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The Oregon Method of Controlling Moisture and Fat in Butter

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FOREWORD

Analysis at the Oregon Agricultural Experiment Station of thousands of commercial samples of butter submitted by creameries during the past eleven years has shown that a large percentage of the samples contained an excessive amount of fat. As butter contains about 16.5 per cent moisture, the 31 million pounds of butter now made annually in the Oregon creameries contain approximately five million pounds of water. Unless there is proper control over the amount of water present, the butter may either be illegal in composition or it may contain too little moisture, resulting in an economic loss.

A method for calculating the exact amount of water to add to churnings of butter that contain less than the desired percentage of moisture and fat has been developed at the Experiment Station and is presented herein. This method, if applied, should aid the creameries in making butter of more uniform composition.

SUMMARY

In a former bulletin of the Agricultural Experiment Station published in 1935, the attention of the butter industry was called to the lack of uniformity in the composition of the butter made in creameries. From the analysis of several thousand samples of butter, it was found that 27 per cent contained more than 81.0 per cent fat and averaged approximately 81.5 per cent fat (1.0 above 80.5 per cent fat), while a considerable percentage contained less than the legal amount of 80 per cent fat. It was estimated that the loss to the dairy industry due to making butter containing an excessive amount of fat was $25,000 a year.

The bulletin gave specific directions for analyzing butter in the creameries. These directions were based on research at the Experiment Station.

Of the samples of butter analyzed during the eleventh year of the analysis service, 31.6 per cent contained above 80.7 per cent fat, while 50.1 per cent contained above 80.5 per cent fat.

Perhaps the chief reason for the irregularity in the composition of butter has been the lack of an accurate method for calculating the exact amount of water to add and incorporate with churnings of unfinished butter, which contain less than the desired amount of moisture, in order that the percentage of moisture in the finished butter will be as desired. The amount of water to add, calculated by the conventional method, falls short of the amount actually required and will result in finished butter containing from 0.1 to 0.3 per cent less moisture than desired. Because of the importance of this problem to the dairy industry, it has been studied by the Experiment Station and it is possible to offer a practical solution for it at this time.

We present in this bulletin an algebraically derived formula, by application of which it is possible to calculate the amount of water that it is necessary to add to a churning of butter in order that the finished butter will contain the correct percentage of moisture.

To facilitate the use of the formula in creameries a table has been prepared which gives the amount of water to add to churnings containing from 300 to 1,250 pounds of fat with moisture percentages in the unfinished butter ranging from 13.5 to 16.4 per cent. The desired composition of the finished butter is 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd.

Directions for applying the formula to butter of a composition different from that mentioned above are also given.

The method has been used in the manufacture of 93 churnings of butter. The percentage of moisture in the finished butter was within 0.1 per cent of that desired in 84.9 per cent of the churnings.

A second formula to use for calculating the amount of water to add to churnings of butter that contain the desired moisture percentage but contain more than the desired amount of fat, owing to a smaller content of salt and curd than desired, is also given in the bulletin.

Butter should contain not less than 80 per cent fat. A standard of 80.5 per cent fat is suggested for the majority of the creameries. Where exceptional facilities for technical control are available, a standard of 80.2 or 80.3 per cent fat may be used. It is necessary to correctly analyze each churning of butter before it is removed from the churn in order to be sure that the composition is right.

The Oregon Method of Controlling Moisture and Fat in Butter

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IMPORTANCE OF MOISTURE AND FAT CONTROL IN OREGON CREAMERIES

THE problem of regulating the amount of moisture and fat in butter is closely related with efficient creamery management. Normally, butter contains about one-sixth by weight of moisture. There is no State or Federal regulation regarding the amount of water in butter. The law does specify, however, that butter must contain at least 80 per cent fat. This is also the Federal standard. The creameries aim to standardize the fat content of the butter at from 80.0 to 80.5 per cent.

The average composition of Oregon butter is now 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd. A decrease in the moisture content from normal causes a decrease in the yield of butter obtained owing to a higher fat content, while an increase reduces the percentage of fat, sometimes to the extent of making the butter illegal in composition.

If the fat content of Oregon's total butter production of about 31 million pounds a year is 0.1 per cent too high, owing to the incorporation of too little moisture, it would mean a loss, if fat is worth 30 cents a pound, of $9,300, and if it is 0.5 per cent too high the loss would be $46,500.

If the 1,800,000,000 pounds of butter made in creameries in the United States in one year contained 0.1 per cent fat in excess, it would represent a loss of $540,000, and if the excess is 0.5 per cent, the loss would be $2,700,000.

If 800 pounds represent an average churning, the Oregon buttermakers make nearly 40,000 churnings of butter a year. That it is economically important to have technical control in a creamery is seen from the following:

On 350,000 pounds of butter (the yearly production of an average Oregon creamery) the manufacture of butter containing 0.1 per cent more fat than 80.5 per cent through the incorporation of 0.1 per cent too little moisture causes a loss, with fat at 30 cents a pound, of $105, and if it contains 0.5 per cent in excess of the desired fat content the loss would be $525. If the excess is 1 per cent, the annual loss would be $1,050.

A creamery that has good control over the composition will, therefore, be able to return more to the producers than will one that has poor control.

The authors are grateful to Dr. W. E. Milne, Head, Department of Mathematics, for his generous assistance in developing the mathematical formulas presented herein. They appreciate the kindness of Dr. M. Mortensen of the Iowa State College, Ames, Iowa, in reading the manuscript.

CHANGE IN THE COMPOSITION OF OREGON BUTTER SINCE 1929

There has been a steady improvement in regulating the composition of the butter made in Oregon since the monthly butter scoring and analysis service was offered to the nearly 100 creameries in the state in 1929. A comparison of the composition of the butter analyzed during the first month of the first year of the analysis service and during the last month of the tenth year is given in Table 1.

TABLE 1. TEN YEARS OF IMPROVEMENT IN THE COMPOSITION OF OREGON BUTTER

Content	Percentage of all samples	
	First month March 1929	Last month February 1939
	Per cent	*Per cent*
Fat content of samples:		
Range in per cent fat	78.5 to 83.2	79.6 to 82.4
Less than 80 per cent fat	12.9	2.0
80.0 to 80.7 per cent fat	48.7	64.7
80.8 to 81.0 per cent fat	7.7	17.7
81.1 to 82.0 per cent fat	25.6	11.7
82.1 to 83.0 per cent fat	2.5	3.9
More than 83.0 per cent fat	2.6	0
Moisture content of samples:		
Range in per cent moisture	14.6 to 17.4	14.9 to 17.4
Less than 15.4 per cent moisture	25.6	2.0
15.4 to 16.0 per cent moisture	53.9	15.7
16.1 to 16.5 per cent moisture	7.7	49.0
16.6 to 17.0 per cent moisture	7.7	27.4
More than 17.0 per cent moisture	5.1	5.9
Salt content of samples:		
Range in per cent salt	1.2 to 3.55	1.3 to 3.0
Less than 2.0 per cent salt	10.2	17.7
2.0 to 2.5 per cent salt	15.4	76.4
2.6 to 3.0 per cent salt	53.9	5.9
More than 3.0 per cent salt	20.5	0

The fat, moisture, and salt contents of the samples analyzed during the eleventh year of the analytical service, March 1939 to February 1940, are shown in Table 2.

The data in Tables 1 and 2 show that although a considerable improvement in the composition of Oregon butter has been effected through the monthly butter scoring and analysis service, further standardization is desirable.

Change in the per cent fat in butter. A greater percentage of the butter made during the last month of the tenth year and during the eleventh year of the scoring and analysis contained from 80.0 to 80.7 per cent fat than in 1929 when the analytical work was started. Whereas during the first month of the first year of the analytical service only 48.7 per cent of the samples contained from 80.0 to 80.7 per cent fat, during the eleventh year 64.5 per cent of the samples contained that amount. During the first month of 1929, 12.9 per cent of the samples analyzed contained less than the legal amount of fat required (80 per cent), while during the eleventh year only 3.9 per cent fell in this class. In March 1929, a total of 38.4 per cent of the samples contained above 80.7 per cent of fat and during the eleventh year 31.6 per cent contained above 80.7 per cent. The data show that considerable improvement has taken place, but it also indicates that perfection has not yet been reached. A good deal more standardization needs to be done in the creameries.

Change in the moisture content. The moisture percentages have shown definite increases during the eleven years. The increases have been effected

TABLE 2. FREQUENCY DISTRIBUTION OF THE PERCENTAGES OF FAT, MOISTURE, AND SALT

Eleventh Year (617 samples)
March 1939 to February 1940

Content	Percentage of all samples
	Per cent
Fat:	
Less than 80.0 per cent	3.9
80.0 to 80.7 per cent	64.5
80.8 to 81.0 per cent	13.9
81.1 to 82.0 per cent	14.9
82.1 to 83.0 per cent	2.6
Over 83.0 per cent	0.2
Moisture:	
Less than 15.4 per cent	2.9
15.4 to 16.0 per cent	15.3
16.1 to 16.5 per cent	38.2
16.6 to 17.0 per cent	34.0
Over 17.0 per cent	9.6
Salt:	
Less than 2.0 per cent	17.4
2.0 to 2.5 per cent	78.1
2.6 to 3.0 per cent	4.2
3.1 to 3.5 per cent	0.3

partly in order to compensate for the lower salt content of the butter. This lowering of the salt content took place after the second year of the analytical work. In order to meet market demands the industry decided to lower the standard for salt. This necessitated a corresponding increase in the moisture content.

It will be noted by referring to Table 2 that considerable variation existed in the moisture percentage of the 617 churnings of butter analyzed during the eleventh year. Deviation occurred both below and above the average content of 16.5 per cent.

Change in the salt content. The industry decided in 1930 on a salt content of from 2.0 to 2.5 per cent, with an ideal of 2.3 per cent. During the eleventh year 78.1 per cent of the churnings analyzed contained from 2.0 to 2.5 per cent salt. The average for all samples was 2.2 per cent. There is need, however, for further standardization in the salt content because 17.4 per cent of the churnings for the eleventh year contained less than 2.0 per cent while 4.5 per cent contained more than 2.5 per cent salt.

CONTROL OF THE FAT, MOISTURE, SALT, AND CURD CONTENT OF BUTTER

With a legal standard for fat of 80 per cent both for butter sold in Oregon and for butter shipped to other states, it is necessary that, when butter is offered for sale, it never contain less than 80 per cent fat. The buttermakers should endeavor to make butter which contains slightly in excess of 80 per cent fat. A standard percentage of 80.5 would seem practical, although some

buttermakers are able to maintain an average of 80.2 or 80.3 per cent fat in their butter.

Even in the creameries that exercise considerable control over the composition of the butter made, deviations of 0.2 or 0.3 per cent from the standard are generally encountered. Perhaps it will be possible through refinements in butter-working methods to make butter that shows either no deviation or only a slight deviation in the desired percentage of fat.

When butter contains 80.5 per cent fat, which is 0.5 per cent in excess of the legal requirement, the butter produced annually in Oregon would contain:

$$\frac{31{,}000{,}000 \times 0.5}{100} = 155{,}000 \text{ pounds fat in excess.}$$

In terms of butter containing 80 per cent fat this would be:

$$\frac{155{,}000 \times 100}{80} = 193{,}750 \text{ pounds, or about 9 carlots.}$$

At 30 cents a pound the butter that could be obtained would have a value of $58,125.

It is likely that it will be possible during the coming years to gradually reduce the fat content of the butter made. Perhaps the creameries will be able to improve the method of determining the total amount of fat present in the cream to be churned and perhaps certain refinements in the churns manufactured will enable the buttermakers to make butter with a uniform fat content of 80.0 or 80.1 per cent. Proper technical control will be necessary.

For the present most creameries will probably decide on an average fat content of 80.5 per cent with a fluctuation of from 80.3 to 80.7. The present range of from 79.0 to 83.0 per cent is entirely too wide.

REGULATION OF THE COMPOSITION OF BUTTER

The fat content is regulated by the amounts of moisture, salt, and curd present in the butter. Ordinarily, the curd content shows little variation in the butter made at a creamery when careful attention is given to neutralization, pasteurization, and washing the butter. The salt content of butter should show little variation between different churnings. Control of the salt content involves (1) accurate determination of the pounds fat present, (2) correct calculation of the amount salt to add, (3) correct weighing of the salt, (4) proper distribution and incorporation of the salt with the butter granules, and (5) avoiding loss of brine. The moisture content is regulated by (1) accurate determination of the pounds fat present, (2) correct churning procedure so as to obtain firm granules, irregular in shape and of the size of small peas, (3) washing the granules with water of such a temperature that the butter can be worked thoroughly, (4) having the churn drum exactly level, (5) correct analysis of the partly finished butter for moisture, (6) draining the churn, (7) correct calculation of the necessary amount of water to add to bring the moisture content up to that desired, (8) correctly weighing the water to be added, and (9) working the butter to completion, followed by a final analysis of the finished butter.

The regulation of the amount of moisture in the butter is the chief method whereby the fat content can be regulated.

ECONOMIC IMPORTANCE OF CONTROLLING THE MOISTURE CONTENT OF BUTTER

It has been found from the analytical work in connection with the monthly butter scoring and analysis service that 31.6 per cent of the samples submitted during the eleventh year of the work contained more than 80.7 per cent fat. This included butter that contained from 80.8 to 83.2 per cent fat and had a weighted average of 81.25 per cent (0.55 above 80.7 per cent fat). Many creameries, however, attempt to make butter containing not more than 80.5 per cent fat. During the eleventh year 50.1 per cent of the samples analyzed contained in excess of this amount and averaged 81.03 per cent fat (0.53 above 80.5 per cent fat).

The butter sent to the monthly scoring and analysis service was made by creameries manufacturing approximately 75 to 80 per cent of the butter in the state. Therefore, if the above figures can be taken as representative of all the butter manufactured in Oregon, which was 31,205,111 pounds for 1938, the net loss to the dairy industry during 1938 due to the manufacture of butter containing an excessive amount of fat can be calculated. If 31.6 per cent of the butter contained from 80.8 to 83.2 per cent fat, 9,860,815 pounds of butter contained fat contents within this range. The excess amount of fat due to making butter containing more than 80.7 per cent fat amounted to 54,235 pounds. With fat at 30 cents per pound, the economic loss was $16,270.50 for the year.

If the calculation is based on the loss encountered for making butter that contained more than 80.5 per cent fat, 15,633,760 pounds of butter contained 82,860 pounds of fat in excess, which at 30 cents a pound was a net loss of $24,858 for the year. This serious loss can be corrected through application of proper methods for butter composition control.

THE PROBLEM OF MOISTURE CONTROL

It has been known for a considerable time that the buttermakers have experienced difficulty in correctly calculating the exact amount of water to add to churnings of unfinished butter that contain less than the desired percentage of moisture in order to bring the moisture and fat contents to those desired. Reference to this was made in an earlier bulletin of the Experiment Station,* in which it was pointed out that the amount of water calculated by the method commonly used in creameries usually falls short of the theoretical amount required. It has therefore been the practice of some buttermakers to add a certain amount of water in addition to that calculated by the conventional method. This naturally has led to considerable variation in the percentage of moisture and fat in the finished butter. At the time that the above-mentioned bulletin was published, no satisfactory practical method for determining the correct amount of water to add was available.

This problem has therefore been given some consideration by the Agricultural Experiment Station. Through the application of algebra a simple formula was derived, by use of which the correct amount of water necessary to add to a churning can be obtained. Because the formula is somewhat cumbersome to use in an average creamery, a table was prepared that gives the correct number of pounds of water to add to various churnings ranging in size from

* Wilster, G. H. *Methods of Controlling the Composition of Oregon Butter,* Oregon Agr. Exp. Sta. Bul. 338, 1935.

300 to 1,250 pounds of fat and with moisture contents in the partly finished butter ranging from 13.5 to 16.4 per cent. All a buttermaker has to do is to determine by testing the moisture content of the unfinished butter and then refer to the table and obtain at a glance the number of pounds of water necessary to add to the churning in order to obtain the desired amount of moisture (16.5 per cent) in the finished butter. He must, of course, know how many pounds of fat are present in the cream and he must have added the correct amount of salt.

In preparing the table, the formula mentioned above was applied. This formula is based on a final composition of the butter of 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd. A fat loss in the buttermilk of 1 per cent of the total amount of fat churned,* and a miscellaneous loss of 0.05 per cent were considered.

DEVELOPMENT OF THE ALGEBRAIC FORMULA

Let F = pounds fat in churning.
B = pounds finished butter from F pounds fat.
m = ratio of pounds moisture to pounds of unfinished butter.
M = ratio of pounds moisture to pounds finished butter.
w = pounds water to be added to unfinished butter.
W = pounds water in unfinished butter. ($W + w$ = pounds water in finished butter.)

Since M is the ratio of pounds water to pounds finished butter we have

$$M = \frac{w + W}{B} \tag{1}$$

Similarly, since m is the ratio of pounds of water at the time of first test to pounds of unfinished butter $(B - w)$ we get

$$m = \frac{W}{B - w} \tag{2}$$

From equations (1) and (2) we eliminate W by solving (2) for W and substituting in (1), obtaining

$$M = \frac{w + mB - mw}{B}$$

Solving this for w we get

$$w = B\frac{(M - m)}{(1 - m)} \tag{3}$$

Substituting the values

$B = 1.2292\,F$ or pounds butter obtained from F pounds fat (22.92 per cent overrun)

$M = 0.165$ (16.5 per cent) or desired moisture ratio in finished butter, we obtain

* For example:
2,500 pounds 32-per-cent cream in a churn contain 800 pounds fat.
Approximate amount of butter before salting $800 + [800 \times \frac{1}{4}] = 960$ 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.
Percentage of total fat lost $= \frac{8 \times 100}{800} = 1.0$

(4) Pounds water required $= 1.2292\ F \dfrac{(0.165 - m)}{1 - m}$

which can also be written as

(5) Pounds water required =

$$1.2292 \times \text{pounds fat in the cream} \times \frac{(0.165 - \text{first moisture})}{(1.00 - \text{first moisture})}$$

CALCULATION OF WATER REQUIRED

(1) ARITHMETICAL METHOD
(2) ALGEBRAIC FORMULA METHOD
(3) CONVENTIONAL METHOD

Problem: A vat of cream containing 1,000 pounds of fat is to be churned. The desired composition of the finished butter is 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd. Of the total amount of fat in the churning one per cent is lost in the buttermilk and the mechanical loss amounts to one-half pound of fat (0.05 per cent). How many pounds of water must be added to the partly worked butter in the churn if the first moisture test is 14.0 per cent, 15.0 per cent, 16.0 per cent?

1. **Arithmetical method.** The exact amount of water to add to a churning of unfinished butter which contains less than the desired moisture percentage can be correctly calculated by the arithmetical method of calculation. This can be shown as follows:

Pounds fat lost during churning

1,000 pounds $\times$ 0.01 = 10.0 pounds fat lost in buttermilk.
0.5 pounds = mechanical loss of fat.
10.0 + 0.5 = 10.5 pounds fat total amount lost.

Pounds butter to be obtained

1,000 pounds fat — 10.5 pounds lost = 989.5 pounds fat for butter.

$$\frac{989.5 \times 100}{80.5 \text{ fat in finished butter}} = 1{,}229.2 \text{ (22.92 per cent overrun) pounds of finished butter}$$

Pounds fat, salt, and curd contained in butter

1,229.2 $\times$ .023 = 28.3 pounds salt.
1,229.2 $\times$ .007 = 8.6 pounds curd.
989.5 pounds fat

1,026.4 pounds total salt, curd, and fat.

Pounds water required

(a) First moisture 14.0 per cent (100.0 — 14.0 = 86.0 per cent salt, curd, and fat).

$$\frac{1{,}026.4 \times 100}{86} = 1{,}193.5 \text{ pounds of butter when it contains 14.0 per cent moisture}$$

TABLE 3. AMOUNT OF WATER TO ADD TO CHURNINGS OF UNFINISHED BUTTER FOR VARIOUS MOISTURE TESTS

Table shows pounds of water to add to churnings of unfinished butter with the fat in the cream before churning varying from 300 to 1,250 pounds and the moisture in the unfinished butter at the time of making the first moisture test varying from 13.5 to 16.4 per cent. The desired composition of the butter is 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd. A loss of 1 per cent of the original fat occurs in the buttermilk and 0.05 per cent occurs as a mechanical loss.

HOW TO USE THE TABLE. A batch of cream contains 800 pounds fat. The first moisture test is 14.0 per cent. Add 28.6 pounds water. If the first moisture is 15.0 per cent, add 17.3 pounds water. If the first moisture is 16.0 per cent, add 5.8 pounds water.

Pounds Butterfat	Amount of Water to Add to Churnings of Unfinished Butter														
	13.5 Moisture	13.6 Moisture	13.7 Moisture	13.8 Moisture	13.9 Moisture	14.0 Moisture	14.1 Moisture	14.2 Moisture	14.3 Moisture	14.4 Moisture	14.5 Moisture	14.6 Moisture	14.7 Moisture	14.8 Moisture	14.9 Moisture
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
300	12.8	12.4	12.0	11.6	11.1	10.7	10.3	9.9	9.5	9.0	8.6	8.2	7.8	7.4	6.9
325	13.8	13.4	13.0	12.5	12.1	11.6	11.2	10.7	10.2	9.8	9.3	8.9	8.4	8.0	7.5
350	14.9	14.4	13.9	13.5	13.0	12.5	12.0	11.5	11.0	10.6	10.1	9.6	9.1	8.6	8.1
375	16.0	15.5	14.9	14.4	13.9	13.4	12.9	12.4	11.8	11.3	10.8	10.2	9.7	9.2	8.7
400	17.0	16.5	15.9	15.4	14.8	14.3	13.7	13.2	12.6	12.1	11.5	10.9	10.4	9.8	9.2
425	18.1	17.5	16.9	16.4	15.7	15.2	14.6	14.0	13.4	12.8	12.2	11.6	11.0	10.4	9.8
450	19.2	18.6	17.9	17.3	16.7	16.1	15.4	14.8	14.2	13.6	12.9	12.3	11.7	11.0	10.4
475	20.2	19.6	18.9	18.3	17.6	17.0	16.3	15.7	15.0	14.3	13.7	13.0	12.3	11.6	11.0
500	21.3	20.6	19.9	19.2	18.6	17.9	17.2	16.5	15.8	15.1	14.4	13.7	13.0	12.3	11.5
525	22.4	21.7	20.9	20.2	19.5	18.8	18.0	17.3	16.6	15.8	15.1	14.3	13.6	12.9	12.1
550	23.4	22.7	21.9	21.2	20.4	19.6	18.9	18.1	17.3	16.6	15.8	15.0	14.3	13.5	12.7
575	24.5	23.7	22.9	22.1	21.3	20.5	19.7	18.9	18.1	17.3	16.5	15.7	14.9	14.1	13.3
600	25.6	24.8	23.9	23.1	22.3	21.4	20.6	19.8	18.9	18.1	17.2	16.4	15.6	14.7	13.9
625	26.6	25.8	24.9	24.1	23.2	22.3	21.5	20.6	19.7	18.8	18.0	17.1	16.2	15.3	14.4
650	27.7	26.8	25.9	25.0	24.1	23.2	22.3	21.4	20.5	19.6	18.7	17.8	16.8	15.9	15.0
675	28.8	27.8	26.9	26.0	25.1	24.1	23.2	22.2	21.3	20.3	19.4	18.4	17.5	16.5	15.6
700	29.8	28.9	27.9	26.9	26.0	25.0	24.0	23.1	22.1	21.1	20.1	19.1	18.1	17.2	16.2
725	30.9	29.9	28.9	27.9	26.9	25.9	24.9	23.9	22.9	21.9	20.8	19.8	18.8	17.8	16.7
750	32.0	30.9	29.9	28.9	27.8	26.8	25.7	24.7	23.7	22.6	21.6	20.5	19.4	18.4	17.3
775	33.0	32.0	30.9	29.8	28.8	27.7	26.6	25.5	24.4	23.4	22.3	21.2	20.1	19.0	17.9
800	34.1	33.0	31.9	30.8	29.7	28.6	27.5	26.4	25.2	24.1	23.0	21.9	20.7	19.6	18.5
825	35.2	34.0	32.9	31.8	30.6	29.5	28.3	27.2	26.0	24.9	23.7	22.5	21.4	20.2	19.1
850	36.2	35.1	33.9	32.7	31.5	30.4	29.2	28.0	26.8	25.6	24.4	23.2	22.0	20.8	19.6
875	37.3	36.1	34.9	33.7	32.5	31.3	30.0	28.8	27.6	26.4	25.2	23.9	22.7	21.4	20.2
900	38.4	37.1	35.9	34.6	33.4	32.2	30.9	29.7	28.4	27.1	25.9	24.6	23.3	22.1	20.8
925	39.4	38.2	36.9	35.6	34.3	33.0	31.8	30.5	29.2	27.9	26.6	25.3	24.0	22.7	21.4
950	40.5	39.2	37.9	36.6	35.3	33.9	32.6	31.3	30.0	28.6	27.3	26.0	24.6	23.3	21.9
975	41.6	40.2	38.9	37.5	36.2	34.8	33.5	32.1	30.8	29.4	28.0	26.6	25.3	23.9	22.5
1,000	42.6	41.3	39.9	38.5	37.1	35.7	34.3	33.0	31.5	30.1	28.7	27.3	25.9	24.5	23.1
1,025	43.7	42.3	40.9	39.5	38.0	36.6	35.2	33.8	32.3	30.9	29.5	28.0	26.6	25.1	23.7
1,050	44.8	43.3	41.9	40.4	39.0	37.5	36.1	34.6	33.1	31.7	30.2	28.7	27.2	25.7	24.3
1,075	45.8	44.3	42.9	41.4	39.9	38.4	36.9	35.4	33.9	32.4	30.9	29.4	27.9	26.4	24.8
1,100	46.9	45.4	43.9	42.3	40.8	39.3	37.8	36.3	34.7	33.2	31.6	30.1	28.5	27.0	25.4
1,125	48.0	46.4	44.9	43.3	41.8	40.2	38.6	37.1	35.5	33.9	32.3	30.7	29.2	27.6	26.0
1,150	49.0	47.4	45.9	44.3	42.7	41.1	39.5	37.9	36.3	34.7	33.1	31.4	29.8	28.2	26.6
1,175	50.1	48.5	46.9	45.2	43.6	42.0	40.3	38.7	37.1	35.4	33.8	32.1	30.5	28.8	27.1
1,200	51.2	49.5	47.9	46.2	44.5	42.9	41.2	39.5	37.9	36.2	34.5	32.8	31.1	29.4	27.7
1,225	52.2	50.5	48.8	47.2	45.5	43.8	42.1	40.4	38.6	36.9	35.2	33.5	31.8	30.0	28.3
1,250	53.3	51.6	49.8	48.1	46.4	44.7	42.9	41.2	39.4	37.7	35.9	34.2	32.4	30.6	28.9

TABLE 3. AMOUNT OF WATER TO ADD TO CHURNINGS OF UNFINISHED BUTTER FOR VARIOUS MOISTURE TESTS (Continued)

Pounds Butterfat	Amount of Water to Add to Churnings of Unfinished Butter														
	15.0 Moisture	15.1 Moisture	15.2 Moisture	15.3 Moisture	15.4 Moisture	15.5 Moisture	15.6 Moisture	15.7 Moisture	15.8 Moisture	15.9 Moisture	16.0 Moisture	16.1 Moisture	16.2 Moisture	16.3 Moisture	16.4 Moisture
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
300	6.5	6.1	5.6	5.2	4.8	4.4	3.9	3.5	3.1	2.6	2.2	1.8	1.3	0.9	0.4
325	7.0	6.6	6.1	5.7	5.2	4.7	4.3	3.8	3.3	2.8	2.4	1.9	1.4	0.9	0.5
350	7.6	7.1	6.6	6.1	5.6	5.1	4.6	4.1	3.6	3.1	2.6	2.0	1.5	1.0	0.5
375	8.1	7.6	7.1	6.5	6.0	5.4	4.9	4.4	3.8	3.3	2.7	2.2	1.6	1.1	0.5
400	8.7	8.1	7.5	7.0	6.4	5.8	5.2	4.7	4.1	3.5	2.9	2.3	1.8	1.2	0.6
425	9.2	8.6	8.0	7.4	6.8	6.2	5.6	4.9	4.3	3.7	3.1	2.5	1.9	1.2	0.6
450	9.8	9.1	8.5	7.8	7.2	6.5	5.9	5.2	4.6	3.9	3.3	2.6	2.0	1.3	0.7
475	10.3	9.6	8.9	8.3	7.6	6.9	6.2	5.5	4.8	4.2	3.5	2.8	2.1	1.4	0.7
500	10.8	10.1	9.4	8.7	8.0	7.3	6.5	5.8	5.1	4.4	3.6	2.9	2.2	1.5	0.7
525	11.4	10.6	9.9	9.1	8.4	7.6	6.9	6.1	5.4	4.6	3.8	3.1	2.3	1.5	0.8
550	11.9	11.1	10.4	9.6	8.8	8.0	7.2	6.4	5.6	4.8	4.0	3.2	2.4	1.6	0.8
575	12.5	11.6	10.8	10.0	9.2	8.4	7.5	6.7	5.9	5.0	4.2	3.4	2.5	1.7	0.8
600	13.0	12.2	11.3	10.4	9.6	8.7	7.9	7.0	6.1	5.3	4.4	3.5	2.6	1.8	0.9
625	13.5	12.7	11.8	10.9	10.0	9.1	8.2	7.3	6.4	5.5	4.6	3.7	2.7	1.8	0.9
650	14.1	13.2	12.2	11.3	10.4	9.4	8.5	7.6	6.6	5.7	4.7	3.8	2.9	1.9	0.9
675	14.6	13.7	12.7	11.7	10.8	9.8	8.8	7.9	6.9	5.9	4.9	3.9	3.0	2.0	1.0
700	15.2	14.2	13.2	12.2	11.2	10.2	9.2	8.2	7.2	6.1	5.1	4.1	3.1	2.0	1.0
725	15.7	14.7	13.7	12.6	11.6	10.5	9.5	8.4	7.4	6.3	5.3	4.2	3.2	2.1	1.1
750	16.3	15.2	14.1	13.1	12.0	10.9	9.8	8.7	7.7	6.6	5.5	4.4	3.3	2.2	1.1
775	16.8	15.7	14.6	13.5	12.4	11.3	10.1	9.0	7.9	6.8	5.7	4.5	3.4	2.3	1.1
800	17.3	16.2	15.1	13.9	12.8	11.6	10.5	9.3	8.2	7.0	5.8	4.7	3.5	2.3	1.2
825	17.9	16.7	15.5	14.4	13.2	12.0	10.8	9.6	8.4	7.2	6.0	4.8	3.6	2.4	1.2
850	18.4	17.2	16.0	14.8	13.6	12.4	11.1	9.9	8.7	7.4	6.2	5.0	3.7	2.5	1.2
875	19.0	17.7	16.5	15.2	14.0	12.7	11.5	10.2	8.9	7.7	6.4	5.1	3.8	2.6	1.3
900	19.5	18.2	17.0	15.7	14.4	13.1	11.8	10.5	9.2	7.9	6.6	5.3	4.0	2.6	1.3
925	20.1	18.7	17.4	16.1	14.8	13.4	12.1	10.8	9.4	8.1	6.8	5.4	4.1	2.7	1.4
950	20.6	19.2	17.9	16.5	15.2	13.8	12.4	11.1	9.7	8.3	6.9	5.6	4.2	2.8	1.4
975	21.1	19.7	18.4	17.0	15.6	14.2	12.8	11.4	9.9	8.5	7.1	5.7	4.3	2.9	1.4
1,000	21.7	20.3	18.8	17.4	16.0	14.5	13.1	11.7	10.2	8.8	7.3	5.9	4.4	2.9	1.5
1,025	22.2	20.8	19.3	17.8	16.4	14.9	13.4	11.9	10.5	9.0	7.5	6.0	4.5	3.0	1.5
1,050	22.8	21.3	19.8	18.3	16.8	15.3	13.7	12.2	10.7	9.2	7.7	6.1	4.6	3.1	1.5
1,075	23.3	21.8	20.2	18.7	17.2	15.6	14.1	12.5	11.0	9.4	7.9	6.3	4.7	3.1	1.6
1,100	23.9	22.3	20.7	19.1	17.6	16.0	14.4	12.8	11.2	9.6	8.0	6.4	4.8	3.2	1.6
1,125	24.4	22.8	21.2	19.6	18.0	16.4	14.7	13.1	11.5	9.8	8.2	6.6	4.9	3.3	1.6
1,150	24.9	23.3	21.7	20.0	18.4	16.7	15.1	13.4	11.7	10.1	8.4	6.7	5.1	3.4	1.7
1,175	25.5	23.8	22.1	20.5	18.8	17.1	15.4	13.7	12.0	10.3	8.6	6.9	5.2	3.4	1.7
1,200	26.0	24.3	22.6	20.9	19.2	17.4	15.7	14.0	12.2	10.5	8.8	7.0	5.3	3.5	1.8
1,225	26.6	24.8	23.1	21.3	19.6	17.8	16.0	14.3	12.5	10.7	8.9	7.2	5.4	3.6	1.8
1,250	27.1	25.3	23.5	21.8	20.0	18.2	16.4	14.6	12.8	10.9	9.1	7.3	5.5	3.7	1.8

1,229.2 pounds of butter expected.

1,229.2 — 1,193.5 = 35.7 pounds of water required to bring butter up to the expected total weight.

(b) First moisture 15.0 per cent (100.0 — 15.0 = 85.0 per cent salt, curd, and fat).

$$\frac{1{,}026.4 \times 100}{85} = 1{,}207.5 \text{ pounds of butter when it contains 15.0 per cent moisture}$$

1,229.2 — 1,207.5 = 21.7 pounds of butter short or the pounds of water required to add to the churn.

(c) First moisture 16.0 per cent (100.0 — 16.0 = 84.0 per cent salt, curd, and fat).

$$\frac{1{,}026.4 \times 100}{84} = 1{,}221.9 \text{ pounds of butter when it contains 16 per cent moisture}$$

1,229.2 — 1,221.9 = 7.3 pounds butter short or pounds of water required.

2. **Oregon algebraic formula method for moisture control.** By applying the algebraic formula method it is found that when a churning of butter contains 1,000 pounds fat before churning, the total fat loss is 10.5 pounds, and the desired composition is 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent fat, and 0.7 per cent curd, it will require the addition of 35.7 pounds of water when the first moisture test is 14.0 per cent; if the first moisture test is 15.0 per cent, 21.7 pounds of water will be required; and if the first moisture test is 16.0 per cent, 7.3 pounds of water are required.

The formula is:

$$1.2292 \times \text{pounds fat in cream} \frac{(0.165 - \text{first moisture})}{(1.00 - \text{first moisture})}$$

The calculations are as follows:

(a) First moisture 14.0 per cent

$$1.2292 \times 1{,}000 \frac{(0.165 - 0.14)}{(1.00 - 0.14)} = 35.7$$

(b) First moisture 15.0 per cent

$$1.2292 \times 1{,}000 \frac{(0.165 - 0.15)}{(1.00 - 0.15)} = 21.7$$

(c) First moisture 16.0 per cent

$$1.2292 \times 1{,}000 \frac{(0.165 - 0.16)}{(1.00 - 0.16)} = 7.3$$

By referring to Table 3 it may be seen that the above amounts are also given in the table.

3. **Conventional method.**

Pounds water to add = (desired moisture — first moisture) × pounds butter expected.

Pounds fat lost in buttermilk = 1,000 × .01 or 10 pounds.
Mechanical loss = 1,000 × 0.0005 or 0.5 pound.
Total fat lost = 10.00 + 0.5 or 10.5 pounds.
Fat available for butter = 1,000 — 10.5 or 989.5 pounds.

$$\text{Butter to be obtained} = \frac{989.5 \times 100}{80.5} \text{ or } 1{,}229.2 \text{ pounds.}$$

$$\text{Overrun} = \frac{1{,}229.2 - 1{,}000}{1{,}000} \times 100 = 22.92 \text{ per cent.}$$

(a) First moisture 14.0 per cent.
16.5 — 14.0 = 2.5 per cent of moisture short.
1,229.2 × 0.025 = 30.7 pounds water required.

(b) First moisture 15.0 per cent.
15.5 — 15.0 = 1.5 per cent moisture short.
1,229.2 × 0.015 = 18.4 pounds of water required.

(c) First moisture 16.0 per cent.
16.5 — 16.0 = 0.5 per cent moisture short.
1,229.2 × 0.005 = 6.2 pounds water required.

In Table 4 are shown the pounds of butter which will be in a churning of butter containing 1,000 pounds fat (of which 10.5 pounds are lost during churning) at different moisture contents. The desired composition is 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd.

TABLE 4. AMOUNT OF BUTTER CONTAINING DIFFERENT PERCENTAGES OF MOISTURE

Moisture	Butter	Shortage as compared with butter containing 16.5 per cent*	Water found by conventional method of calculation	Difference between pounds water actually desired and pounds water calculated by conventional method†
Per Cent	*Pounds*	*Pounds*	*Pounds*	*Pounds*
16.5	1,229.2	0.0	0.0	0.0
16.0	1,221.9	7.3	6.2	1.1
15.0	1,207.5	21.7	18.4	3.3
14.0	1,193.5	35.7	30.7	5.0

* Pounds of butter short is made up for by adding a corresponding amount of water.
† 1,229.2 — 1,221.9 = 7.3 pounds butter containing 16 per cent moisture, or a difference of 1.1 pounds water.
1,229.2 — 1,207.5 = 21.7 pounds butter containing 15.0 per cent moisture, or a difference of 3.3 pounds water.
1,229.2 — 1,193.5 = 35.7 pounds butter containing 14.0 per cent moisture, or a difference of 5.0 pounds water.

It will be noted from the table that the pounds of water contained in the pounds of butter short at the time of making the first moisture determination is equal to the difference between the pounds of water actually required and the pounds of water obtained from the conventional calculation. To illustrate, 1,229.2 pounds of butter containing 16.5 per cent moisture are expected. If the first moisture test is 14.0 per cent, the churning will not contain 1,229.2 pounds of butter but instead, 1,193.5 pounds, which is 35.7 pounds less than is expected. In the 1,193.5 pounds butter containing 14.0 per cent moisture 167.1

pounds water are present. The finished butter (1,229.2 pounds) should contain 16.5 per cent moisture, or 202.8 pounds. The shortage is therefore 202.8 — 167.1, or 35.7 pounds. By the conventional method of calculating the amount of water to add, it would be necessary to add only 30.7 pounds water, calculated as follows:

$16.5 - 14.0 = 2.5$; $1{,}229.2 \times .025 = 30.7$. The shortage is $35.7 - 30.7 =$ 5.0 pounds.

What is the mathematical explanation for this error? When determining the moisture percentage in the unfinished butter there are actually only 1,193.5 pounds butter present containing 14.0 per cent moisture. The water present amounts to 167.1 pounds. Actually it is being incorrectly assumed that the full amount of 1,229.2 pounds butter containing 14.0 per cent moisture is present. If this amount of butter is present, it would contain 172.1 pounds water. It will thus be seen that this accounts for the five pounds difference ($172.1 - 167.1 = 5$).

To illustrate this further:

A buttermaker makes the first moisture test. He obtains 14.0 per cent. He desires 16.5 per cent in the finished butter. On the basis of the final amount of butter (as 1,229.2 pounds used in the problem) he adds $1{,}229.2 \times 0.025 = 30.7$ pounds water. Actually, he has only 1,193.5 pounds butter containing 14.0 per cent moisture. By adding the 30.7 pounds he will have $1{,}193.5 + 30.7 = 1{,}224.2$ pounds butter.

The partly finished butter contains $1{,}193.5 \times 0.15 = 167.1$ pounds water and by adding 30.7 pounds additional it contains $167.1 + 30.7 = 197.8$ pounds water.

After incorporating the added water the finished butter will contain

$$\frac{197.8 \times 100}{1{,}224.2} = 16.16 \text{ per cent moisture}$$

or $16.5 - 16.16 = 0.34$ per cent less than desired, causing a loss due to a shortage of 5 pounds butter or $1.50 when the price of butter is 30 cents a pound.

Summary of the three methods. The summary of the three methods of calculating the amount of water to add to the unfinished butter is given in Table 5.

TABLE 5. SUMMARY OF THE THREE METHODS OF CALCULATING THE AMOUNT OF WATER TO ADD

Per cent Moisture Desired 16.5

Moisture content of unfinished butter	Amount of water to add		
	Conventional method	Arithmetical method	Oregon algebraic formula method
	Pounds	*Pounds*	*Pounds*
14.0%	30.7	35.7	35.7
15.0%	18.4	21.7	21.7
16.0%	6.2	7.3	7.3

It is seen that the conventional method of calculating obviously is unsatisfactory to use. For the churning of unfinished butter that contains 14.0 per cent moisture, the amount of water added would be 5.0 pounds too little, for the

churning that contains 15.0 per cent, 3.2 pounds too little would be added, and for the churning that contains 16.0 per cent, 1.1 pounds too little would be added.

The final moisture content of the butter when the conventional method is used and no additional water to that calculated is added would be 0.34 per cent low if the first moisture was 14.0, 0.2 per cent low if the first moisture was 15.0 per cent, and 0.1 per cent low if the first moisture content of the butter was 16.0 per cent.

Application of the algebraic formula when the desired fat and moisture contents are different from 80.5 per cent and 16.5 per cent. If it is desired to make butter of a composition different from 80.5 per cent fat and 16.5 per cent moisture, another factor has to be calculated and used in the formula. The application of the formula when different fat and moisture percentages are desired in the finished butter is given below.

(a) 1,000 pounds of fat are contained in a vat of cream. The fat loss in the buttermilk amounts to one per cent of the total fat and the mechanical loss amounts to 0.05 per cent. The desired composition of the butter is 80.3 per cent fat, 16.7 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd. The per cent of moisture in the unfinished butter is 14.0 per cent. Calculate (1) the factor to use in the formula and (2) the pounds of water required to adjust the moisture content to that desired.

(1) $1.0 + 0.05 = 1.05$ per cent of total fat lost.
$1{,}000$ pounds fat $\times\ 0.0105 = 10.5$ pounds of fat lost.
$1{,}000 - 10.5 = 989.5$ pounds fat left for butter.

$$\frac{989.5 \times 100}{80.3} = 1{,}232.3 \text{ pounds of finished butter.}$$

$$\frac{1{,}232.3}{1{,}000} = 1.2323 \text{ pounds of finished butter from each pound of the original fat, or 23.23 per cent overrun.}$$

The factor to use in formula is 1.2323.

(2) Therefore, the formula to use for butter of above composition and fat losses is:

$$1.2323 \times \text{pounds original fat} \frac{(0.167 - \text{first moisture})}{(1.00 - \text{first moisture})}$$

Substituting in the values and solving we obtain

$$1.2323 \times 1{,}000 \frac{(0.167 - 0.14)}{(1.00 - 0.14)} = 38.8 \text{ pounds of water required.}$$

If this problem were solved by the arithmetical method, the calculation would be as follows:

Butter available—1,000 pounds.
Butterfat after loss deducted—989.5 pounds.

$$\text{Butter anticipated} - \frac{989.5 \times 100}{80.3} = 1{,}232.3 \text{ pounds.}$$

Salt content of butter = 1,232.3 × 0.023 or 28.3 pounds.
Curd content of butter = 1,232.25 × 0.007 or 8.6 pounds.
Unfinished butter (14 per cent moisture) contains 989.5 + 28.3 + 8.6 = 1,026.4 pounds fat, salt, and curd.

$$\text{Unfinished butter in churn} = \frac{1{,}026.4 \times 100}{86} \text{ or } 1{,}193.5 \text{ pounds.}$$

Water to add = 1,232.3 — 1,193.5 = 38.8 pounds.

If the water to add in order to increase the per cent moisture from 14.0 to 16.7 per cent is calculated by the conventional method, the calculation would be:

16.7 — 14.0 = 2.7 per cent water to add.
Total water to add = 1,232.3 × 0.027, or 33.3 pounds.
By this method 5.5 pounds water too little would be added.
With butter at 30¢ per pound, this would mean a loss of $1.65.

(b) If the fat lost in the buttermilk is 0.9 per cent of the total fat churned, and the miscellaneous loss is 0.06 per cent and the composition of the finished butter is the same as in the preceding calculation the factor to use would be calculated as follows:

Pounds fat lost in buttermilk = 1,000 × 0.009, or 9 pounds.
Miscellaneous loss = 1,000 × 0.0006, or 0.6 pounds.
Total fat lost = 9 + 0.6, or 9.6 pounds.
Fat available for butter = 1,000 — 9.6, or 990.4 pounds.

$$\text{Butter to be obtained} = \frac{990.4 \times 100}{80.3} \text{ or } 1{,}233.4 \text{ pounds (1.2334 pounds butter from each pound of fat).}$$

$$\text{Overrun} = \frac{1{,}233.4 - 1{,}000}{1000} \times 100 \text{ or } 23.34 \text{ per cent.}$$

Formula to use would be

$$1.2334 \times \text{Fat} \frac{(0.167 - \text{first moisture})}{(1.00 - \text{first moisture})}$$

Any creamery can thus devise its own formula to use with any desired composition of butter and with specific fat losses. A table similar to that shown in this bulletin can easily be prepared by the use of a calculating machine.

TESTS TO DETERMINE THE ACCURACY OF THE OREGON METHOD OF MOISTURE CONTROL

In order to determine whether the new method of moisture control would be satisfactory, observations were made on 93 churnings of butter. Of these, 38 were made in the Experiment Station Dairy Products Laboratory, and the rest were made in three commercial plants.

The method was first tested out in the Dairy Products Laboratory. It was found to be very satisfactory. It was then tested in the three creameries. Each buttermaker was instructed to keep an accurate record of (1) the amount of fat present in each batch of cream for churning, (2) the per cent moisture in the unfinished butter, (3) the amount of water to add, and (4) the compo-

sition of the finished butter. At first the buttermakers were skeptical in the application of the method, because of the additional water necessary to add when compared with that calculated by the conventional method. After using the method with a few churnings and seeing that the results were satisfactory, they gained confidence and felt the method was very satisfactory.

It was not expected that the final moisture content of the butter would always be exactly as calculated, because differences due to inaccurate determination of the fat present in the churning, slight variations in the composition of the butter from different parts of the churn, and slight errors in analyzing the butter were anticipated.

The butter was made during the period June 1939 to January 1940, inclusive.

With 67 churnings the desired moisture percentage was to be 16.5, with 10 it was to be 16.7, and with 16 it was to be 16.8.

The data obtained are presented in Table 6 and are summarized.

SUMMARY OF OBSERVATIONS ON 93 CHURNINGS OF BUTTER

Total number of churnings	93
Percentage churnings with correct moisture	35.5
Percentage churnings with moisture within 0.1 above and below correct amount	84.9
Percentage churnings with moisture within 0.2 above and below correct amount	97.8

Of the 93 churnings, 84.9 per cent contained within 0.1 per cent of the desired moisture and 97.8 per cent contained within 0.2 per cent of the desired moisture. This should be considered very satisfactory.

Had the formula method not been used and had the amount of water to add been calculated by the conventional method and no additional water added, the percentage of moisture in the finished butter would have been from 0.1 to 0.3 per cent lower and the yield of butter would have been considerably lower.

STANDARDIZING THE FAT CONTENT OF BUTTER

Although the moisture content of the finished butter can be closely regulated, some fluctuations may occur in the fat content. This is due to variations in the salt and curd. Occasionally fluctuations in the salt and curd cause the fat content to vary from 0.1 to 0.5 per cent, plus or minus, from that desired. This is unfortunate because if the fat content is much below that desired, there is a danger of its falling below the 80.0 per cent legal limit. Creameries standardizing butter to from 80.1 to 80.3 per cent have only a small margin for fluctuation in the fat content. On the other hand, butter containing more fat than that desired represents a considerable loss.

The most satisfactory method to determine the amount of water required to add to the partly worked butter in the churn in order to obtain a certain fat content in the finished butter would be to make this calculation on the basis of the fat content of the unfinished butter. Because of the additional time required to make the fat determination, it has become a practice to make only the moisture determination. As manufacturing methods improve, however, only small variations in the fat content will be allowed for economic reasons. This

Table 6. Regulation of Moisture in Butter by Applying the Oregon Algebraic Formula Method

	O.S.C. Dairy Products Laboratory	Creamery 1	Creamery 2	Creamery 3
General Description				
Period of test	June 1939 to October 1939, incl.	December 1939 to January 1940, incl.	December 1939	June to September 1939, incl.
Type of churns	One 650-pound capacity, single roll One 750-pound capacity, roll-less	One 1,000-pound capacity, single roll	One 1,000-pound capacity, single roll	One 1,500-pound capacity, single roll. One 1,500-pound capacity, roll-less
Size of churnings	200 to 700 pounds fat	500 to 850 pounds fat	450 to 750 pounds fat	750 to 1,250 pounds fat
Number of churnings	38	20	10	25
Desired composition of butter	80.5 per cent fat 16.5 per cent moisture 2.3 per cent salt 0.7 per cent curd	80.5 per cent fat 16.5 per cent moisture 2.3 per cent salt 0.7 per cent curd	80.3 per cent fat 16.7 per cent moisture 2.3 per cent salt 0.7 per cent curd	80.5 and 80.2 per cent fat 16.5 and 16.8 per cent moisture 2.3 and 2.3 per cent salt 0.7 and 0.7 per cent curd
Range in moisture content of partly finished butter	13.6 to 16.4 per cent	13.2 to 16.3 per cent	15.3 to 16.5 per cent	13.7 to 16.2 per cent

Moisture in finished butter	Desired 16.5 per cent moisture		Desired 16.5 per cent moisture		Desired 16.7 per cent moisture		Desired 16.5 per cent moisture		Desired 16.8 per cent moisture	
	Number of churnings	Percentage of all	Number of churnings	Percentage of all	Number of churnings	Percentage of all	Number of churnings	Percentage of all	Number of churnings	Percentage of all
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
16.9%	....	.....	....	.....	....	.....	....	.....	5	31.3 } 75.0
16.8%	....	.....	....	.....	4	40 } 100	....	.....	4	25.0
16.7%	3	7.9	1	5	5	50	1	11.1	3	18.7
16.6%	17	44.7 } 84.2	6	30 } 85.0	1	10	3	33.3 } 88.9	4	25.0
16.5%	11	29.0	8	40	....	.....	5	55.6	....	.....
16.4%	4	10.5	3	15	....	.....	....	.....	....	.....
16.3%	1	2.6	2	10	....	.....	....	.....	....	.....
Less than 16.3%	2*	5.3	....	.....	....	.....	....	.....	....	.....
Total	38	100.0	20	100.0	10	100.0	9	100.0	16	100.0

* Inaccurate calculation of pounds fat in churning.

may force the buttermakers to standardize the fat content of the butter, using the per cent of fat in the unfinished butter rather than the per cent of moisture as the basis for calculations.

Efficient managers realize the importance of proper regulation of the fat content of butter. In some plants the managers require that the analysis for fat be made on each churning before the butter is removed from the churn. If the fat content is greater than desired and if additional working will not injure the body and texture of the butter, additional water is added and incorporated with the butter in order that the butter will contain the desired percentage of fat.

The Oregon algebraic formula method for standardizing the percentage of fat in butter. The following shows the development of a formula which may be used in order to standardize the fat content of the butter by the addition of water. Consideration is given to the average fat losses in buttermilk, etc. The formula is mathematically correct and if properly applied it should be possible by the addition of water to standardize the fat content of butter to the desired percentage.

The formula may be used for butter of any desired fat content. For example: One thousand pounds of fat are contained in a vat of cream. A total of 1.05 per cent of the fat is lost (1.00 per cent in the buttermilk and 0.05 per cent as mechanical loss). The desired composition of the butter is 80.5 per cent fat, 16.5 per cent moisture, 2.3 per cent salt, and 0.7 per cent curd.

After incorporating the pounds of water calculated from the first moisture test the composition of the butter was 80.7 per cent fat, 16.5 per cent moisture, 2.2 per cent salt, and 0.6 per cent curd. The only practical method of reducing the fat percentage from 80.7 to 80.5 per cent is to add and incorporate water with the butter, assuming, of course, that the body of the butter will not be injured by the additional working.

Calculate the pounds of water required to add in order to reduce the fat content from 80.7 to 80.5 per cent, when 1,229.2 pounds of finished butter are expected.

The pounds of finished butter to be obtained can be calculated as follows:

1,000 pounds of fat $\times$ 0.0105 = 10.5 pounds fat lost.

1,000 — 10.5 = 989.5 pounds fat actually in butter

$\frac{989.5}{80.5}$ = 1,229.2 pounds of finished butter (22.92 per cent overrun)

or

1,000 pounds fat in cream $\times$ 1.2292 pounds butter from 1 pound of the original fat = 1,229.2 pounds finished butter

The development of the formula through the application of algebra is as follows:

Let F = pounds fat in the churning,

f = pounds fat lost in buttermilk and in miscellaneous losses,

R = ratio of pounds fat in finished butter to pounds unfinished butter,

r = ratio of pounds fat in finished butter to pounds finished butter,

B = pounds finished butter and may be expressed as $\frac{(F-f)}{r}$ or when overrun is 22.92 as $(1.2292F)$,

w = pounds of water to be added in order to reduce the fat content from R to r.

Since R is the ratio of pounds of fat in the butter $(F-f)$ to pounds unfinished butter $(B-w)$, we have

$$(1) \qquad R = \frac{F-f}{B-w}$$

Similarly, since r is the ratio of pounds fat in the butter to pounds finished butter, we get

$$(2) \qquad r = \frac{F-f}{B}$$

From equations (1) and (2) we eliminate B by solving (1) for B and substituting in (2) obtaining

$$r = \frac{F-f}{w + \frac{F-f}{R}}$$

Solving for w, we get

$$(3) \qquad w = \frac{F-f}{r}\,\frac{(R-r)}{(R)}$$

As $\frac{F-f}{r}$ = pounds finished butter (B), the formula may be further simplified to give

$$(4) \qquad w = B\,\frac{(R-r)}{(R)}, \text{ or, } 1.2292 \times \text{pounds original fat } \frac{(R-r)}{(R)}.$$

which can also be written:

(5) Pounds water required =

$$1.2292 \times \text{pounds fat } \frac{(\text{first fat} - \text{desired fat})}{(\text{first fat})}.$$

Substituting in the values and solving for the problem given above, we obtain

$$(6) \qquad \text{Pounds water required} = 1.2292 \times 1000\,\frac{(0.807-0.805)}{(0.807)} = 3.05.$$

Pearson Square Method. If the buttermaker would find it more convenient to use the Pearson Square Method, the calculations for the above problem would be as follows:

80.7 per cent fat in butter to be standardized	80.5 per cent desired in finished butter	80.5 parts of unfinished butter
0.0 per cent fat in water to be added		0.2 parts of water to add
		80.7 total parts of unstandardized butter + water

Therefore, mix in the ratio of 80.5 pounds unfinished butter to 0.2 pounds water.

$$\frac{\text{1,229.2 pounds of finished butter} \times \text{0.2 parts water}}{\text{80.7 parts unstandardized butter and water}} = 3.05 \text{ pounds water}$$

Proof: $\frac{1{,}229.2 \times 80.5}{80.7} = 1{,}226.15$ pounds butter containing 80.7 per cent fat

$1{,}226.15 + 3.05 = 1{,}229.2$ pounds butter containing 80.5 pounds fat

CALCULATION OF AMOUNT OF BUTTER AND SALT

A table has been calculated for buttermakers to use in determining the amount of butter that can be obtained from batches of cream of different fat contents and the correct amount of salt that must be added to the butter. The table covers churnings ranging in size from 500 to 4,000 pounds of cream with fat contents ranging from 29 to 36 per cent. Copies can be obtained for $0.25 each from the Oregon Dairy Products Improvement Association, Corvallis.

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