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THE ACCURACY OF COMPOSITE CREAM SAMPLES

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CONTENTS

ILLUSTRATIONS

THE ACCURACY OF COMPOSITE CREAM SAMPLES[1]

W. B. COMBS, L. M. THURSTON, A. E. GROTH, AND S. T. COULTER

INTRODUCTION

The introduction of the cream separator, between 1880 and 1890, resulted in the development of what was later known as the whole-milk creamery. The invention, in 1890, of the Babcock method for determining the fat percentage of milk, placed the buying and selling of milk upon the basis of the fat percentage. Under the plan of operation which brought the whole milk to the creamery, sampling for testing was an easy matter. It was soon apparent that to test each delivery of milk required too much time. To meet this condition the composite sample was suggested by Patrick (1) in 1890. He called attention to the importance of using an aliquot part of each delivery in preparing the composite sample. Farrington (2) soon made it clear, however, that the aliquot composite milk sample was no more accurate under practical conditions than a sample taken by means of a small sampling dipper, disregarding the amount of milk delivered. During the days of the whole-milk creamery it was a comparatively simple matter to sample the milk received. The composite milk sample was used by the butter factories then as it is used in the market-milk plant, cheese factory, and condensory today.

With the introduction of the farm separator and a change from the delivery of milk to the creameries to the delivery of cream, practical creamerymen applied composite sampling to cream. The composite cream sample doubtless has no place in creameries receiving cream from long distances or to which the cream comes in a sour, thick, or viscous state. Hunziker (3) pointed out this fact in 1910, when he criticized the practice, which was becoming common in Indiana creameries. Dean (4) contributed a brief paper on the subject which did not substantiate the criticisms of Hunziker. The most exhaustive study published on the subject was presented by Lee and Hepburn (5-4) who concluded from their work: (1) "Reasonable allowance should be

[1] The experimental work here reported was conducted primarily at the State Experimental Creamery, at Albert Lea. Appreciation of co-operation is due M. E. Gardner, of the Farmers Co operative Creamery, Waseca; A. H. Esse, of the Fulda Co-operative Creamery, and Alfred Camp, of the Gilt Edge Creamery, Owatonna, Minn. The writers wish also to express their appreciation to J. R. Keithley, of the Twin City Milk Producers Association, of St. Paul, and W. Ahlstrom, of the Franklin Co-operative Creamery, of Minneapolis.

made for difference in duplicate samples tested by the same or different testers. (2) In testing cream there is a marked tendency for variation between composite and individual testing for short periods of time but the distribution of this variation is such as to occasion very small amounts of difference when figured on seasonal periods. (3) Composite samples tend to test slightly higher than individual samples in summer and lower in winter. (4) Based on yearly averages, there is practically no difference between composite and individual samples. (5) Testing in creamery practice should be accorded a place of prominence commensurate with the importance of the results to be derived from it."

The average Minnesota creamery receives cream from a relatively small area. Seldom is cream received that is more than three or four days old. It may be conceded, therefore, that the cream received in the average Minnesota creamery is better adapted to composite sampling than is the sour cream received by many plants elsewhere.

Approximately 75 per cent of the creameries of Minnesota are co-operative. These creameries are relatively small, manufacturing, on the average, about 400,000 pounds of butter a year. The cost of manufacturing butter is inversely proportional to the volume of butter manufactured, hence it is necessary for a co-operative creamery to seek methods of reducing costs. The testing of cream at each delivery is a problem of economy in the average creamery of the state. As the composite cream sample has been severely criticized by a majority of the authorities who have considered the question, the members of the staff of the Dairy Division at the University of Minnesota have frowned on the practice of using the composite cream sample in Minnesota co-operative creameries. In spite of the fact that they believed that composite cream samples were inaccurate, practical creamery operators have insisted that the daily testing of cream is too expensive. Many of these men agreed that the practice of using the composite test is not well adapted to modern business principles, and that it is impossible to check daily operations when the composite sample is used.

The investigation may be logically divided into three distinct parts: (1) A general survey of the practice of sampling cream by Minnesota creameries, (2) methods of caring for composite samples, and (3) a comparison of the accuracy of the composite sample and the daily sample. Accordingly the subject matter is presented under the three subdivisions mentioned.

SURVEY OF PRESENT PRACTICE OF CREAM SAMPLING IN MINNESOTA

Before beginning experimental work a survey was made of the practices in the state, in order to learn to what extent the composite cream sample was being used and the methods employed by Minnesota creamerymen in taking samples and caring for them. A questionnaire was sent out to the operator of each local creamery in the state. Of these, 455 answered all the questions. A total of 308, or 68 per cent, reported that daily analyses were made and 147, or 32 per cent, that composite samples were used.

Reasons for using composite cream sample.—Each creamery operator using the composite cream sample was asked to give his reason for so doing. The principal reason given was that it reduces operating expenses. Such statements as the following appeared in more than 90 per cent of the replies: "Less work required," "More economical," "Daily testing would require one more man," "The gain is not worth the extra cost." The size of the business does not determine the use of the composite sample plan, as it is used by both large and small creameries.

Method of preparing composite sample.—The use of a small sampling dipper seems to be the popular method of taking a cream sample in the preparation of the composite. Table I shows the various methods of obtaining cream samples by the creameries using the composite plan.

TABLE I

METHOD OF SAMPLING CREAM IN MINNESOTA CREAMERIES USING THE COMPOSITE TEST

Device used	No. of creameries	Per cent of creameries
Dipper	102	69.5
Stirring rod	23	15.6
Stirring rod and dipper	8	5.4
McKay sampler	7	4.7
Sampling tube	2	1.4
No reply	5	3.4

Table I shows that 70 per cent of the creameries using the composite cream samples were using the sampling dipper, 15.6 per cent were using a cream stirring rod, and 5.4 per cent were using both, apparently using the stirring rod to stir the cream and the dipper to take the sample.

Preservative used in Minnesota creameries.—Of the 147 creameries using the composite sample, 131 (89 per cent) reported using corrosive sublimate as a preservative; 10 (7 per cent) did not name the preservative used; while 6 (4 per cent) used no preservative.

Testing interval for composite cream samples.—The general practice of the local creamery operator is to prepare a composite sample of cream representing deliveries during two weeks. Eighty per cent of the creameries using the composite cream sample reported testing every two weeks, 12 per cent every four weeks, 3.4 per cent once each week, and 1.4 per cent at the end of each two weeks in summer and once a month in winter. One operator reported testing twice a week; another three times a month in summer and once in two weeks in winter.

Type of container used.—Each operator using the composite cream sample was requested to indicate the type of container used. The answers are presented in Table II.

TABLE II

TYPES OF CONTAINERS USED BY MINNESOTA CREAMERY OPERATORS FOR COMPOSITE SAMPLES

Type of container	No. of creameries	Per cent of creameries
Glass-stoppered bottle	104	70.7
Metal-screw-top jar	12	8.1
Cork-stoppered bottle	9	6.1
Rubber-stoppered bottle	8	5.4
Tin cup	5	3.5
Both cork- and rubber-stoppered bottle	3	2.0
Paper-cap bottle	1	0.7
No reply	5	3.5
Total	147	100.0

Glass-stoppered bottles are used in more than 70 per cent of the plants using composite cream samples. Of the other containers in use, the metal-screw-top jar is most popular, being used in 8 per cent of the plants. Cork-stoppered bottles in 6 per cent of the plants and rubber-stoppered bottles in 5 per cent, follow in order. Both cork- and rubber-stoppered bottles were used in 2 per cent of the plants. One operator was using paper-capped bottles and 5 operators were using open tin cups.

Place of storing composite samples.—Of the 147 creameries reporting the use of the composite sample, 9 (6 per cent) reported storing samples in the icebox; the others reported storing in the weigh room, the creamery room, or, in one case, in a separate testing laboratory.

Present practice regarding cream testing.—The common method of making the Babcock test in Minnesota creameries differs little from the method used in practical plants in other parts of the country. Cream samples are weighed on scales which hold from two to twelve test bottles. The steam turbine tester is commonly used. The cream test is read directly from the machine, no hot water bath being used.

METHODS OF CARING FOR COMPOSITE SAMPLES

Using the type of bottle found in creameries operating the composite method of sampling cream, a study was made of the amount of evaporation taking place in cream samples under practical conditions. Further work was conducted under controlled conditions to note the relation of the stoppers used, the amount of surface exposed, and the storage temperature to the amount of evaporation.

The study conducted under practical conditions consisted of daily weighings of the composite samples prepared in several creameries of the state. These records yielded data on the amount of cream added at each delivery and the amount of evaporation between deliveries. It was the practice at the creameries where the work was conducted to store the composite samples in the weigh room or at a place convenient to the man receiving cream. A solution balance sensitive to one gram was used for weighing the samples, and mercuric chloride tablets were used in all cases as a preservative.

Definite amounts of cream were carefully weighed into the sample bottles and stored under controlled conditions. The stoppers were removed daily and the samples given such a moderate mixing as might be given under practical conditions by rotating the bottles. Samples were held in glass-, cork-, and rubber-stoppered 8-ounce glass bottles. The amount of evaporation was determined by weighing the samples individually on a chemical balance. This phase of the work was conducted in the laboratories of the Dairy Division of the University of Minnesota.

EVAPORATION OF MOISTURE FROM CREAM SAMPLES UNDER PRACTICAL CONDITIONS

Previous workers have pointed out that one of the chief difficulties in using the composite sample is that evaporation of moisture results in an abnormally high test. It is a simple matter to calculate the effect of evaporation. To learn how serious this might be in the practical plant was the object of the experiments presented below. The dipper composite samples were weighed daily in groups of ten. The results are shown in Table III.

This group of experiments, which includes the daily weights of 966 dipper composites in groups of ten, shows that the average was 0.78 per cent. On 30 per cent cream, this would mean an increase of 0.23 per cent in the fat reading.

TABLE III

EVAPORATION OF MOISTURE FROM COMPOSITE CREAM SAMPLES UNDER PRACTICAL CONDITIONS

Creamery No.	Date	No. of patrons' cream samples	Total weight of cream added to bottles	Weight of cream after 2 weeks	Evaporation	Evaporation
			gm	gm.	gm.	per cent
4	Oct. 16–Nov. 1, 1925	161	22,588	22,452	136	0.60
4	Dec. 1–15, 1925	164	24,436	24,143	293	1.20
2	Feb. 1–15, 1926	107	11,191	11,028	163	1.46
1*	Mar. 1–15, 1926	166	24,598	24,365	233	0 95
3	Mar. 16–31, 1926	96	6,656	6,628	28	0.42
2	Apr. 1–15, 1926	112	13,076	13,010	66	0.50
4	Apr.17–May 1, 1926	160	26,546	26,461	85	0.32
	Total	966	129,091	128,087	1004	
	Average evaporation	...	.....	.....	....	0.78

* Eight-ounce rubber-stoppered bottles were used at this creamery, all others used 8-ounce glass-stoppered bottles.

EVAPORATION OF MOISTURE FROM CREAM SAMPLES UNDER CONTROLLED OR OBSERVED CONDITIONS

A similar study was conducted in the Dairy Division laboratory by using single samples of cream in 8-ounce containers similar to those used in the commercial creameries in order to note the difference, if any, when glass, rubber, and cork stoppers were used. The samples were weighed on a chemical balance at the beginning and at the end of the experiment. The stoppers were removed from the bottles daily and the bottles given some agitation, as might be given under practical conditions. Samples 1, 2, and 3 were held under summer conditions at a temperature ranging from 85 to 110 degrees F. Sample 4 was held at room temperature (approximately 70 degrees F.) and sample 5 in the icebox (approximately 40 degrees F.). The results are tabulated in Table IV. All samples were preserved with formalin. Trials 1, 2, and 3 were conducted under practically similar conditions and are therefore replications of each other.

TABLE IV

EVAPORATION FROM CREAM SAMPLES OF APPROXIMATELY 100 GRAMS IN GLASS-, RUBBER-, AND CORK-STOPPERED BOTTLES AT VARIOUS TEMPERATURES

Trial No.	Temperature during two weeks	Loss of weight of original 100-gram sample stored in		
		Glass-stoppered bottle	Rubber-stoppered bottle	Cork-stoppered bottle
		per cent	per cent	per cent
1	Summer	0.93	0.45	0.14
2	Summer	2.71	1.16	0.39
3	Summer	4.40	1.18	0 36
4	Room	0.16	0.14	0.08
5	Icebox	0.02	0.01	0.07

The results indicated in Table IV show that evaporation is greatest at the highest temperature, as is to be expected. The outstanding fact revealed, however, is that the greatest evaporation took place in

the glass-stoppered bottles and the least in the cork-stoppered bottles. Trials 1, 2, and 3, under summer conditions, show that the smaller the sample the greater the percentage of evaporation. This fact may be explained by the statement that the amount of evaporation from any given sample is in proportion to the surface exposed, regardless of size of sample.

EVAPORATION FROM OPEN CONTAINERS

The average creamery uses some form of stopper in the composite cream bottle. To illustrate the effect of using no stopper, and the relation of the surface exposed to the amount of evaporation, the above experiment was repeated with two styles of containers of different diameters, one being the common 8-ounce sample bottle and the other larger. The samples were preserved with formaldehyde and held under summer, room, and icebox temperatures, as in the previous trial. The results are given in Tab'e V.

TABLE V

EVAPORATION OF MOISTURE FROM CREAM SAMPLES IN OPEN CONTAINERS

Relative temperature	Days held	Container 1 (Surface area 8.17 sq. cm.)			Container 2 (Surface area 10.99 sq. cm.)		
		Initial weight of sample	Evaporation from sample	Per cent evaporated	Initial weight of sample	Evaporation from sample	Per cent evaporated
		gm.	gm.		gm.	gm	
Summer	9 and 6	128.0872	25.4998	19.908	131.9497	23.7840	18.03
Summer	8	99.9876	15.8778	15.88	100 0870	29.9986	29.97
Summer	9	85.8321	26.7330	31.14	92.8820	35.5519	38.28
Room	9	94 8354	16.8354	17.90	93.7310	32.0918	34.24
Icebox	9	93.4975	0.6085	0.65	94.5495	3.6230	3.83

The results shown in Table V clearly demonstrate the importance of using a stoppered bottle or container for holding the composite cream sample. Altho size of sample is a factor influencing the percentage of evaporation, the tabulations presented in Table V show a relation between the surface exposed and the amount of evaporation.

ABSORPTION OF FAT BY THE STOPPER

It is commonly observed that much fat adheres to the stopper used with cream sample bottles. The question arose as to whether the stopper might absorb fat from the cream. Glass stoppers need no consideration in this connection and rubber stoppers give no apparent trouble. Cork stoppers, however, appear greasy in a short time after being used. Cork stoppers were washed free of fat by keeping them in a mixture of ether and alcohol and shaking them intermittently for 24 hours. The stoppers were then used on composite cream samples

for 14 days. The cream was shaken against the stoppers daily, as when in use. On ether-alcohol extraction at the end of the period, an amount of butterfat ranging from 0.12 to 0.48 gram was removed from each cork. Altho only a few determinations were made, the authors feel disposed to condemn the cork and to use the rubber stopper.

COMPOSITE VS. DAILY TEST

Plan of Experiment

The object of this experiment was to study the relative accuracy of the composite cream sample as compared with cream tests made daily or at each delivery.

Composite samples were prepared covering two-week periods, as this interval represents the common practice in the state. Two sets of composite samples were prepared; the first is designated the "dipper composite" and was taken according to the common method used by the creameries of the state. The daily sample was taken with a small dipper and was essentially the same size regardless of the amount of cream delivered. The second composite, designated as the "aliquot composite," was taken in proportion to the weight of cream delivered. The aliquot composite consisted of one cubic centimeter of cream for each pound of cream delivered. For patrons making large deliveries, this was cut to one-half cubic centimeter per pound. A check sample, designated as the "daily analysis," was taken of each delivery of cream by each patron. The fat determination by the Babcock test was made on the check samples daily, while the composites, as mentioned, were tested at the end of two weeks. As nearly as possible, the composites were handled just as the average creameryman would handle them. Eight-ounce glass-stoppered bottles were used for the aliquot samples and 2-ounce screw-top jars for the daily sample. The 8-ounce glass-stoppered bottle was also used for the dipper composite sample in all but trial 4. As buttermakers seldom make duplicate tests of cream, the same practice was followed in the experimental work. The buttermaker in all cases took the dipper samples. The experiment station representatives prepared the aliquot sample and the sample for the daily test. They made the Babcock test and read the fat tests. The fat determinations were read to the 0.5 per cent division in all trials except the dipper composite samples in trial 3. The fat tests were read directly from the steam tester, and glymol was used to eliminate the meniscus, according to common practice. All cream delivered by the patrons was weighed by the creamery operator. It is possible that some discrepancies in total pounds of fat delivered may result from not recording half-pounds, but this discrepancy should not enter in, as

comparisons are made on the same weights with the daily sample test and the two composite tests.

Eight two-week trials were conducted, four at the state experimental creamery, two at one local creamery, and one at each of two others. The data are supplied by 1003 cream patrons who delivered 319,434 pounds of cream in 8168 single deliveries. Trial 5 was conducted with a creamery receiving sour cream. In trial 3, the results of which are not included, the operator read the dipper composite tests by dropping all 0.5 per cent readings. The season of year and the number of patrons in each of the other trials are tabulated below.

Trial No.	Creamery No.	No. of Patrons	Date
1	4	148	Oct. 16–Nov. 1, 1925
2	4	146	Dec. 1–Dec. 15, 1925
4	1	107	March 1–March 15, 1926
5	3	106	March 16–March 31, 1926
6	2	109	April 1–April 15, 1926
7	4	140	April 17–May 1, 1926
8	4	141	Aug. 16–Aug. 30, 1926

The work was conducted through all four seasons of the year. Cream from 897 patrons was used and 7432 separate deliveries were made.

Facts Concerning the Creameries

Creamery I.—The receiving room is directly connected with the creamery room on a raised platform. An 8-ounce, rubber-stoppered bottle was used as a receptacle for the cream sample. It is the practice at this plant to keep the samples in tin trays on a table convenient to the man who weighs the cream. No change was made in this respect in conducting the experiment. Aliquot composite samples were placed beside the creamery dipper samples.

Creamery II.—The receiving room is separated from the main creamery room by a light partition and the receiving room is raised to a convenient height. The composite samples were kept in 16-ounce glass-stoppered bottles in a wooden rack along one wall of the receiving room. Aliquot composites were placed close to the rack used for the creamery composite.

Creamery III.—The receiving room of Creamery III is located in the main creamery room. This creamery was particularly well ventilated; no moisture adhering to the walls was noticable at any time. Eight-ounce glass-stoppered bottles were used. The samples were kept in a portable slanting rack against the creamery wall, convenient to the man weighing the cream.

Creamery IV.—The weigh room is on an elevated platform completely separated from the creamery room. The sample bottles used were similar to those used in Creamery III. They were kept in a rack on the wall in the receiving room. It was necessary to place the aliquot samples in the creamery room when conducting the work at this plant, because of lack of space in the receiving room.

Data Collected

The data sheet which follows indicates the record kept regarding each cream patron through the two weeks of the test.

DATA SHEET

Name of Patron_____ Number of Patron_____

Date	Lbs. of Cream	Per cent Fat	Lbs. of Fat
Total			

RESULTS FOR PERIOD

True average test_____

Test of composite taken in aliquot portions _____

Test of composite taken with dipper _____

Actual pounds fat_____
Calculated from true average test

Pounds fat by aliquot composite _____

Pounds fat by dipper composite _____

Variation from actual pounds of fat by aliquot composite_____

Variation from actual pounds of fat by dipper composite_____

From the data sheet it will be observed that a record was kept of the pounds of cream credited to the patron. Daily tests were made and the weight of fat delivered was recorded. After two weeks the total weight of cream and butterfat delivered by each patron was calculated. By dividing the weight of fat by the weight of cream delivered, the average is obtained. In this work the term "true average" is used to designate the figure obtained by this calculation. This average was accepted as the check test against which the accuracy of the two composite samples was judged.

In addition to the study of the accuracy of the composite sample, a study was made of the relative accuracy of the Babcock test as compared with the Roese-Gottlieb (Mojonnier) method. In all, 195 de-

terminations were made, each in duplicate, following the generally accepted methods of operating each. This comparison is used in the interpretation of the data obtained in comparing the two composites with the daily tests.

Relative Accuracy of Aliquot and Dipper Methods of Composite Sampling

The tabulated results presented in Table VI show the number and percentage of the patrons' tests which fall within a given class. Chart 1 illustrates the per cent variation from the true test of the composite made by the dipper and of that made by taking aliquot amounts from each delivery. The chart was prepared by plotting the values shown in Table VI.

TABLE VI

PERCENTAGE OF ALIQUOT AND DIPPER COMPOSITE SAMPLES COMPARED TO TRUE AVERAGE

Variation from true average, per cent fat	No. of composite samples*		Per cent of composite samples	
	Aliquot	Dipper	Aliquot	Dipper
−8.0	0	1	0	0.11
−5.6	1	0	0.11	0
−2.8	0	1	0	0.11
−2.6	4	2	0.45	0.22
−2.4	0	0	0	0
−2.2	0	1	0	0.11
−2.0	2	7	0.22	0.78
−1.8	6	14	0.67	1.56
−1.6	10	13	1.11	1.45
−1.4	10	23	1.11	2.56
−1.2	24	38	2.68	4.24
−1.0	31	57	3.46	6.35
−0.8	48	84	5.35	9.36
−0.6	66	99	7.36	11.04
−0.4	115	111	12.82	12.37
−0.2	181	122	20.18	13.60
0	196	87	21.85	9.70
+0.2	95	58	10.59	6.47
+0.4	46	63	5.13	7.02
+0.6	22	37	2.45	4.12
+0.8	15	28	1.67	3.12
+1.0	10	21	1.11	2.34
+1.2	6	11	0.67	1.22
+1.4	3	5	0.33	0.56
+1.6	2	4	0.22	0.45
+1.8	2	2	0.22	0.22
+2.0	1	2	0.11	0.22
+2.2	1	1	0.11	0.11
+2.4	0	1	0	0.11
+2.6	0	2	0	0.22
+2.8	0	0	0	0
+3.0	0	1	0	0.11
+4.6	0	1	0	0.11

* Each composite sample represented the cream delivered during two weeks by one cream producer or patron.

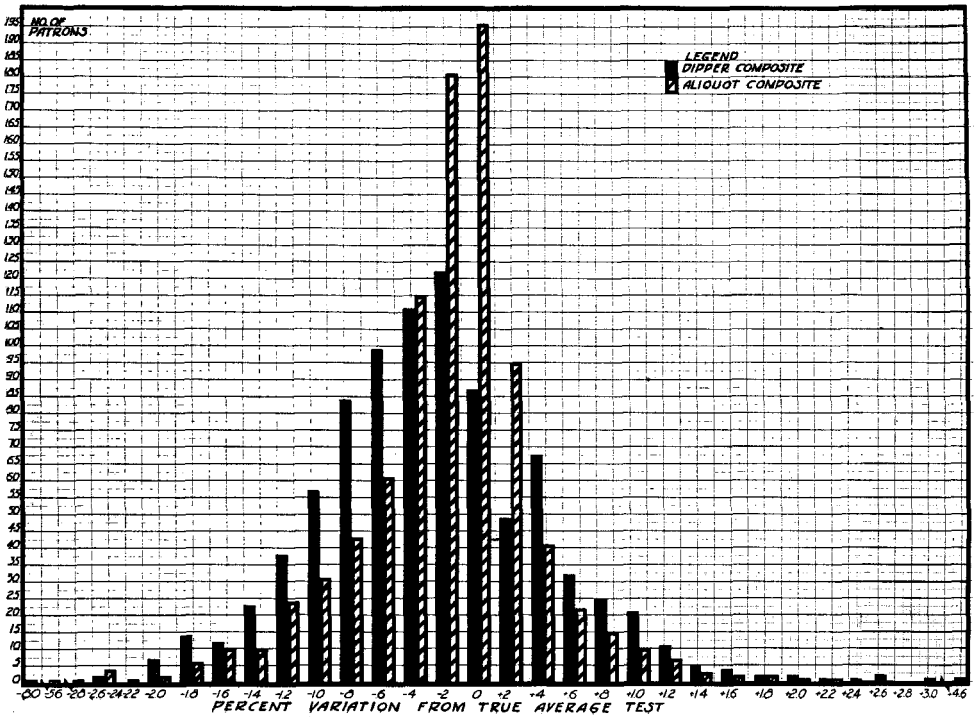

Chart. 1. Relative Accuracy of Aliquot and Dipper Methods of Composite Sampling

Accuracy is determined by finding the difference between the percentage of fat in each composite sample and true average percentage of fat of each producer's cream deliveries for two weeks. The true average percentage of fat is calculated from Babcock determinations of each delivery of cream. Differences are plotted in number of composite samples varying in percentage of fat from the true average test according to the numbers located at the base of the chart, or abcissa. Results from sampling and analyses of cream delivered by 897 producers are included. Note that the aliquot determinations show a smaller variation from the true average than do the dipper determinations, showing that the aliquot is the more accurate of the two methods. The standard deviation of the aliquot variations from the true average is 0.59 as compared to 0.79 for the dipper tests.

Theoretically, the aliquot composite sample should check with the true average test. Chart 1 shows that in practice this is not always the case when the aliquot cream sample is used. The results do clearly indicate, however, that even in practice, the aliquot sample is more accurate than the dipper composite. Chart 1 shows this definitely by bringing out two facts: (1) A greater number of the aliquot composite tests than of the dipper composite tests agreed with the true average. This is shown by the fact that 196 aliquot composite tests fell in the zero class as compared to only 87 of the dipper tests—less than half as many. (2) The aliquot composite analyses as a whole varied much less from the true average fat percentages than the dipper composite analyses. This is readily seen by noting from Chart 1 that the aliquot analyses are much nearer the zero point than the dipper results. It is significant that the extremes show only dipper composites, as no aliquot analyses varied as far from the true average as the dipper composites.

A more detailed mathematical study of the data also showed the difference in favor of the aliquot. (See Appendix, 1.) The results obtained on the samples prepared by means of the dipper varied considerably more from the true average or the check analysis than the sample prepared in aliquot portions.

Variation of Babcock Results from Roese-Gottlieb (Mojonnier)

Theoretically, the aliquot method of preparing composite samples should show fat percentages which are identical with the true average. We have just pointed out that this is not the case by showing in Chart 1 that the aliquot tests were spread on both sides of the true average test. The results obtained by Lee and Hepburn (5) suggested that a part of this discrepancy might be caused by inaccuracies in the Babcock method as applied to cream. Our own laboratory experience strengthened this possibility, and a study of the accuracy of the Babcock method was undertaken.

Any method of making such a study requires that one or more assumptions be made and the results are therefore open to some criticism. The procedure in this case was to compare the results from the Babcock method with those from the Roese-Gottlieb (Mojonnier) method, using 195 samples. The assumption here is that results by the latter method are always correct. As the Roese-Gottlieb (Mojonnier) method is ordinarily considered more accurate than the Babcock, this comparison seemed justified, for altho it is admitted that some variability must occur in replicated tests of a single sample of cream by the Roese-Gottlieb (Mojonnier) method, these variations are con-

sidered small in comparison to the variability of Babcock results. Therefore, if we accept the Roese-Gottlieb test as the more accurate, a comparison of these two methods should yield an approximate index of the variability and accuracy of the Babcock test.

Most of the analyses were made by laboratories of two Twin City dairy plants where large amounts of cream are handled. The difference between the average of duplicate Babcock determinations and the average of duplicate Roese-Gottlieb (Mojonnier) determinations for each sample was determined by subtracting the Babcock result from that obtained by the Roese-Gottlieb (Mojonnier) method. The results are tabulated in a frequency distribution in Table VII and shown graphically in Chart 2. For the sake of comparison, the variations between the Babcock and Roese-Gottlieb (Mojonnier) tests are given the same class intervals as were used in comparing the two composite tests with the true average test in Chart 1.

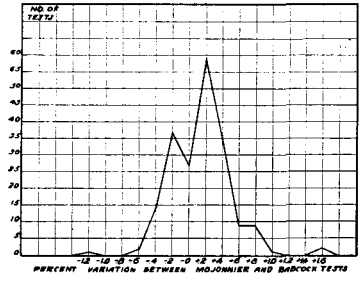

Chart 2. Accuracy of Babcock Fat Determinations of Cream

The curve was prepared by plotting differences between duplicate Babcock and Mojonnier fat percentage determinations of 195 samples of cream of varying percentage fat content. The test for accuracy is based on the assumption that the Mojonnier method yields accurate results. The differences are plotted in number of Babcock determinations which varied from the Mojonnier according to the values indicated at the base of the chart, or abcissa. Note the wide spread of some of the Babcock determinations around the Mojonnier. The standard deviation was 0.359 with a probable error of 0.0122.

Instead of comparing exactly with the Roese-Gottlieb (Mojonnier), the Babcock results vary from the Mojonnier, or assumed correct determinations, much as the aliquot test varies from the true average test. It is possible, therefore, that variations in results from the Babcock method play a part in determining the accuracy of either plan of composite sampling.

The next step was to attempt to determine to what extent these variations by the Babcock method might be responsible for the inaccuracies of the composite samples.

As pointed out, there are unavoidable errors in the Babcock method when applied to cream. (See Appendix, 2.) Table VIII shows the relative accuracy of the aliquot and dipper samples for the various

trials, assuming 100 per cent accuracy where the variability is no greater than 0.36 per cent, which was found to indicate the variability of the Babcock test. Altho this figure may not be an exact measure of the variability of the Babcock test, it must be conceded that a determination of the variability of the Roese-Gottlieb test would not alter the general tendency of the relative accuracy shown for the dipper and aliquot composite samples as determined in this investigation. (See Appendix, 3.)

TABLE VII

VARIATION BETWEEN BABCOCK AND ROESE-GOTTLIEB (MOJONNIER) CREAM TESTS

Variation from the Mojonnier analysis, per cent	No. of tests	Per cent of total tests
−1.2	1	0.51
−0.0	0	0
−0.8	0	0
−0 6	2	1.02
−0.4	14	7.14
−0.2	37	18 88
0	27	13.78
+0.2	59	30.10
+0.4	35	17.86
+0.6	9	4.59
+0.8	9	4.59
+1.0	1	0 51
+1.2	0	0
+1.4	0	0
+1.6	2	1.02
		100.00

TABLE VIII

PERCENTAGE ACCURACY OF ALIQUOT AND DIPPER METHODS OF COMPOSITE SAMPLING

Trial No.	Percentage accuracy	
	Aliquot analyses	Dipper analyses
1	52	42
2	100	58
4	100	47
5	90	45
6	100	65
7	100	56
8	47	36
Av. all trials	61	45
Av. trials 2, 4, 5, 6, 7	100+	50

It is still more interesting to note from Table VIII the percentage accuracy of the aliquot method for the combined results from trials 2, 4, 5, 6, and 7, (70 per cent of the trials) because the variations from the true average are fully 100 per cent within the variability of the Babcock method. (See Appendix, 4.)

The analyses of the dipper composite samples for the same trials were but 50 per cent as accurate as those of the aliquot composite

samples. It seems logical, therefore, to conclude that the aliquot composite, in a majority of cases, can be expected to render just as reliable results as can be obtained by daily testing. Charts 3 and 4 illustrate these facts more clearly. Chart 3 illustrates the variations between the percentage of fat in the cream and the true average test as made

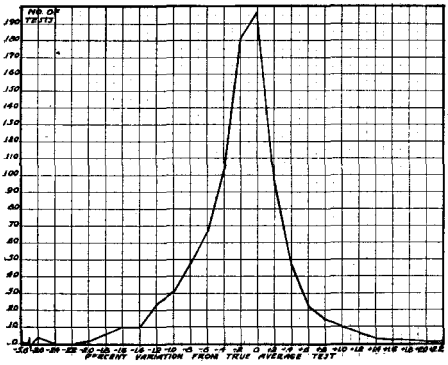

Chart 3. Relative Accuracy of Aliquot Composite Sample

The degree of accuracy was determined here, as in Chart 1, by difference between the aliquot and true average fat percentage determinations, but the curve for the aliquot test is here presented alone. Note that the majority of the analyses agree very closely with the true average. The standard deviation is 0.59.

from the aliquot composite samples of trials 1, 2, 4, 5, 6, 7, and 8; Chart 4, the same for the dipper composite samples. By comparing Charts 3 and 4 with Chart 2, another picture can be had of the relative accuracy of the two methods of sampling. The actual number of tests falling within the variability of the Babcock test can also be noted.

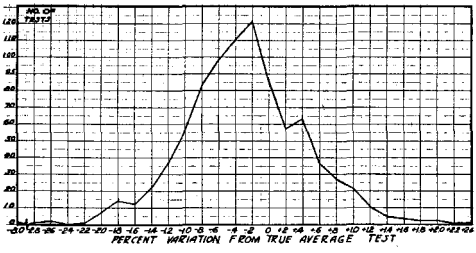

Chart 4. Relative Accuracy of Dipper Composite Sample

This chart was prepared in the same manner as Chart 3. By comparing this curve with that of Chart 3 it is seen, as in Chart 1, that the analyses of the dipper composite samples agree less closely with the true average than those of the aliquot composite samples. The standard deviation is 0.79.

As mention was made of the results of trials 2, 4, 5, 6, and 7, Charts 5 and 6 are presented to illustrate the facts shown in Charts 3 and 4 for these trials. Little improvement is noted in the dipper composite samples shown in Chart 6. Chart 5, however, illustrates determinations which were 100 per cent within the variability of the Babcock test.

Relation of Size of Delivery to Accuracy of Composite Samples

The amount of cream delivered from day to day by any one producer varies. The variations are greatest from month to month and from season to season. In localities where winter dairying is practiced,

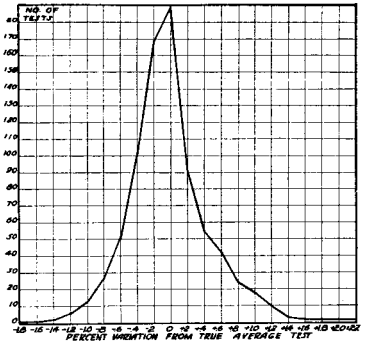

Chart 5. Relative Accuracy of Aliquot Composite Samples in Several Selected Trials

This chart was prepared in the same manner as were Charts 3 and 4 but represents the relative accuracy of the aliquot composite samples in trials 2, 4, 5, 6, and 7, omitting trial 8. These tests are 100 per cent within the variability of the Babcock method and therefore illustrate how accurate the aliquot method may become. The standard deviation is 0.353.

it is logical to expect the large deliveries of cream to occur during the winter because deliveries are made less often. The results of our study indicate that the smallest average daily deliveries with both composite samples, yielded results which were less accurate than larger deliveries. For the smaller deliveries, the dipper method proved nearly as accurate as the aliquot. (See Appendix, 5.)

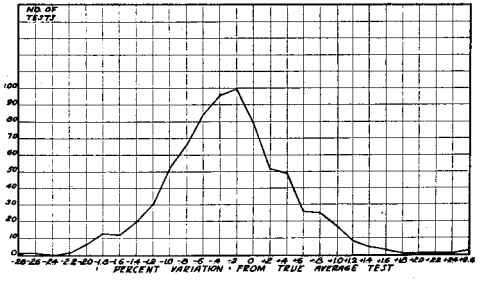

Chart 6. Relative Accuracy of Dipper Composite Sample in Several Selected Trials

This chart represents the relative accuracy of the dipper composite analyses for trials 2, 4, 5, 6, and 7, omitting trial 8. This curve should be compared with that of Chart 5, which gives data on the aliquot composite samples for the same trials. Altho the aliquot composite analyses for these selected trials showed greater accuracy than for all the trials, the same is not true of the dipper composite tests, for this curve shows nearly as wide a distribution of tests as is found in Chart 4. The standard deviation was 0.72.

Causes of Inaccuracy of Dipper Sample

It is a comparatively easy matter to show theoretically, as Hunziker has shown (3), that when the cream delivered consecutively by any one producer varies in both weight and percentage of fat, the analysis of the dipper composite sample may not agree with the true average percentage of fat. Because of this fact an attempt has been made to correlate the degree of inaccuracy found in each dipper composite sample with the two factors just mentioned, namely, variation in weight and variation in percentage of fat of consecutive deliveries by one patron.

Under average farm conditions a variation in the percentage fat content of creams separated from day to day is usually accompanied by an inverse variation in their weight. As these two factors are closely related, it was thought that either should show a relationship to the accuracy of the dipper method of composite sampling. For this reason the relation of each of these factors to the accuracy of the dipper method of composite sampling was studied, after which an attempt was made to evaluate the combined effect of the two factors.

A study of several trials showed that virtually no relation existed between the variability of either fat content or amounts of cream delivered by a patron during a two-week period and the accuracy of the dipper composite sample. A slight relation was found when the combined effects of these two factors were considered. This correlation was too small to have much effect on the accuracy of the dipper composite sample under the conditions usually encountered where this type of samples is taken.

Accuracy of Composite Sample of Sour Cream

It is to be expected that it would be more difficult to obtain an accurate composite sample of sour cream than of sweet cream, owing to the greater difficulty in obtaining a representative sample of any one delivery. With the aliquot composite sample the difficulty might be expected to be even greater, because viscosity of the cream interferes with accurate measurements of definite amounts. For the purpose of studying this condition, trial 5 was conducted at a plant receiving mainly sour cream.

The data obtained are presented in Chart 7. The chart was constructed in the same way as Chart 1, showing the number of patrons and the variation from the true average of the Babcock analyses of the samples taken by both the aliquot and the dipper methods.

In this trial, data were obtained from the deliveries of 106 cream producers. Chart 7 shows a wide variation between the fat percent-

ages as calculated for the true average and as determined from the dipper composite samples. On the other hand, there were but 20 cream producers whose aliquot tests fell in the zero class with a variation ±0.5 per cent; 32 patrons' aliquot composite tests fell at −0.2 per cent, while the extreme variations are from −1.4 to +0.6 per cent. These results clearly show again the inaccuracy of the dipper composite sample in comparison with one made in proportion to the weight of cream delivered.

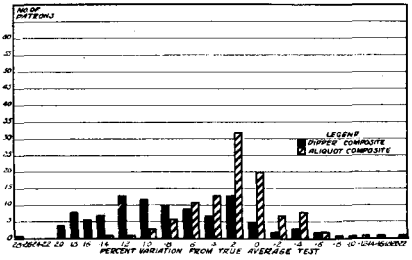

Chart 7. Effect of Sour Cream on Relative Accuracy of Aliquot and Dipper Composite Samples

This chart shows the relative accuracy of the two methods of composite sampling and testing in a plant where most of the cream received is sour. Note, again, that the aliquot method yields more accurate results than the dipper, as shown by the narrower range of variations from the true average. The standard deviation of the variations was 0.40 for the aliquot analyses around the true average, while the corresponding standard deviation for the dipper samples was 0.79.

With regard to the effect of sour cream on the accuracy of the two methods of composite sampling, it must be borne in mind that the condition of the sour cream to be sampled varies greatly under different conditions. The term "sour cream" may refer to cream that has become only mildly sour or it may refer to the very sour, extremely viscous product resulting from prolonged storage at relatively high temperatures. The cream studied in trial 5 was only moderately sour. It is evident from Chart 7 that both dipper and aliquot samples yielded results which compare very closely with those shown in Chart 1. It is difficult to show from these data that the type of sour cream studied interfered with the accuracy of either method of composite sampling.

EFFECT OF DROPPING 0.5 PER CENT READINGS

It was previously pointed out that in all trials, with one exception, the cream tests were read to the nearest 0.5 per cent. Trial 3, which is not included in the data heretofore presented, represents results where all conditions were similar to those of the other trials except that the analyses of the dipper composite samples were read to the nearest whole percentage figure rather than to the nearest 0.5 per cent. When a fat column stood at some point between two whole percentage figures, the lower one was recorded. On the contrary, the analyses of the

aliquot composite samples were made by reading the fat column at the nearest 0.5 per cent graduation. A frequency distribution of the results on the two composite samples is shown in Chart 8. The data cover cream deliveries of 106 producers.

Chart 8 clearly shows the effect of dropping the 0.5 per cent reading. It will be observed that in the analyses of the dipper composite samples, by far the greatest majority ranged on the minus side of the zero class, or true average. The greatest variation from the true average per cent of fat was —3.2, while only 4 patrons were above the true average. This method of testing cream should be discontinued, as it is doubtless responsible for some of the excessive overruns

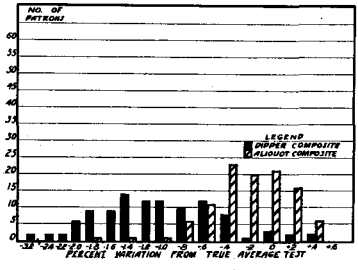

Chart 8. Effect on Accuracy of Dipper Composite Sample of Dropping 0.5 per Cent Readings

In this trial no 0.5 per cent readings were recorded in testing the dipper composite samples. When a fat column read at some point between two full percentage graduations, the lower full per cent was recorded. On the contrary, the aliquot tests were read as in the other trials. The accuracy of the aliquot determinations of these samples compares favorably with that of the aliquot samples analyzed in other trials, but the dipper analyses are nearly all on the minus side of the zero class. They indicate a large loss of fat by the producers.

reported by creameries and probably results in inflated prices paid for butterfat. The results of the aliquot composite tests compare very favorably with those shown in Chart 1, as the Dairy Division representative conducted and read the tests, as usual.

It must be emphasized that the work of this trial in no way differed from that of other trials except in the reading of the Babcock analyses of the dipper composite samples.

RELATION OF CREAMERY TO COMPOSITE SAMPLE

Comparison of Average Tests

The data presented in Chart 1 should be considered from the viewpoint of the creamery manager. He is interested in knowing just how the results are going to influence his business. Will the creamery pay for more fat than it receives by the dipper or aliquot composite? Seldom do these men question the accuracy of the daily fat determination, yet more will be said of this later. The creamery manager wishes to

know how the two methods of sampling will average, and particularly if there is likely to be an average increase by any method.

To show the relation between the two methods of sampling cream on the average fat percentages over a two-week period, the data of Table IX are presented.

TABLE IX

AVERAGE FAT PERCENTAGES AS DETERMINED BY THE ALIQUOT AND COMPOSITE METHODS COMPARED WITH THE DAILY METHOD

Trial No.	No. of producers	Cream	True average fat	Aliquot average fat	Dipper average fat	Average difference from true av. fat	
						Aliquot	Dipper
		lb.	per cent	per cent	per cent	per cent	per cent
1	148	34,105	29.99	30 25	29.91	+0.25	—0.09
2	146	41,368	30.76	30.58	30.44	—0.18	—0.32
4	107	45,555	26.06	25.93	25.81	—0 13	—0.25
5	106	24,922	31.53	31 32	30.76	—0.21	—0.77
6	109	43,966	27.48	27 25	27.08	—0.23	—0.40
7	140	54,954	30.22	30.17	30.20	—0.05	—0.02
8	141	34,720	30.74	29.95	30.50	—0 79	—0.24
Total average.	897	279,590	29.35	29.16	29.08	—0.18	—0.26

The data presented in Table IX would please the average creamery manager. In actual practice the average variation of the fat percentage determined from the aliquot composite sample was but —0.18 from the true average in the seven trials, while that from the dipper composite sample varied only —0.26. Altho the aliquot composite more closely approaches the true average, it is doubtful if the small difference would turn the average creameryman from the dipper to the aliquot composite, because of the difficulty generally experienced in getting an aliquot sample.

As has been stated, trial 5 was conducted at a creamery receiving sour cream. Here will be noted the greatest difference between the dipper composite and the true average determinations. The aliquot composite compared very favorably with the true test, however. In trial 8 there is a significant difference between the average fat percentage of the aliquot sample and the true average, and the variation is greater than in the average for the dipper composite sample. This trial was conducted in August, 1926, and, as shown in Table IX, the size of the delivery affected the accuracy of the aliquot composite sample.

Comparison of Amount of Fat Received According to Analyses of the Two Composites

The total amount of butterfat which the creamery must pay for is of great importance. The tests may average well, yet there is the possibility that the total fat may not average so well. The data in

Table X compare the amounts of fat received at the various creameries as calculated from the true average and from the two composites.

TABLE X

TOTAL AMOUNT OF FAT RECEIVED ACCORDING TO ANALYSES OF DIPPER AND ALIQUOT COMPOSITES AS COMPARED WITH ACTUAL AMOUNT OF FAT

A comparison of the pounds of fat received as determined from the true average and from the aliquot and dipper composite samples

Trial No.	Actual fat received according to true average	Fat received according to		Net variation	
		Aliquot composite	Dipper composite	Aliquot composite	Dipper composite
	lb.	lb.	lb.	lb.	lb.
1	10,229	10.316	10,200	+ 87	− 29
2	12,724	12,648	12 592	− 76	−132
4	11,871	11,811	11,758	− 59	−113
5	7,858	7,805	7,665	− 53	−192
6	12,081	11,979	11,904	−102	−177
7	16,609	16,581	16,598	− 28	− 11
8	10,672	10,397	10,590	−275	− 82
Total	82,046	81,539	81,308	−507	−735

The data presented in Table X clearly show that the creamery has little to fear in the use of a composite cream sample. In every case except the determinations made on the aliquot composite sample in trial 1, less fat is accounted for by either method of sampling than was actually delivered, according to the true average. Here, again, the results favor the aliquot composite sample, as the tendency is clearly toward more accurate results. From the data presented in Tables IX and X, the authors believe that there is little reason for the average creameryman to fear losses from the use of either the dipper or the aliquot composite sample.

RELATION OF CREAM PRODUCER TO COMPOSITE SAMPLE

The cream producer is interested in getting credit for every pound of butterfat delivered. The question, therefore, arises as to whether the composite sample may yield results which are unfair to the producer.

In studying this question, the amount of fat delivered by each patron through each trial was calculated from the daily determinations. This total was then compared with the total fat with which each patron was credited, according to the two composite samples. Chart 9 is based on the actual amount of fat delivered in the seven trials, and pictures the effect on the cream patron of using dipper and aliquot samples as compared with a daily analysis.

The results indicated by Chart 9 will be first considered from the standpoint of the composite samples taken in aliquot portions. According to the chart, 347 cream producers were credited with gains

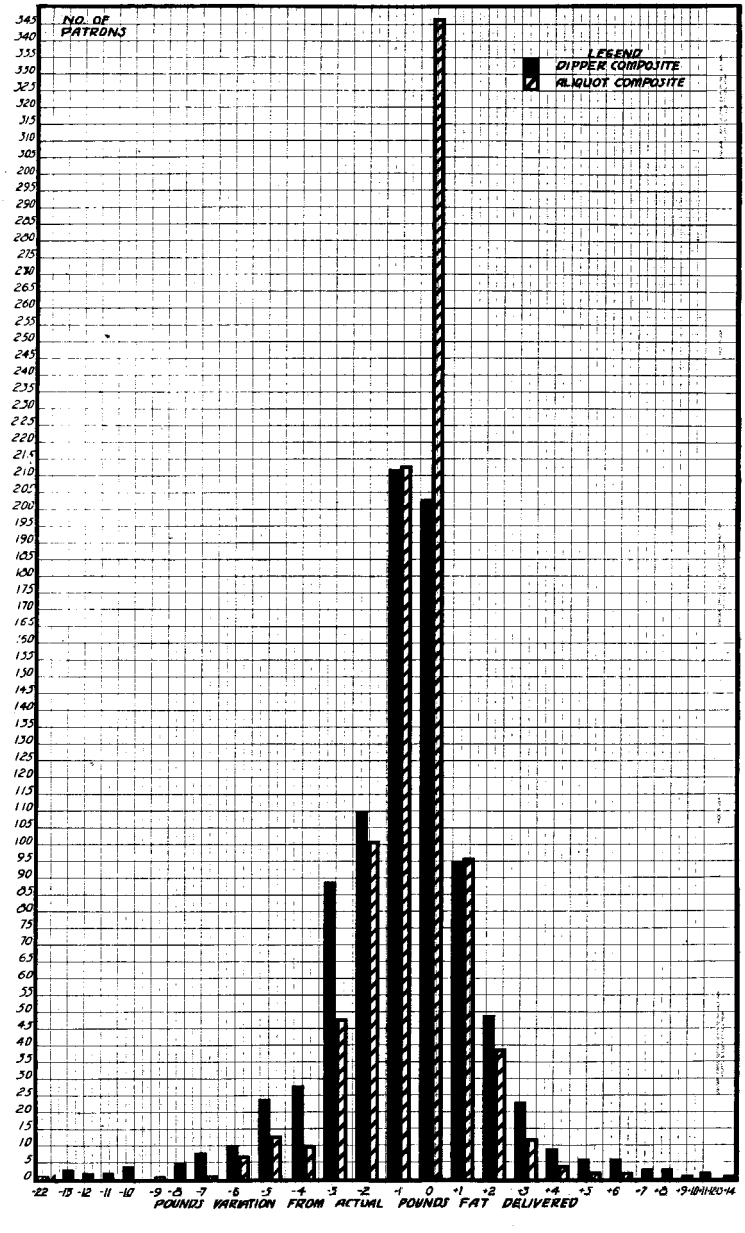

Chart 9. Relation of Cream Producer to Composite Sample

This chart shows the frequency distribution of differences between the amount of fat actually delivered by the patrons and the amount credited to them by each of the analyses. Results are plotted in number of patrons who lost or gained butterfat according to the figures located across the base of the chart, or abcissa. The aliquot sample shows up more favorably than the dipper, not only by a narrower spread from the zero class, but also by averaging closer to the zero class than the dipper composite. The standard deviation for the differences as found by the aliquot method is 1.73, while the corresponding standard deviation for the dipper method is 2.61.

or losses of fat which varied only from —0.5 to +0.5 pound, or the amount of fat received by this group of producers fell in the zero class. Of 897 cream producers, 38.7 per cent were credited with an amount of fat by the aliquot composite sample test which practically checked with that with which they would have been credited by the daily test. It will be observed, too, that 213 producers lost from 0.5 to 1.5 pounds of butterfat and 96 producers gained from 0.5 to 1.5 pounds, according to the aliquot composite test. One producer lost 22 pounds of fat while two others gained from 5.5 to 6.5 pounds. These represent the extreme losses or gains according to the Babcock analyses of the aliquot composite samples. Only 3 patrons had a loss or a gain greater than 6.5 pounds of butterfat.

It is interesting to note here the tendency of a majority of the analyses to fall on the minus side of the zero class. This is evidenced by a glance at Chart 9, where it is seen that the producers' fat losses, as shown by the cases appearing on the minus side of zero, greatly outnumber those falling on the plus side; and further, by the fact that the average of the variations from the actual pounds of fat delivered is —0.55 in the aliquot samples, and —0.83 in the dipper samples. It is interesting to note that 88.9 per cent of all the producers lost or gained not more than 2.5 pounds of butterfat. The general tendency appears to be a loss, which fact must not be overlooked, yet it is conceded by the authors as difficult to explain.

The results obtained from the dipper samples are not so favorable as those from the aliquot samples, yet a glance at Chart 9 impresses the fact that there is a grouping about the zero class. The total variations are greater, ranging from a loss by 3 producers of from 12.5 to 13.5 pounds of fat to a gain by one of from 13.5 to 14.5 pounds. For 203 producers there was a loss or gain of but 0.5 pound according to the dipper composite. Of the 897 producers, 212 lost from 0.5 to 1.5 pounds of fat while 95 gained a like amount. In the dipper composite, 74 per cent of the producers lost or gained not more than 2 pounds of butterfat.

Loss or Gain per 100 Pounds of Fat Delivered

No two producers deliver the same amount of butterfat. In order that all may be on an equal basis, the data obtained with trials 1, 2, 4, 5, 6, 7, and 8 were again calculated on a basis of gain or loss of fat per 100 pounds of fat delivered, according to the two composites. These amounts are compared with the amount of fat delivered by the producers according to the true average, in Chart 10.

According to Chart 10, 265 of the 897 producers lost or gained 0.5 pound per 100 pounds of fat delivered. According to results ob-

tained by the aliquot composite sample, 215 producers lost from 0.5 to 1.5 pounds per 100 pounds of fat delivered. By the aliquot composite method, 99 producers gained from 0.5 to 1.5 pounds per 100 pounds of fat delivered. According to the dipper composite, 160 producers lost 0.5 to 1.5 pounds per 100 pounds, and another 160 lost from 1.5 to 2.5 pounds for each 100 pounds of fat delivered. A small group, 81, gained from 0.5 to 1.5 pounds per 100 pounds of fat, and 57 gained from 1.5 to 2.5 pounds according to the determination made

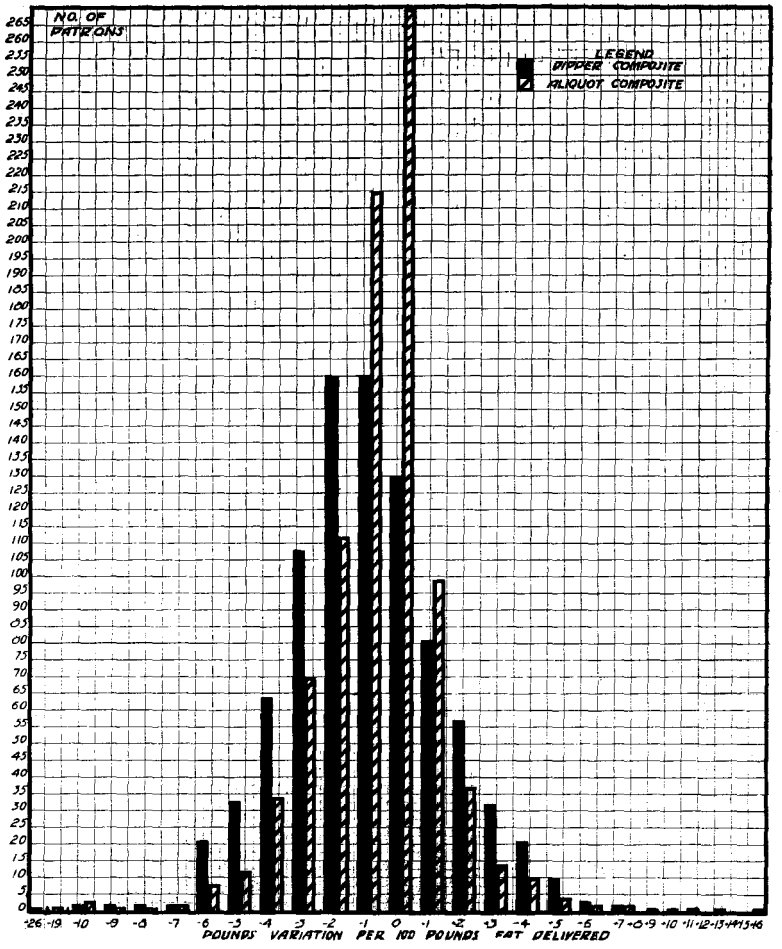

Chart 10. Loss and Gain per 100 Pounds of Fat Delivered

This chart shows the same data as Chart 9 but all producers have been put on a comparable basis by calculating the amount of fat each patron would have lost or gained had his cream deliveries for the two weeks contained exactly 100 pounds of fat. The standard deviation for the results obtained by the aliquot method is 2.74 and for the dipper method, 3.31.

on the samples taken by the dipper. One producer lost from 25.5 to 26.5 pounds of fat for every 100 pounds of fat delivered, while another gained from 15.0 to 16.5 pounds. The extreme cases are not considered serious by the authors because they are too few. The average variation per 100 pounds of fat delivered by the average producer was —0.745 by the aliquot method and —1.012 by the dipper method. (See Appendix, 7.)

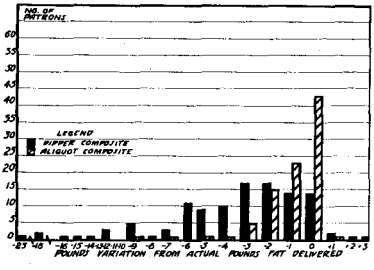

Chart 11. Producer's Losses and Gains of Fat when 0.5 per Cent Readings Are Dropped

This chart shows the frequency distribution of the actual gains and losses of butterfat suffered by the patrons in the dipper test due to dropping 0 5 per cent readings in conducting the Babcock test. Nearly a'l producers lost by the dipper method while a distribution much more favorable to the producers resulted in the case of the aliquot sample where 0.5 readings were not dropped.

Effect of Dropping 0.5 per Cent Reading

The presentation dealing with trial 3 in which the 0.5 per cent readings were not included in case of the dipper composites, should be considered from the standpoint of the cream producer. Chart 11 presents the frequency distribution of the differences between the pounds of fat credited to each producer by each composite sample and those actually delivered as determined from the true average fat percentage. Chart 12 presents the same data, with the producers on a more comparable basis, by calculating the losses and gains on the basis of a delivery of 100 pounds of fat by each.

A glance at Charts 11 and 12 shows that in this trial far the more accurate work is accomplished where the aliquot composite sample is used, and most of the inaccuracy of the dipper composites can be laid to the error involved by dropping the 0.5 per cent readings. This trial included 106 producers. According to the true average fat percentage, these patrons delivered 10,850 pounds of fat. According to the aliquot composite fat percentage, they would have been credited with but 10,773 pounds of fat—a difference of 77 pounds. The average loss or gain according to the aliquot composite sample was 0.7453 pound per 100 pounds of fat delivered. When all 0.5 per cent readings of the dipper composite samples were dropped, the producers were credited with

10,385.02 pounds of fat. The loss sustained would have been 465 pounds of fat, which was at the rate of 4.3 pounds per 100 pounds of fat delivered. Charts 11 and 12 show that the losses and gains are well on the minus side of the zero class, particularly in the results on the dipper composite.

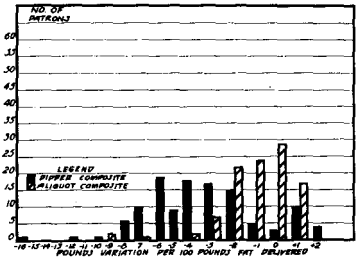

Chart 12. Losses and Gains per 100 Pounds of Fat Delivered when 0.5 per Cent Readings Are Dropped

This chart presents the data shown in Chart 11 except that all producers have been put on a comparable basis by calculating the amount of fat each producer would have lost or gained if his cream deliveries for the two-week period had contained exactly 100 pounds of fat.

GENERAL DISCUSSION OF RESULTS

The experimental work clearly demonstrates that under practical conditions the evaporation of moisture from composite cream samples is not sufficient to affect the Babcock cream test. The average evaporation from 966 dipper composite samples was but 0.78 per cent. The type of stopper used on cream composites should receive attention. There appears to be a greater evaporation from the glass-stoppered than from the cork- or rubber-stoppered bottles. This is probably due to the inability of the average creameryman to keep a stopper with the bottle for which it was ground. The cork stopper is condemned because it absorbs butterfat from the cream sample. The rubber stopper fits closely and apparently absorbs no fat or moisture.

The experimental work further shows the aliquot composite cream sample to be more accurate than a composite sample prepared with a sampling dipper. Chart 1 shows that by far the most cream patrons have tests which fall around the zero class. This fact is clearly shown also in charts 3, 4, 5, 6, 7, 8, 9, and 10, which picture the results of trials 2, 4, 5, 6, and 7. The average obtained by making daily tests of the patrons' cream served as a check.

A statistical study of the data was made on the eight trials. The arithmetic mean of the variations of the aliquot composite test from the true average test for trials 1, 2, 4, 5, 6, 7, and 8 was —0.182. The standard deviation around this mean was 0.59. The corresponding mean for the dipper test was —0.264 and the standard deviation

around this mean was 0.79. Here, again, the accuracy of the two methods of sampling is shown.

The relative accuracy of the Babcock test as compared with the Roese-Gottlieb (Mojonnier) test was studied. The standard Babcock test may be the cause of inaccurate work even when carefully conducted. The calculations presented in Table VIII show the relative accuracy of the two methods of preparing the composite cream tests when the error involved in conducting the Babcock analysis is considered. It is shown that in trials 1, 2, 4, 5, 6, 7, and 8, 61 per cent of the analyses of the aliquot samples were accurate within the variability of the Babcock method, and the corresponding accuracy was 42 per cent for the dipper composite samples. By selecting the trials having the more nearly uniform standard deviations, trials 2, 4, 5, 6, and 7, which represent 70 per cent of the trials conducted, it was found that the tests made on the aliquot composite samples were fully as accurate as might have been obtained by a daily analysis of each patron's cream. The dipper composites, however, in this group of trials, were but 50 per cent as accurate as the daily test. These facts may lead us to favor the aliquot method of sampling cream. However, in trials 1 and 8 the fact stands out that the aliquot tests, though more accurate within the trials, were little better than the average dipper composite test of trials 2, 4, 5, 6, and 7. Trials 1 and 8 are considered exceptional, as they were conducted during periods of small deliveries. Variations in size of cream deliveries and variations in the percentage of fat in cream will affect the accuracy of the dipper composite. These factors apparently are taken care of in the aliquot composite sample to a certain extent, but not in all cases. The inaccuracy in the dipper composite sample, however, can not be entirely blamed to these two factors. The resulting error is overshadowed by the relatively great error introduced by the inaccuracy of the Babcock test when operated under practical conditions.

That the errors made in testing are probably more important than the method of preparing the composite sample, was illustrated in trial 3, in which the 0.5 per cent readings on the dipper composite samples were dropped. The results are shown in Chart 8, and tho the frequency distributions of the aliquot composites compare very favorably with those of the aliquot composite tests in Chart 1, the frequency distribution of the dipper composites ranges well over to the minus side of the mid-value class. Should 0.5 per cent readings on daily tests be dropped, the results would be very much in favor of almost any type of composite sample.

Judging from averages, the work herein reported corroborates that of Lee and Hepburn. (5) It would be difficult to criticize the dipper

composite if averages alone were considered. Comparing the results of the two composites with the results of daily tests, the tests made in trials 1, 2, 4, 5, 6, 7, and 8 were found to vary 0.18 per cent in the aliquot composites and 0.26 per cent in the dipper composites. The creamery operator may therefore favor the dipper composite cream sample if he is to use such a method in the creamery operations.

In the opinion of the authors there is a place for the composite cream sample. Before expressing our preference for a method, however, the loss or gain experienced by the individual cream producer will be considered. Chart 9 shows the actual amount of fat credited to producers by the two composite tests in comparison with the amount actually delivered, according to the daily test. Of 897 producers, 3 lost or gained more than 6.5 pounds of butterfat according to the aliquot composite sample. Thirty-four producers lost or gained 6.5 pounds of fat according to the dipper composite, yet 74 per cent of the producers lost or gained not more than 2 pounds of fat.

When considering the relative accuracy of the composite sample, the cream producer must be considered. In order that all producers may be on an equal basis, the losses or gains are calculated per 100 pounds of fat delivered. Chart 10 illustrates the frequency distribution of the amount of fat per 100 pounds delivered according to the two composites, as compared with the amount according to the true average test. These results show that, as a rule, the patron receives fair treatment. It is impossible to say what one might lose or gain by either method of sampling. It is certain, however, that with an aliquot composite the average loss or gain will not be so great as with the dipper composite sample. By either method a patron may gain in one month what he lost in another. With sour cream, which is delivered to some local creameries of Minnesota, the aliquot composite is preferred to the dipper composite. In the plant receiving relatively small single deliveries of sweet cream, the dipper composite will serve.

The composite cream sample, as used by approximately 33 per cent of the creameries of Minnesota, aids in reducing the cost of manufacturing butter. Daily testing is better adapted to creameries desiring to pay cash for cream in attempting to meet competition. It is recommended for plants receiving cream from long distances. This cream is generally sour, thick, viscous, and very difficult to sample. Regardless of the size of the plant, when sweet or slightly sour cream is received, the composite sample prepared in aliquot amounts will yield results which will compare favorably with those of daily testing.

The operation of the Babcock test may be more serious than the method of sampling the cream. This fact was forcibly shown in discussing trial 3.

CONCLUSIONS

1. The average evaporation of moisture from composite cream samples under practical conditions is not sufficient to justify condemning this method of analysis when cream samples are kept as the average creameryman of Minnesota keeps them.

2. The amount of evaporation is greatest from glass-stoppered bottles. Rubber- and cork-stoppered bottles follow in order.

3. The rubber stopper is preferred to the cork, as a small amount of butterfat may be absorbed by the cork stopper.

4. The composite cream sample can not be condemned as inaccurate as taken in Minnesota.

5. Where possible, the composite cream sample should be prepared in aliquot portions or in proportion to the weight of cream delivered. The dipper composite can not yield as accurate results as the aliquot.

6. The operation of the Babcock test can be a more serious source of error in determining the pounds of fat in cream than the method of preparing the composite cream sample.

7. The dropping of 0.5 per cent when reading the Babcock test should never be practiced where accuracy is desired.

8. The cream producer can expect an accurate test on 60.8 per cent of his deliveries if composites are prepared in aliquot, and in 45 per cent of his deliveries if the dipper is used.

9. The average variation per 100 pounds of fat delivered is —0.745 pound by the aliquot composite test and —1.012 pounds by the dipper composite test.

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APPENDIX

1. The arithmetic mean of the variations of the aliquot composite from the true or weighted average for the trials shown in Chart 1 was —0.182 and the standard deviation around this mean was 0.59.

The corresponding mean for the dipper tests was —0.264 and the standard deviation 0.79. As the frequency distributions of the two composite tests are made up in the same class intervals, the standard deviations may be used to compare the accuracy of the two composite tests. It is noticed that the standard deviation around the average of the dipper tests is considerably greater than that around the average of the aliquot composite tests.

2. Obviously, if we can establish the limits of error due to the Babcock method, we can to the same extent account for the variation between the composite samples and the true average.

The standard deviation, which is a measure of variability, is also a measure of accuracy in these studies, because the variability found is a variation from the true fat percentage, both in the comparison between the Babcock and the Roese-Gottlieb (Mojonnier) methods, and in the comparison between each composite and the corresponding true average. Therefore the standard deviation of the differences between the Babcock and the Roese-Gottlieb (Mojonnier) fat percentage determinations is a measure of the accuracy of the Babcock method if we assume the Roese-Gottlieb (Mojonnier) to be correct.

3. Likewise, the standard deviation of the differences between each of the two composites and the true average test can be used as a measure of the accuracy of the composites. Therefore the standard deviations obtained in the three cases are comparable, and a part of the inaccuracy of the two composite tests may be eliminated as being due to the inaccuracy resulting from the Babcock procedure itself, by deducting the standard deviation of the differences between the Babcock and Roese-Gottlieb (Mojonnier) determinations from the standard deviations of the differences of each of the two composites from the true average. The remainder represents the inaccuracy due to sampling.

Furthermore, granting the truth of these deductions, we may use the standard deviations to calculate the per cent accuracy of each composite sampling method, as we can eliminate the inaccuracy of the Babcock method by making the following simple calculations:

$$\frac{\text{Standard deviation of differences between Babcock and Roese-Gottlieb (Mojonnier)}}{\text{Standard deviation of differences between either composite test and true average test}} \times 100 = \text{Percentage accuracy of the method of sampling}$$

The value of the standard deviation for the comparison between the Babcock and Mojonnier methods was 0.36. The value of the

standard deviation for the comparison of the aliquot to the true average results was 0.59, while the corresponding value for the dipper method was 0.79. Making calculations according to the above formula, 61 per cent of the analyses of the aliquot composite samples were accurate within the variability of the Babcock method, and 45 per cent of the dipper composite samples. The results of similar calculations on each trial are shown in Table A.

TABLE A

PERCENTAGE ACCURACY OF ALIQUOT AND DIPPER METHODS OF COMPOSITE SAMPLING

Percentage accuracy for each method is determined by calculations from the standard deviations for each method and the standard deviation of the variations between Babcock and Mojonnier results. Calculations were made according to the formula given above.

Trial No.	Standard deviation for aliquot analyses	Standard deviation for dipper analyses	Accuracy of aliquot analyses	Accuracy of dipper analyses
			per cent	per cent
1	0.69	0.85	52	42.2
2	0.33	0.62	100	58.0
4	0.36	0.77	100	47.0
5	0.40	0.79	90	45.2
6	0.32	0.55	100	65.0
7	0.33	0.64	100	56.0
8	0.77	1.01	47	36.0
All trials	0.59	0.79	61	45.0
Trials 2, 4, 5, 6, 7	0.35	0.72	100+	50.0

4. This group of trials had a standard deviation of 0.35 for the variations between the aliquot samples and the true average.

5. The data tabulated in Table B show the pounds of cream delivered during the various trials, the size of the deliveries, and the relation of the size of delivery to the standard deviation between the two composites and the true average in each trial.

TABLE B

INFLUENCE OF SIZE OF DELIVERY ON ACCURACY OF COMPOSITE SAMPLES

Using the standard deviation of measure of accuracy, there is a direct relation between size of delivery and accuracy of each method of composite sampling, the larger deliveries making possible more accurate results.

Trial No.	Season	Cream delivered	No. of deliveries	Average amount of cream delivered	Standard deviation of differences between	
					Aliquot and true test	Dipper and true test
		lb.		lb.		
1	Fall	34,105	1282	26.60	0.69	0.85
2	Winter	41,368	1126	36.74	0.33	0.62
4	Winter	45,555	672	67.79	0.36	0.77
5	Winter	24,922	640	38.95	0.40	0.79
6	Spring	43,966	856	51.36	0.32	0.55
7	Spring	54,954	1100	49.96	0.33	0.64
8	Summer	34,720	1756	19.77	0.77	1.01
Total av.		82,045.78	7432	37.62		

Trials 1 and 8 show the highest standard deviation between the aliquot composite samples and the true average test. It is significant that the average amount of cream delivered during these two trials was lower than in any of the other trials. A correlation between size of delivery and accuracy of the composite test is shown by the fact that there is a coefficient of correlation between the size of deliveries and the standard deviations between the aliquot composite and true average of -0.76 with a probable error of ± 0.11. The coefficient of correlation between the size of delivery and the standard deviation between the dipper composite and true average was 0.19, with a probable error of ± 0.25, which would not be considered significant.

6. It was necessary in conducting this study to use a standard measure of the amount of variation in the pounds of cream delivered by each producer. The coefficient of variability best serves this purpose. To determine the coefficient of variability, the standard method of determining the standard deviation of each patron's series of daily deliveries for the two weeks covered by the composite sample was used, dividing this standard deviation by the average daily delivery in pounds and multiplying by 100. If there was a relation between the variation in pounds of cream delivered and the accuracy of the test, a correlation would be expected between the coefficient of variability and the difference in per cent fat between the dipper and the true average fat percentages for the same patrons.

These calculations showed only a slight correlation between these variables. Correlation coefficients on two different trials were 0.03 and 0.04 respectively, showing that there is probably only a slight relation, if any, between variations in daily amounts of cream delivered by individual patrons and the accuracy of the dipper test as carried out under practical conditions.

In studying the effect of variations in fat percentage of consecutive deliveries of cream by any one producer on the accuracy of the dipper method of composite sampling, the coefficient of correlation was determined between the coefficient of variability and the difference between the fat percentage as determined from the dipper composite sample and as determined from the analysis of each delivery of cream.

The correlation coefficients for the two trials were 0.05 and 0.33 respectively. These results seem to indicate that fluctuations in the daily tests of cream delivered are a greater factor contributing to the inaccuracy of the dipper composite sample than are variations in the daily amounts of cream delivered. That these two factors influence the inaccuracy of the dipper composite test seems certain. However, the resulting error is overshadowed by the relatively great error introduced by the inaccuracy of the Babcock method.

It is difficult to evaluate the combined effect on the accuracy of the dipper composite sample. Of the two factors just discussed, the best method of attempting this evaluation seems to depend on determining the multiple correlation coefficient between the two factors in question and the figures representing the accuracy of the sampling. This coefficient was 0.43. The authors believe that this is sufficiently high to indicate that variations in both size of delivery and per cent of fat are sufficient to explain a part of the inaccuracy due to the dipper method of composite sampling. As it has been shown that a part of the inaccuracy of the dipper composite sample is probably due to inaccuracies in the Babcock method, a close correlation should not be expected.

7. The average losses or gains in the various trials are interesting, altho their distribution is not shown. The data in Table C present these losses and gains in connection with the calculations of the standard deviation having to do with the variations in the amount of fat delivered and per 100 pounds of fat delivered by each producer.

TABLE C

Trial No.	Standard deviation of variation in pounds of fat delivered		Average loss or gain per 100 pounds of fat delivered		Standard deviation of variation per 100 pounds of fat delivered	
			lb.	lb.		
1	1.41	2.10	+0.96	−0.32	1.96	2.97
2	0.95	2.19	−0.64	−0.82	1.13	2.05
4	1.52	3.48	−0.55	−0.97	1.44	2.67
5	1.19	1.95	−1.15	−2.61	1.26	2.57
6	1.23	2.51	−1.08	−1.58	1.18	2.19
7	1.29	3.08	−0.39	−0.39	1.17	2.30
8	2.56	2.74	−2.82	−0.01	2.74	3.31

The calculations presented in Table C clearly indicate that when averages are used the cream patron has little to fear from the composite sample, yet more accurate work is accomplished, under Minnesota conditions, when an aliquot composite sample is used.