bottle,
10. Centrifuge 2 minutes,
11. Add water (140° F.) to bring the fat column into the graduated portion of the bottle,
12. Centrifuge 2 minutes,
13. Place in water bath (135° to 140° F.) for 5 minutes.
14. Measure the fat column, using a pair of needle-pointed calipers and double the reading to obtain the per cent fat in the buttermilk.

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Food Industries

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Horticulture

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W. S. Brown, M.S., D.Sc.....Horticulturist
A. G. B. Bouquet, M.S.....Horticulturist (Vegetable Crops)
C. E. Schuster, M.S.....Horticulturist (Division of Fruit and Vegetable Crops and Diseases)*
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Soil Science

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C. I. Branton, B.S.....Assistant Agricultural Engineer†
G. R. Stafford.....Engineering Aid, Bureau of Agricultural Chemistry and Engineering*
H. F. Carnes, B.S.....Junior Agricultural Engineer, Bureau of Agricultural Chemistry and Engineering*
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Bacteriology

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J. E. Simmons, M.S.....Associate Bacteriologist
W. B. Bollen, Ph.D.....Associate Bacteriologist
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Entomology

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Joe Schuh, M.S.....Assistant Entomologist
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Home Economics

Maud M. Wilson, A.M.....Home Economist

Plant Pathology

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D. M. Goode, M.A.....Editor of Publications
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