Materials-Balance Method for Determining Losses of Butterfat in the Creamery

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IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS

DAIRY INDUSTRY SECTION

AMES, IOWA
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SUMMARY

1. An average overrun of 22.03 percent was obtained from 272 churnings from 24 select creameries, the cream having been pasteurized in coil vats. In figuring this overrun the miscellaneous losses of fat were not considered; had they been considered the overrun would have been slightly less.

2. An average overrun of 21.21 percent was obtained from 25 churnings from 3 selected creameries, the cream being pasteurized in the vacreator. Miscellaneous losses were not considered in figuring this overrun.

3. An average of 1.39 percent of the total butterfat received by the creameries was lost in the buttermilk from cream pasteurized in the coil vat. This loss reduced the overrun 1.74 percent of the theoretical.

4. An average of 1.98 percent of the total butterfat received was lost in the buttermilk from cream pasteurized in the vacreator. This loss reduced the overrun 2.74 percent of the theoretical.

5. In the butter of 272 churnings the average percent of fat was 80.43 which reduced the theoretical overrun 0.67 percent of the theoretical.

6. The overweight allowed on the butter amounted to 0.45 percent of the fat received and reduced the overrun 0.56 percent of the theoretical.

7. When cream testing 26 percent fat was churned, the overrun was reduced 2.0 percent from the theoretical overrun due to fat losses in the buttermilk, while in churning cream testing 33 percent fat the reduction amounted to only 1.4 percent, making a difference of 0.6 percent and representing 0.48 percent of the total amount of fat saved by churning the richer cream.

8. Since butterfat is the most important raw product handled in the creamery, extreme care should be taken to assure that the losses be reduced to the minimum, and a definite system should be employed by the creamery by which it will become possible to definitely determine the daily losses.
Materials-Balance Method for Determining Losses of Butterfat in the Creamery

BY M. MORTENSEN.

Since this project has been carried on primarily with the view of determining what will constitute a fair butter overrun it seems advisable first to explain what is understood by overrun and how it is determined.

Butter overrun is a term used to designate the number of pounds of butter that is made in excess of the pounds of butterfat used for its manufacture. It is generally spoken of as “percent overrun” which is expressed as equal to the number of pounds of butter made in excess of each 100 pounds of fat used for its manufacture, thus if 122 pounds of butter were obtained from 100 pounds of butterfat the percent overrun would be 22.

Applying this definition for percent overrun then

\[ B = F + \frac{F}{100} \times Y \]

or

\[ Y = \frac{B - F}{F} \times 100 \]

B represents pounds of butter churned
F represents pounds of butterfat used for churning
Y represents percent overrun

The overrun was originally of importance as a barometer by which to determine the butterfat losses, such as fat losses in the buttermilk and other losses of fat occurring during the process of manufacturing. In addition thereto the overrun is also affected by allowing overweight on butter and by having more than 80 percent fat in the butter. Reduction of the overrun due to such factors has been lost sight of to some extent. The primary reason for this may be traced to the creamery director’s lack of technical knowledge, resulting in his opinion that a creamery operator should be able to obtain an overrun which closely approaches the legal limit, and that one who fails in that respect is incompetent. As a result the annual reports from the various creameries generally show overruns from 24 to 24.5 percent.

1 Project 685 of the Iowa Agricultural Experiment Station.
2 The author is indebted to Dr. E. W. Bird, under whose direction the chemical analyses were made, also to Professor A. W. Rudnick, of the Iowa State College Agricultural Extension Service, Professor G. W. Snedecor, Director of the Statistical Laboratory, and E. E. Houseman, who have rendered valuable assistance. Credit is due to the creamery operators cooperating, without whose assistance this work would have been impossible.
3 The legal limit for overrun in Iowa is 24.5 percent.
The work reported in this bulletin was carried on to determine the overrun that is actually being obtained in well-managed Iowa creameries and to devise a system by which losses and other factors influencing the overrun may be readily determined. A group of 26 well-managed creameries located in the various parts of the state were kind enough to cooperate with us until, as a result of the war, the labor problems became so serious that the work had to be discontinued; by that time analyses had already been made of 297 churnings.

LITERATURE REVIEW

MATERIALS-BALANCE RECORDS

Bass and Mease (3) recommend “Materials-balance records” as a means to reduce manufacturing costs. They maintain that although the system has been used to a certain extent it is far from receiving the attention it deserves. They refer to a materials-balance system that has been developed for milk plants and present a flow sheet of fluid milk plant operation (4) which may be applicable to the operation of certain milk plants.

In this work the milk plants and the ice cream factories have taken the lead over the butter plants. Marshall (15) introduced a system of checking losses in a combined ice cream and market milk plant. The improvement is evident from his statement “The saving we have realized on this report in the last 2 years is almost unbelievable.” Similar results were obtained by Baldwin (2) who maintained detailed records in butterfat and recommended that the supervisor receive a record of the amount of products charged to each department and the amount actually accounted for at the end. Weber (24) likewise checked the operations in the market milk plant by balancing the amount of butterfat sold against that purchased. Dahlberg, Hening and Durham (8) found from work carried on with market milk plants that 0.5 percent of the milk received would be lost when no special attempt was made to completely drain milk from equipment and cans.

The application of the materials-balance has not been entirely neglected in the butter manufacturing plants. In 1918, Washburn, Dahlberg, Sorenson and Mortensen (23) determined the butterfat losses in some of the well-managed creameries in Minnesota. From this work they reported that the creamery receiving milk lost about 3.17 percent of the butterfat during the process of manufacture, while the creamery receiving cream lost about 1.4 percent.
Several experiment station workers have assisted the creamery operators by working with them on the chemical standardization of the products. Abbott (1) reports that in his butter improvement work in California he reached the makers of approximately 75 percent of the butter manufactured in that state and brought the creameries closer to a uniform standard and reduced the butterfat losses. Similar results were reported by Mortensen, Breazeale, Meyer and Michaelian (19) and by Wilster (25, 26). Eckles, Keithley and Combs (10) estimated after completing analyses of 363 samples of Minnesota butter that if the average composition of those would represent the average composition of Minnesota butter then it should have been possible to produce an additional 3,396,186 pounds during the year 1923 by standardizing the composition at 80.5 percent butterfat. Wilster (27) developed algebraic formulas for the chemical standardization of butter.

**FAT LOSSES IN CHURNING**

The losses of fat in the buttermilk are one of the principal losses responsible for a low overrun. Wallace (22) as early as 1893 made several analyses of buttermilk from Iowa creameries and found samples testing as high as 2.5 percent butterfat. He also tested a number of samples from the farm dairies, some of which tested up to 4.0 percent fat. Derby (9) found that the test of the buttermilk varied from as high as 2.431 percent to as low as 0.549 percent. Sweet cream churned immediately after cooling gave the highest fat loss, while sweet cream containing starter and held overnight gave the lowest fat content of the buttermilk.

Hansen and Langmack (13) in 1926 carried on extensive experiments to determine the fat losses in the buttermilk from the Danish creameries. Their results indicated that when they churned what they called rich cream (cream containing from 26 to 35 percent fat) the buttermilk would test from 0.523 to 1.102 percent fat, while the buttermilk from cream of normal richness (20 to 26 percent fat) contained from 0.468 to 0.772 percent fat and that from thin cream (14 to 20 percent fat) from 0.494 to 0.773 percent fat. The loss figured in percent of the total amount of fat handled came in the reverse order.

Bird and Derby (7) reported the lowest churning loss they attained to be in the vicinity of 1.00 to 1.20 percent of the total fat churned and was from churning cream testing 37.5 percent fat. When churning a 30-percent cream they found
the lowest loss figure to fall between 1.40 and 1.60 percent of the total fat placed in the churn.

Wilster, Robichaux, Stout and Stein (28) reported that an average of 1.22 percent of the total fat was lost in the buttermilk from 148 lots of cream pasteurized in the vat and churned in the Oregon Experiment Station Dairy Products Laboratory during the year 1937, the tests of buttermilk ranging from 0.5 to 3.2 percent. The same authors report an average fat test of the buttermilk from a creamery operating a 5000-pound capacity vacreator at 0.80 percent, and after changing manufacturing methods the fat test was reduced to 0.71 percent. Another creamery operating a 2,500-pound capacity vacreator obtained an average of 0.97 percent fat in the buttermilk; but by changing manufacturing methods the average for the following churnings was reduced to 0.91 percent. It should be noted that the butylalcohol test for fat was used, which gives a slightly lower reading than the Mojonnier test.

CALCULATING THE AMOUNT OF BUTTERMILK

To determine the amount of butterfat lost in the buttermilk it is essential to calculate as accurately as possible the amount of buttermilk obtained from the churning. Farr (11) made analyses of the dry butter granules obtained from a series of churnings. In accordance with this the butter granules were found to contain about 11 percent of buttermilk. This is in harmony with the report made by Valentine (21) that under New Zealand conditions the butterfat will retain 12 percent of its own weight of buttermilk.

Accepting the analysis by Farr, Mortensen (17) made the following formula:

\[
Y = C \times \frac{100 - (b + T)}{100 - (b + t)}
\]

derived from the equation

\[
C = \left( C \times \frac{T}{100} - Y \times \frac{t}{100} \right) \times \frac{100}{100 - b + Y}
\]

Y = lbs. of buttermilk obtained in free form;
\( b \) = % of buttermilk content of the butter granules;
C = lbs. cream churned;
T = test of cream;
t = test of buttermilk.

LIMITS OF ERROR OF THE BABCOCK TEST FOR CREAM

Martin, Fay and Renner (16) conducted a series of experiments to measure the limits of error of the Babcock test for cream. "A large number of tests were made on a single
can of sweet cream, and, in another trial, on cream, before and after it had soured. The tests were read by several readers, both experienced and inexperienced.

"The results of the first trial, consisting of 456 readings, indicate that the practical limits of variation of the tests were 0.444 percent. The second trial substantiated the results of the first, showing the limits to be over 0.413 percent on sweet cream and 0.443 on sour cream." It was also found that when submitting samples of known and unknown identity for determining the percent of butterfat, the error of testing was much greater when the operator was unaware that his work was being checked.

THE KOHMAN METHOD FOR MAKING ANALYSIS OF BUTTER

The Kohman method of making a complete analysis of the butter is simple and readily can be performed by the creamery operator. Guthrie (12) found it to be "fully as nearly accurate" as the Association of Official Agricultural Chemists procedure. Overman and Okimoto (20) in making comparisons of the decantation method with the Kohman method of direct weighing found from 24 comparisons on fat determinations that the differences would range 0.01 to 0.19 percent, and they recommended the method by saying

1. "The method is accurate, giving results which check very closely with the slower laboratory methods.
2. "The method is simple and easy to manipulate. No more skill is necessary for its successful use than is required in the usual moisture determination."

Bird and Breazeale (6) concluded after comparing the A. O. A. C., the Rose-Gottlieb, the Mojonnier and the Kohman methods that the Kohman method was sufficiently accurate for plant use.

EXPERIMENTAL PROCEDURE

The outstanding objective of this project was to determine the various fat losses in the manufacture of butter in Iowa creameries. These losses were classified as follows: Losses in skimmilk; losses in buttermilk; losses due to faulty fat content of the butter; losses due to overweight allowed on butter; miscellaneous losses, such the result of spillage of milk or cream, cream adhering to pipes, inaccuracy in weighing and testing, etc.

In order to be able to determine the various losses occurring during the process of manufacturing it was necessary to obtain from the creameries samples of the cream, rinsings from cream cans, starter, buttermilk and butter. The
samples were transferred to 8-ounce jars with perfect seals and expressed to the Dairy Industry laboratory for analysis. The various systems of operation employed by the operators determined to some extent the number of samples that would be required.

The day a creamery would start to take samples and prepare a record to be used for the project, Professor A. W. Rudnick, or the leader of the project, would work with the operator and instruct him in the methods he was to follow.

OBTAINING THE SAMPLES FOR ANALYSIS

The creamery operators selected for this work were known to be careful and capable, which was essential to the success of the project, since the results had to be based on the reports and the accuracy of the samples turned over to the Experiment Station laboratory by the operators.

THE CREAM SAMPLES

If the cream was smooth and uniform in texture the sample might be taken after it had been stirred in the vat from 20 to 30 minutes without making any attempt to heat the cream. The samples were taken with a McKay sample tube and from three positions in the vat; one part of the sample was taken 12 inches from the gear-end of the vat, one 12 inches from the cream-outlet-end and a third from a position midway between the two.

A clean and dry dipper would be used as a receptacle, and after thoroughly mixing the cream in the dipper enough of it would be transferred to the sample jar to thoroughly fill it so to prevent the cream from churning while in transit. If the cream showed any irregularity in texture then it was heated to 70° F., and stirred in the vat until it was smooth and absolutely uniform throughout before the sample was taken.

After the cream had been pasteurized a second sample was taken. This was for the purpose of being able to determine the amount of water that evaporated during the process of pasteurization.

The water used for rinsing the vat after transferring the cream to the churn was weighed and the weight added to the pounds of cream recorded for the vat after pasteurization; no sample was taken from such rinsings, but a third sample was taken from the cream in the churn after five revolutions of the churn in working gear. Some of the creamery operators were able to bring the churn samples to the laboratory in perfect condition, and such samples served as valuable checks on the other samples; but the ma-
The majority of the operators were in too great a hurry when transferring to the sample jars. There would generally be considerable air left in the cream and the jars would not be filled. The cream would therefore partly churn while in transit and the churn samples would in that case be of no value. Certain creameries were equipped for weighing the cream in a weigh tank, and the can steamer was connected so the rinsings from the cans would enter the weigh tank. In that case no sample was taken from the rinsings since they were mixed with the cream before the cream sample was taken.

**SAMPLE FROM CAN RINSINGS**

The can rinsings were collected in 10-gallon cream cans, and the cans were filled to the breasts. The samples were taken with a McKay tubular sampler in the manner followed when taking the cream samples.

**THE STARTER SAMPLE**

The same method as outlined for taking the sample from the can rinsings was followed in taking the starter sample.

**THE BUTTERMILK SAMPLE**

The sample was obtained by taking with a dipper from six to eight samples of about equal size and taken at equal intervals from the buttermilk at the time it was being drained from the churn, this being thoroughly mixed and the sample jar filled.

**THE BUTTER SAMPLE**

The butter sample was obtained by taking equal parts from three different locations in the churn; one 12 inches from the gear-end of the churn, one the same distance from the buttermilk-outlet-end and a third from an equal distance between the two. The three samples together would constitute about 4 ounces.

After all the samples had been obtained they were expressed immediately to the Dairy Industry Department, Iowa State College, and Report I was made out on a specially prepared form and mailed to the department.

**ANALYTICAL METHOD**

The chemical analyses were made in the Dairy Industry chemistry laboratory by the Mojonnier method.

**FORM FOR RECORDING RESULTS**

A special form was prepared for recording results, a copy of which, Report II, completely worked out, was mailed to
the creamery operator for each churning on which he had reported.

CALCULATING THE RESULTS

To give a definite understanding of the system employed in calculating the results the following will serve as illustration.

Report I represents a report of a churning by one of the operators participating, and Report II represents the report mailed to the operator after the samples had been analyzed and the calculations completed.

REPORT I

THE CREAMERY OPERATOR'S REPORT

<table>
<thead>
<tr>
<th>Name of creamery</th>
<th>Date</th>
<th>Lbs. of cream received from patrons for churning</th>
<th>Lbs. neutralizer and water added before first vat sample</th>
<th>Additional neutralizer and water added before second vat sample</th>
<th>Lbs. neutralizer and water added after second vat sample</th>
<th>Lbs. rinsings from cans</th>
<th>Were can rinsings added to experimental vat?</th>
<th>Before or after taking first vat sample?</th>
<th>Was cream weighed in cream cans or in weigh tank?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>3,969</td>
<td>1⁄4</td>
<td>none</td>
<td>none</td>
<td>65</td>
<td>yes</td>
<td>Before</td>
<td>Cream Cans</td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

If in weigh tank were rinsings weighed with cream? ________________

Lbs. of starter added 71

Acidity of starter 0.85%

Lbs. of vat and pipe rinsings, etc. added to the churn 16

Amount of salt added to butter 28 lbs.

Total pounds of butter taken from churn 1,261

Lbs. of butter allowed for overweight or shrinkage 5

Pasteurization temperature 145°F. Min. held at that temp. 30

Minutes for heating from initial to pasteurizing temperature 12

Size of vat 400 gallons

Vat open or closed during heating? open. During holding? closed

Acidity of cream received? 0.3%. Neutralized to 0.15%

Churning temperature 46°F.

Hours between pasteurization and churning 14

Kind of churn Cherry-Burrell Size 1,200 lb. Capacity

Signed: .............................................................................

Operator
### EXPERIMENT STATION REPORT:

**Report II**

**Name of Creamery**

**Name of Operator**

<table>
<thead>
<tr>
<th>DATE</th>
<th>ANALYSIS FOR FAT</th>
<th>SALT</th>
<th>LBS. CREAM IN VAT WHEN SAMPLE IS TAKEN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Butter</td>
<td>Vat</td>
<td>Churn</td>
</tr>
<tr>
<td>80.22</td>
<td>25.68</td>
<td>25.53</td>
<td>13.98</td>
</tr>
</tbody>
</table>

### LBS. CREAM IN CHURN

<table>
<thead>
<tr>
<th>Plus lbs. can rinsings</th>
<th>Plus lbs. neutralizer and rinsings added after vat</th>
<th>Less lbs. evaporated during pasteurization</th>
<th>Total lbs. cream in churn</th>
<th>Can rinsings</th>
<th>Starter</th>
<th>Lbs. fat by vat test plus fat added</th>
<th>Lbs. fat by churn test</th>
<th>Lbs. fat in butter</th>
<th>Lbs. butter made</th>
<th>Lbs. butter sold</th>
<th>Lbs. fat in butter made</th>
<th>From vat test</th>
<th>From churn test</th>
<th>Based on fat losses</th>
<th>Total percent reduction by all losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>71</td>
<td>12.5</td>
<td>4,087.5</td>
<td>2.85</td>
<td></td>
<td>1033.38</td>
<td>1043.54</td>
<td>1261</td>
<td>1256</td>
<td>1011.57</td>
<td>21.54</td>
<td>20.36</td>
<td>21.54</td>
<td>3.46</td>
<td></td>
</tr>
</tbody>
</table>

### DISTRIBUTION OF LOSSES

<table>
<thead>
<tr>
<th>Buttermilk</th>
<th>Overweight</th>
<th>Composition</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs. buttermilk</td>
<td>Lbs. fat lost</td>
<td>Lbs. butter lost</td>
<td>Lbs. fat lost</td>
</tr>
<tr>
<td>2,932</td>
<td>15.25</td>
<td>1907</td>
<td>1.58</td>
</tr>
</tbody>
</table>

### REMARKS

- Total lbs. of cream in churn: 4,087.5
- Can rinsings: 2.85
- Starter: 1033.38
- Lbs. fat by vat test plus fat added: 1043.54
- Lbs. fat by churn test: 1261
- Lbs. fat in butter: 1256
- Lbs. butter made: 1011.57
- Lbs. butter sold: 21.54
- Lbs. fat in butter made: 20.36
- From vat test: 21.54
- From churn test: 21.54
- Based on fat losses: 3.46
- Total percent reduction by all losses: 21.54
**TABLE 1. THE AVERAGE FAT LOSSES AND OVERRUN FROM 272 CHURNINGS MADE A VACR**

<table>
<thead>
<tr>
<th>Creamery number</th>
<th>Creamery</th>
<th>A.V. test of cream</th>
<th>Lbs. of fat</th>
<th>Butter</th>
<th>Buttermilk</th>
<th>Fat losses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>churns</td>
<td></td>
<td>In vat</td>
<td>In butter</td>
<td>Churned</td>
<td>Sold</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>27.94</td>
<td>18,683.04</td>
<td>18,292.08</td>
<td>22,768.50</td>
<td>22,679.00</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>28.82</td>
<td>23,409.34</td>
<td>23,161.92</td>
<td>28,557.20</td>
<td>28,515.00</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>29.33</td>
<td>5,664.45</td>
<td>5,741.31</td>
<td>7,145.80</td>
<td>7,111.81</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>27.56</td>
<td>9,280.15</td>
<td>9,008.35</td>
<td>11,218.00</td>
<td>11,178.50</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>33.51</td>
<td>4,530.96</td>
<td>4,451.83</td>
<td>5,809.61</td>
<td>5,874.00</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>30.60</td>
<td>9,981.52</td>
<td>9,706.62</td>
<td>12,645.25</td>
<td>12,588.25</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>31.78</td>
<td>5,251.69</td>
<td>5,199.23</td>
<td>6,497.24</td>
<td>6,393.24</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>34.53</td>
<td>7,534.17</td>
<td>7,555.82</td>
<td>9,630.94</td>
<td>9,539.99</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>32.74</td>
<td>3,031.68</td>
<td>2,932.10</td>
<td>3,720.85</td>
<td>3,525.00</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>33.14</td>
<td>6,486.43</td>
<td>6,409.08</td>
<td>7,960.00</td>
<td>7,956.75</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>35.00</td>
<td>3,406.33</td>
<td>3,329.41</td>
<td>4,113.75</td>
<td>4,071.00</td>
</tr>
<tr>
<td>12</td>
<td>15</td>
<td>31.05</td>
<td>13,002.06</td>
<td>12,693.41</td>
<td>15,720.95</td>
<td>15,675.75</td>
</tr>
<tr>
<td>13</td>
<td>22</td>
<td>36.75</td>
<td>19,342.99</td>
<td>19,059.12</td>
<td>23,765.26</td>
<td>23,688.40</td>
</tr>
<tr>
<td>14</td>
<td>19</td>
<td>25.14</td>
<td>15,102.99</td>
<td>14,738.10</td>
<td>18,358.00</td>
<td>18,273.95</td>
</tr>
<tr>
<td>15</td>
<td>31</td>
<td>32.23</td>
<td>17,277.60</td>
<td>16,990.46</td>
<td>21,151.69</td>
<td>21,070.36</td>
</tr>
<tr>
<td>16</td>
<td>8</td>
<td>28.70</td>
<td>6,170.68</td>
<td>5,874.57</td>
<td>7,279.03</td>
<td>7,244.18</td>
</tr>
<tr>
<td>17</td>
<td>19</td>
<td>25.95</td>
<td>12,999.26</td>
<td>12,603.17</td>
<td>16,555.75</td>
<td>16,498.09</td>
</tr>
<tr>
<td>18</td>
<td>12</td>
<td>34.71</td>
<td>11,029.24</td>
<td>10,933.49</td>
<td>13,618.66</td>
<td>13,548.66</td>
</tr>
<tr>
<td>19</td>
<td>13</td>
<td>27.06</td>
<td>8,083.44</td>
<td>7,700.97</td>
<td>9,575.25</td>
<td>9,513.93</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>33.32</td>
<td>3,230.66</td>
<td>3,227.78</td>
<td>3,905.00</td>
<td>3,893.60</td>
</tr>
<tr>
<td>21</td>
<td>24</td>
<td>28.39</td>
<td>1,324.15</td>
<td>1,293.24</td>
<td>1,814.00</td>
<td>1,808.25</td>
</tr>
<tr>
<td>22</td>
<td>7</td>
<td>34.55</td>
<td>1,504.38</td>
<td>1,460.48</td>
<td>1,820.00</td>
<td>1,810.95</td>
</tr>
<tr>
<td>23</td>
<td>14</td>
<td>30.13</td>
<td>12,713.93</td>
<td>12,602.40</td>
<td>15,706.00</td>
<td>15,649.33</td>
</tr>
<tr>
<td>24</td>
<td>1</td>
<td>31.88</td>
<td>1,018.12</td>
<td>890.71</td>
<td>1,198.60</td>
<td>1,193.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>272</td>
<td></td>
<td>219,648.65</td>
<td>215,591.71</td>
<td>286,151.62</td>
<td>286,931.38</td>
</tr>
</tbody>
</table>

**TABLE 2. THE AVERAGE FAT LOSSES AND OVERRUN FROM 25 CHURNINGS MADE A VACR**

<table>
<thead>
<tr>
<th>Creamery number</th>
<th>Creamery</th>
<th>A.V. test of cream</th>
<th>Lbs. of fat</th>
<th>Butter</th>
<th>Buttermilk</th>
<th>Fat losses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>churns</td>
<td></td>
<td>In vat</td>
<td>In butter</td>
<td>Churned</td>
<td>Sold</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>25</td>
<td></td>
<td>17,244.41</td>
<td>16,512.28</td>
<td>20,544.72</td>
<td>20,422.53</td>
</tr>
</tbody>
</table>
AT THE 24 CREAMERIES REPRESENTED, THE CREAM WAS PASTEURIZED IN VAT.

### Table 1 and 2

<table>
<thead>
<tr>
<th>Percent overrun</th>
<th>From general creamery overrun</th>
<th>Obtained from 35% other than miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lost</td>
<td>Gained</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Lost</td>
<td>Gained</td>
<td>Lost</td>
</tr>
</tbody>
</table>

#### Composition of butter

<table>
<thead>
<tr>
<th>Percent overrun</th>
<th>From general creamery overrun</th>
<th>Obtained from 35% other than miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lost</td>
<td>Gained</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Lost</td>
<td>Gained</td>
<td>Lost</td>
</tr>
</tbody>
</table>

#### Miscellaneous losses

<table>
<thead>
<tr>
<th>Percent overrun</th>
<th>From general creamery overrun</th>
<th>Obtained from 35% other than miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lost</td>
<td>Gained</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Lost</td>
<td>Gained</td>
<td>Lost</td>
</tr>
</tbody>
</table>

### THE THREE CREAMERIES REPRESENTED. THE CREAM WAS PASTEURIZED IN VAT.
WATER AND CREAM IN CAN RINSINGS

The experiment station report, Report II, is self-explanatory up to the second and third column under "Lbs. of cream in vat when sample is taken." After the work had been started it was soon found that the different manufacturing systems employed by the creamery operators required various methods of making the calculations without changing the system employed by the individual creamery operator. What became most difficult was to determine the amount of rinsings that was actually cream and the amount of water that had been added. To determine this correctly was not always possible by simple arithmetic, and in most cases it became necessary to use algebraic formulas.

The simplest calculations were from reports of creameries where the cream, as received, was weighed in a weigh can with adjustment permitting the rinsings to enter the weigh can before recording the weight and taking the sample for testing. In that case the rinsings would be included directly in all considerations.

Some operators were not using neutralizers nor adding the rinsings to the cream for experimental churnings. Under that system of operation the amount of cream in the rinsings would be subtracted from the amount originally weighed in for the churning and would be determined as follows:

\[
\text{Lbs. can rinsings} \times \frac{\text{Test of can rinsings}}{\text{Test of original cream}} = \text{Lbs. of cream in rinsings}
\]

Some operators would add the rinsings to the cream before the sample of cream was taken. The same operator would not use neutralizer or, if used, the neutralizer would be added after the cream sample was taken. In that case the water in the rinsings should be added to the cream originally weighed into the vat and would be determined by the following formula (18):

\[
X = \frac{1}{2} \left( R - C + \sqrt{(C + R)^2 - 4 \frac{C R t T}{T_t}} \right)
\]

This formula is derived from the following equations:

\[
(C + X) T_t = C T
\]

\[
R t = (R - X) T
\]

C represents pounds cream weighed in for vat
R represents pounds can rinsings
X represents pounds water in can rinsings
T represents test of original cream
T_t represents test of (original cream + water in can rinsings)
t represents test of can rinsings

Operators receiving sour cream will generally add the rinsings and the neutralizer solution before the cream sample is taken from the vat, and the vat will thus contain pounds of cream weighed in for the vat + pounds of water in rinsings + pounds of neutralizer solution. Under this system of operation the pounds of water in the rinsings may be determined from the following formula (18):

\[ X = \frac{1}{2} \left\{ C + N + R + \sqrt{(C + N + R)^2 - \frac{4}{T_s} CRt} \right\} -(C + N) \]

derived from equations

\[(C + X + N)T_s = CT\]
\[Rt = (R - X) T\]

N represents lbs. neutralizer solution added
T_s represents (cream + water in can rinsings + neutralizer solution)

Other symbols are the same as in the former formula.

In some creameries the operators follow the procedure of adding only the neutralizer before taking the sample of cream for testing and adding the rinsings to the cream for some different churning. When that method is employed the amount of cream in the rinsings will be subtracted from the original amount weighed in for the experimental vat and is determined by the following formula:

\[ Y = \frac{1}{2} \left( C + N + \frac{Rt}{T_s} \right) - \frac{1}{2T_s} \sqrt{[(C + N)T_s + Rt]^2 - \frac{4}{C R t T_s}} \]

derived from the following equations

\[(C + N - Y)T_s = C T - Rt\]
\[Rt = YT\]

Y represents pounds of original cream in can rinsings.
T_s represents test of (original cream + neutralizer solution — cream in can rinsings).

LBS. CREAM IN CHURN

Two samples were taken from the cream in the vat, one before and one after pasteurization; only the first test is recorded on the report; the second test is taken so as to be able to determine, to a fair degree of accuracy, the amount of evaporation taking place during pasteurization. The amount of evaporation varies with methods employed in pasteurization; in this case the test of the cream was 25.76 after pasteurization, and since the test before pasteurization
was 25.68 the amount of evaporation is equal to

\[ 4013 - \left[ 4013 \times \frac{25.68}{25.76} \right] = 12.5 \text{ pounds.} \]

LBS. FAT AND BUTTER

The figures under the headings of "lbs. fat" and "butter" need no further explanation except that the fat as determined from the cream in the vat is the most dependable and has been used in the following calculations. In the case of this report the difference of 10.15 pounds between the fat calculated for vat and churn falls inside of the difference generally considered to be permissible, and considerably inside when measured by the results obtained by Martin, Fay and Renner (16), who after reading 456 Babcock tests decided that the practical limits of variation of the tests were 0.444 percent. The variation in reading the tests from vat and churn samples for this churning were,

\[ \left( \frac{25.53 \times 1043.54}{1033.38} \right) - 25.53 = 0.25 \text{ percent.} \]

DISTRIBUTION OF LOSSES

The amount of fat actually lost during the churning process is equal to "amount of fat in the vat—amount of fat in the butter," or in this case 1033.38 — 1011.57 = 21.81 pounds. Since 15.25 pounds of this amount is lost in the buttermilk the remaining 6.56 pounds will be entered under "Miscellaneous losses." Under such are included other losses of fat, aside from those in the buttermilk, occurring during the various stages of processing. They furthermore include chemical analytical errors and possible errors in weighing the cream and butter.

Although it is considered that the actual fat losses are divided between buttermilk and miscellaneous losses there is in addition thereto a small percentage of the fat actually incorporated in the butter but on which the operator will not realize any returns; as such it should be considered as a part of that which is allowed for overweight and for the fat contained in the butter in excess of 80 percent. Butterfat thus disposed of will naturally reduce the overrun the same as the fat that has been lost in the manufacturing process.

THE OVERRUN

The creamery operator uses the term "theoretical overrun" to indicate an overrun that would be obtained if it were possible to eliminate all losses and make a product that contains
80 percent butterfat. Under such conditions an overrun of 25 percent would be obtained. The highest overrun that it is possible to obtain by this system is determined by figuring the reduction in overrun caused by the four sources of losses—Buttermilk, Overweight, Composition and Miscellaneous. The sum of these subtracted from 25 gives the correct overrun, and should check within 0.03 percent with the overrun determined from the butterfat in the vat and the butter sold.

Since the overrun consists of pounds of butter made in excess of the butterfat utilized it is natural that when the effect of losses on the percent overrun obtained is considered such reduction in losses must also be based on butter. Therefore, in the case of the report under consideration the loss of butterfat in the buttermilk amounted to 15.25 pounds of fat. This, based on a theoretical overrun, would produce 19.07 pounds of butter. The reduction in overrun as a result of this loss would be equal to

\[
\frac{19.07}{1033.38} \times 100 = 1.85 \text{ percent}
\]

RESULTS OBTAINED

Tables 1 and 2 give a summary of the results obtained from 297 churnings made in 26 different creameries. It represents a total of 809,067 pounds of cream containing 236,893.06 pounds of butterfat. The average percent of fat in the cream received at the creameries was 29.28. Table 1 summarizes results from 26 creameries pasteurizing in coil vats, while table 2 summarizes results from three creameries employing the vacuum process of pasteurization. They were using the vacreator and heating the cream to 190-200° F.

It will be noted from table 1 that 1.39 percent of the fat received was lost in the buttermilk. This loss reduced the overrun 1.74 percent from the theoretical 25 percent. Overweight on butter absorbed 0.45 percent of the fat received and further reduced the overrun 0.56 percent. The chemical composition of the butter, allowing above 80 percent butterfat, absorbed 0.54 percent of butterfat received and reduced the overrun 0.67 percent. Those three together amounted to 2.38 percent of the total amount of butterfat received and were responsible for a reduction in overrun of 2.97 percent. This would allow for an overrun of 22.03 percent, and that only if there were no miscellaneous losses to consider. The miscellaneous losses recorded by these experiments reduced the total fat received 0.42 percent and
decreased the overrun further 0.52 percent.

The buttermilk from cream pasteurized by the vacreator, table 2, contained 1.98 percent of the fat received and the overrun was thus reduced 2.47 percent. Overweight reduced the butterfat 0.57 percent and the overrun 0.71 percent. The butter contained 0.49 percent of excess fat which reduced the overrun 0.61 percent. These together represent 3.04 percent of the butterfat received from which the operator will not receive any return and it represents a reduction in overrun of 3.79 percent, making possible only a 21.21 percent overrun without making any reductions for miscellaneous losses.

STANDARD FOR FAT IN BUTTER

The butterfat content of the butter from the 20 creameries sending the larger number of samples for analysis is presented in table 3. Most creameries are at the present time adopting a standard butterfat content for butter of 80.5 percent. This would seem to be fair and allow for sufficient margin to make up for possible errors in making the analysis at the creamery.

The average fat content of the 297 churnings analyzed under this project was 80.43 percent, which shows a fair improvement over the results published by this Station in 1937 (9) when 43 creameries started with a 4-months average of 81.19 percent and finished with another 4-months average of 80.81 percent, while another group of 16 creameries started with a 4-months average of 80.86 percent and finished with another 4-months average of 81.16 percent.

Some of the creameries will still have an occasional churning falling slightly below the required 80 percent. Ten percent of the samples analyzed fell slightly below 80 percent, but by giving credit for the average overweight of 7.28 oz. of butter for every hundred pounds sold there was only 1 percent of the churnings which should not contain the required amount of butterfat and would most likely give a satisfactory analysis by the time it reached the market.

The creameries have also in this respect made great improvement since the report of 1937 when one creamery was reported making 83.33 percent of its butter low in butterfat and many creameries were making from 25 to 50 percent of their butter with low fat content (9).

MISCELLANEOUS LOSSES

As reported, miscellaneous losses give more of an idea of the operator's system of reporting than of definite losses that might be expected to be entered under the column of "mis-
TABLE 3. THE AVERAGE FAT CONTENT OF BUTTER FROM 20 IOWA CREAMERIES.*

<table>
<thead>
<tr>
<th>Creamery</th>
<th>Fat content of butter</th>
<th>Calculated loss to a creamery having an annual output of 500,000 pounds of butter when the average fat content of the butter exceeds 80.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>High</td>
</tr>
<tr>
<td>A</td>
<td>80.24</td>
<td>80.89</td>
</tr>
<tr>
<td>B</td>
<td>80.42</td>
<td>80.96</td>
</tr>
<tr>
<td>C</td>
<td>80.32</td>
<td>80.72</td>
</tr>
<tr>
<td>D</td>
<td>80.49</td>
<td>81.46</td>
</tr>
<tr>
<td>E</td>
<td>80.71</td>
<td>81.16</td>
</tr>
<tr>
<td>F</td>
<td>80.33</td>
<td>80.67</td>
</tr>
<tr>
<td>G</td>
<td>80.28</td>
<td>80.61</td>
</tr>
<tr>
<td>H</td>
<td>80.13</td>
<td>80.53</td>
</tr>
<tr>
<td>I</td>
<td>80.40</td>
<td>80.86</td>
</tr>
<tr>
<td>J</td>
<td>80.94</td>
<td>81.36</td>
</tr>
<tr>
<td>K</td>
<td>80.62</td>
<td>80.97</td>
</tr>
<tr>
<td>L</td>
<td>80.41</td>
<td>80.69</td>
</tr>
<tr>
<td>M</td>
<td>80.54</td>
<td>80.76</td>
</tr>
<tr>
<td>N</td>
<td>80.59</td>
<td>81.25</td>
</tr>
<tr>
<td>O</td>
<td>80.58</td>
<td>81.09</td>
</tr>
<tr>
<td>P</td>
<td>80.80</td>
<td>82.17</td>
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<tr>
<td>Q</td>
<td>80.30</td>
<td>80.71</td>
</tr>
<tr>
<td>R</td>
<td>80.25</td>
<td>80.67</td>
</tr>
<tr>
<td>S</td>
<td>80.74</td>
<td>81.50</td>
</tr>
<tr>
<td>T</td>
<td>80.34</td>
<td>80.94</td>
</tr>
</tbody>
</table>

* The twenty creameries represented by the largest number of churnings.

cellular losses.” In accordance with the instructions given, the operators were supposed to record half pounds, when receiving cream for the experimental churnings, and for smaller fractions follow the system of “give and take.” In a few cases the operators report less cream than was actually received at the creamery. The shortage readily can be estimated as will be illustrated in the following:

Creamery A reports receipt of 3,263 pounds of cream testing 31.26 percent butterfat, or a total of 1,020 pounds butterfat. This cream produced butter containing, in accordance with analysis, 1027.9 pounds butterfat. The loss in the buttermilk represented 13.15 pounds butterfat. Considering the fat losses in the buttermilk to be the only losses of butterfat to be considered, the creamery actually received 1027.9 + 13.15, or 1041.05 pounds butterfat, which leaves a difference of 1,041.5 — 1,020 or 21.05 pounds butterfat less than was actually received. This converted into cream would amount to $21.05 \times \frac{100}{31.26}$ or 67.3 pounds testing 31.26 percent butterfat. Whether this shortage in the report of butterfat was due to the creameries taking the fractions in weighing the patrons’ cream or to other errors in weighing is not known.
As a result of these irregularities the figures under column “Miscellaneous losses” are of no value for determining actual fat losses that would be entered in that column if the weight had been properly recorded at the creamery, but it is of considerable interest in the matter of observing that there is a marked lack of uniformity, especially in the weighing of cream, at the various creameries.

THE OVERRUN OBTAINED

Column I, tables 1 and 2, gives the overrun as determined from the amount of butterfat received and the amount of butter sold. Figures in column II are obtained by adding the figures for percent reduction in overrun for buttermilk, overweight, composition and miscellaneous, and subtracting the sum from 25. Wherever the figure under “Miscellaneous” shows a gain instead of a loss, as is the case with creamery No. 2 and others, the figure will be subtracted from the sum of the other three figures. The figures in column II should for each individual churning check to within 0.03 of 1 percent with the figure in column I.

The figures recorded in column III are obtained by ignoring the losses recorded under “Miscellaneous.” The percent overrun thus recorded is therefore somewhat higher than the actual overrun that was obtained; the error depending on the real value of miscellaneous losses. This figure is recorded because the calculations up to that point are based on definite results obtained from this research, while, as already stated, the miscellaneous losses as recorded include several irregularities and errors made in some of the creameries and which would therefore not represent a figure that would give the actual loss that should be considered under miscellaneous losses.

DISCUSSION OF RESULTS

In accordance with this survey, there has been great improvement made during recent years in the control of composition of Iowa butter, thus making it a more uniform product and tending toward a more uniform butter overrun for the creamery. There is, however, still room for improvement.

RICHNESS OF CREAM AND OVERRUN

It will be noted, fig. 1, that when churning a cream testing 26 percent fat, the overrun is reduced to 2 percent as a result of fat losses in the buttermilk. By churning cream testing 33 percent fat the overrun is reduced 1.4 percent,
making a difference of 0.6 percent, or it represents a difference in reduction of 0.48 percent of the total amount of fat lost. This additional loss by churning the low-testing cream would at a 22 percent overrun net a creamery receiving 400,000 pounds of fat annually an additional 2,342 pounds of butter which if sold at 35 cents per pound would have increased the annual receipts of that creamery to the amount of $819.70.

It will be noted that one creamery is entirely out of line with the other creameries participating (fig. 1). The average test of the cream received was 28.7 percent and the average test of the buttermilk 2.74 percent, or 2.192 percent of the total amount of butterfat received. This loss in butterfat was 1.072 percent greater than the average loss on a 33 percent cream.

Assume that this creamery received 800,000 pounds of fat annually; then this excessive loss would amount to 8,576 pounds of butterfat or 10,462 pounds of butter, figured at a 22 percent overrun. Had this been sold at 35 cents per pound it would have represented an annual saving of $3,661.

Since the creameries participating in this work had been carefully selected it is evident that greater losses would be expected had the creameries been chosen at random.

---

4 This is less than was actually received by that creamery.
From the figures presented it might appear that it would be advisable to have the producers understand that the butterfat losses decrease much in proportion to the increase in the fat content of the cream and that even a 50 percent cream might be more profitable to produce than a cream testing from 30 to 40 percent.

The operator when giving information to the producers should first of all have in mind the method or methods by which the sale of cream will become most profitable to the producers. As the richness of the cream is increased, there is a slight increase in the fat lost in the skimmilk (14). This loss is, under Iowa conditions, more than offset by the value of the additional amount of skimmilk that will be available for feeding purposes. Extremely rich cream may however cause other losses of butterfat such as having more cream adhering to the inside parts of the separator. A richer cream is also more difficult to transfer from one container to another without loss, as more cream will adhere to the wall of the container. This may be partly overcome by pouring hot water on the outside of the container before emptying. Some will rinse the container with water which will be added to the cream, but by that procedure the amount of fat lost in the buttermilk will be increased (28). It has been the experience of the author that a cream testing from 30 to 35 percent fat, or under certain conditions up to 40 percent, can be satisfactorily produced.

In creameries where whole milk is being received for buttermaking purposes a reasonably rich cream can be produced to advantage, since all conditions then should be under perfect control.

COMPOSITION OF BUTTER AND OVERRUN

The average percent of fat in the butter obtained from the 272 churnings, reported in table 1, was 80.43 percent which should be considered as excellent; but some of the samples are still too close to the 80 percent legal limit for butterfat.

Bird (5) analyzed 1,778 consecutive churnings for moisture from August 1 to December 31, 1941. In accordance with those analyses, 24.38 percent did not deviate from the standard on butterfat set by the creamery.

<table>
<thead>
<tr>
<th></th>
<th>44.41</th>
<th>80.16</th>
<th>87.24</th>
<th>96.96</th>
<th>99.46</th>
<th>100.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>percent deviated</td>
<td>0.05</td>
<td>0.10</td>
<td>0.15</td>
<td>0.20</td>
<td>0.30</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Since the salt content can readily be controlled by the buttermaker and the curd content is generally quite uniform in
the butter from the same creamery, it would, in accordance with these analyses, be fair to expect that the fat analyses of the greater number of churnings should come within 0.2 percent ± of the creamery standard for butterfat and should not go above 0.4 percent ± of that standard; therefore, if a creamery should adopt the safe standard of 80.5 percent for butterfat the greater proportions of the churnings would contain from 80.3 to 80.7 percent butterfat and a comparatively few from 80.1 to 80.9 percent. This would leave a safe margin for the lower-testing butter.

Leaving out of consideration what is generally considered as miscellaneous losses the average overrun from 272 churnings, table 1, was 22.03 percent, and for the 25 churnings, table 2, 21.21 percent. The increased loss of fat in the buttermilk when admitting direct steam into the cream as done when pasteurizing with the vacreator may be justified when considering the improvement in flavor and texture of the butter brought about by vacreation.

CREAMERY OVERRUNS

It would be of interest to know how some creameries are able to report overruns ranging from 24.0 to 24.5 percent. The creamery directors generally expect such overruns, and the operator, in order to hold his position, finds it necessary to drop all fractions, thus crediting a producer with 70 pounds of cream if it weighed a fraction over and a test of 32 if it tested a fraction over, or, on the average the creamery gains a half pound of cream for each weighing and a half percent on the test. The cooperative creamery directors generally agree to that system since they can argue that in the cooperative creamery the patrons share in the income from sales in proportion to the amount of butterfat delivered. This way of reasoning is not absolutely correct, since the system works to the disadvantage of the smaller producer as will be noted from the following illustration.

Assume that A and B both patronize the same creamery. A delivers 20 pounds of cream daily while B delivers 80 pounds. Each will average a loss of one-half pound for each delivery. This loss will represent 2.500 percent of A’s delivery but only 0.625 percent of that delivered by B. The loss from testing will affect both alike. The operator will justify the practice by maintaining that it costs more, to the creamery, to handle the cream from the smaller producer. Regardless of any arguments presented, this system does not give a correct overrun and it destroys one of the most valuable measures by which the manufacturing losses may be determined.
It would seem that the time should not be far off when the local creameries would join together for the purpose of establishing a central laboratory from which an occasional check-up would be made as to the efficiency of the individual creamery. This should not, however, relieve the creamery operator from making daily fat analyses of the butter and buttermilk from each churning. The Kohman method for butter analysis and the butyl-alcohol method for buttermilk\(^6\) give satisfactory results. The training required for the successful operation of these tests is no more difficult than that required for the operation of the Babcock test, and it will require only from 15 to 20 minutes to determine the fat and moisture in butter by the Kohman method. The buttermilk testing can be done together with the regular cream testing.

A complete check-up, as outlined in this publication, should be made frequently. This may be simplified by standardizing the methods of butter manufacture. The formulas made use of in the foregoing may be eliminated by weighing the cream in a weigh can and allowing the rinsings to enter before the weight is recorded and the sample taken for the test. Another simple method to be employed when the cream is weighed in the cream cans is to take the sample for analysis from the cream in the vat before the neutralizer solution and rinsings are added.\(^6\) Such methods could be employed in the average creamery without inconvenience to the operator.

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\(^6\) Both tests are fully outlined in Extension Circular 219, Iowa State College, Ames, Iowa.
\(^6\) This method is fully explained on page 664 of this publication.
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