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# Babcock Testing and Other Methods of Analyzing Dairy Products

L. K. Crowe

# BABCOCK TESTING


*Students Analyzing Dairy Products*

## And Other Methods Of Analyzing Dairy Products

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CONTENTS



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# Babcock Testing and Other Methods of Analyzing Dairy Products

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MILK is the whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy cows, properly fed and kept, excluding that obtained fifteen days before and five days after calving or such longer period as may be necessary to render the milk practically colostrum free.[1] The name "milk," unqualified, means cow's milk. The extent to which each of the principal constituents occurs in normal milk is indicated below.

| CONSTITUENT | AMOUNT IN NORMAL MILK | |
|---|---|---|
| | Average per cent | Variation |
| Water | 87.3 | 84.0–89.5 |
| Lactose (milk sugar) | 4.8 | 4.5– 5.2 |
| Protein: Casein | 2.7 | 2.0– 4.0 |
| Albumin | 0.7 | 0.5– 0.9 |
| Ash (mineral matter) | 0.7 | 0.6– 0.8 |
| Milk fat | 3.8 | 2.6– 6.0 |
| Total solids (all except water) | 12.7 | ........ |
| Serum solids, or solids not fat | 8.9 | ........ |
| Milk serum (all except fat) | 96.2 | ........ |

Milk fat is in suspension or emulsion in the milk serum in the form of small globules of 1/2,500 inch to 1/250,000 inch in diameter. In normal milk one cubic centimeter may contain two to four billion fat globules. The size of fat globules varies and is affected mainly by the breed of cows, season of the year, and the stage of lactation. Milk fat is a complex mixture of 8 to 14 distinct chemical units called fatty acids, which are combined with glycerol. The percentage of each of these fatty acids determines largely the character of the milk fat, particularly its hardness (melting point). Of the protein of milk, casein is the most important. This protein is combined with calcium in milk and occurs as a suspension of fine particles rather than in true solution. Casein is the principal solid constituent of cottage cheese and a very important constituent of cheddar or American cheese. Casein in its pure form is white, odorless, and tasteless, and commercially finds use as a substitute for products such as celluloid, bone, and ivory, and in making glue, cold water paints, etc.

Lactose, or milk sugar, is a disaccharide, i.e., composed of two simpler sugars, glucose and galactose. It is in solution in the serum, much less soluble than ordinary sugar, and only about one-sixth as sweet. The action of bacteria on the sugar of milk produces lactic acid and the normal souring of milk. (For detailed constituents, see page 39.)

[1] United States Department of Agriculture, Food and Drug Administration, Service and Regulatory Announcements, Food and Drug No. 2, Rev. 5, Nov., 1936.

## VARIATION IN COMPOSITION

It is now recognized that the percentage of butterfat in milk is not normally constant. Certain factors that are responsible for this variation will be indicated by the fact that as the percentage of fat varies the percentages of the other constituents also vary, as indicated by the following comparative analysis of milk that is high or low in fat. This fact should not be overlooked.

| CONSTITUENT | AVERAGE AMOUNT IN | |
|---|---|---|
| | High-fat Milk | Low-fat Milk |
| | *Per cent* | *Per cent* |
| Milk fat | 5.0 | 3.0 |
| Milk sugar | 5.0 | 4.7 |
| Protein: Casein | 3.1 | 2.5 |
| Albumin | 0.70 | 0.67 |
| Ash | 0.73 | 0.7 |
| Water | 85.47 | 88.43 |
| Total solids | 14.53 | 11.57 |
| Solids not fat | 9.53 | 8.57 |

**Breed of cows.**—The average percentages of fat in the milk produced by purebred cows on which official records of production have been obtained are as follows: Holstein-Friesian 3.4, Ayrshire 4.0, Brown Swiss 4.0, Guernsey 5.0, and Jersey 5.4 per cent. While it is true that there is a wide variation in the percentage of butterfat produced by individual cows within the breed, the figures above indicate the general tendencies of breeds. These figures of course reveal nothing as to the quantity of milk produced.

**Individual cows.**—Not an unusual variation in the percentage of butterfat is illustrated in the figures taken from the record of a cow milked four times daily during a seven-day period, in which the maximum variation between milkings in one 24-hour period was from 4.5 to 5.9 per cent fat and the minimum variation in a similar period was from 4.5 to 5.1 per cent fat. The lowest percentage of fat during the seven days was 3.7 and the highest 5.9. The average percentage of fat for the entire period was 4.66 and the daily averages were 5.0, 4.9, 4.8, 4.5, 4.3, 4.4, and 4.7 per cent.

**Stage of lactation.**—In general the percentage of butterfat tends to be low at first, gradually increases, remains constant for a period, and then again increases as the end of the lactation period approaches. The following figures represent a complete lactation period for one cow.

| Month of lactation | Days in milk | Average milk | Average butterfat | Month of lactation | Days in milk | Average milk | butterfat Average |
|---|---|---|---|---|---|---|---|
| | | *Lbs.* | *P.ct.* | | | *Lbs.* | *P.ct.* |
| 1 | 13 | 49.0 | 2.77 | 7 | 28 | 55.5 | 3.37 |
| 2 | 30 | 71.3 | 2.77 | 8 | 31 | 58.1 | 3.45 |
| 3 | 31 | 73.6 | 3.23 | 9 | 30 | 54.8 | 3.60 |
| 4 | 30 | 69.8 | 3.06 | 10 | 31 | 57.6 | 3.63 |
| 5 | 31 | 62.7 | 3.42 | 11 | 30 | 54.3 | 3.80 |
| 6 | 31 | 60.1 | 3.42 | 12 | 31 | 46.1 | 4.04 |

**Age of cow.**—A slight but consistent decline in percentage of butterfat as the cow advances in age is to be expected. It is only in very rare cases that this change is more than slight.

**Heat period (oestrum).**—The effect of the heat period is not definite but in general the percentage of butterfat is slightly increased, while the amount of milk is slightly decreased.

**Season of the year.**—The butterfat percentage on the average is highest during the months of December, January, and February and lowest during the months of July and August. This variation cannot be attributed entirely to differences in feeding practices.

**Time of day of milking.**—When cows are milked twice daily at regular intervals the morning's milk will generally contain the higher percentage of butterfat, but the quantity of milk will be less.

**Weather conditions.**—In general, in cool or cold weather cows tend to produce milk containing a higher percentage of butterfat. Hot weather, especially when the atmosphere is moist, tends to lower the percentage of butterfat.

**Feed conditions.**—Early spring pasture tends to increase the milk production and decrease the percentage of butterfat. If cows are well fed the percentage of butterfat cannot permanently be raised by the addition of any particular feed; however, a change in feed may temporarily affect the quantity of milk and the percentage of butterfat. Cows insufficiently fed, when given a well balanced ration, may increase the milk flow and the percentage of butterfat in the milk.

**Other factors.**—The condition of the cow at calving time, completeness of milking, sickness or bodily disturbance of the cow, changing of milkers or milking methods, or excitement or other disturbance of the routine may affect not only the quantity of the milk but also the percentage of butterfat in that milk.

## DISCOVERY OF THE BABCOCK TEST

The manufacturing of dairy products on a commercial scale began about the middle of the nineteenth century and was greatly stimulated by the development of the centrifugal cream separator in the late eighties. The invention of the Babcock test in 1890 overcame some of the difficulties that had developed in paying for milk upon its butterfat content, since it was early recognized that milk varied widely in that respect. A number of practical methods had been developed by dairy manufacturing plants to determine the butterfat in the milk.

Among these were: (1) The creamery inch system, in which a sample of each patron's milk was placed in a glass tube and after 12 to 24 hours, the depth of the cream layer was measured. This was far from satisfactory since it took much time, and milk that contained a large percentage of small fat globules gave an inaccurate cream layer. (2) The trial churning, in which a small sample of each patron's milk was churned and the butter weighed. In this method, even when great care was taken to have

the conditions alike, the moisture content of the butter was not the same for all samples. (3) The oil test churn, in which a small sample of each patron's milk was churned, after which the butter was melted and measured. If the churning was not complete, this method developed inaccuracies.

This and the previous methods were slow, bothersome, and not sufficiently accurate. As the result of much experimentation by the agricultural experiment stations, a number of tests were devised, of which that devised by Dr. S. M. Babcock [2] proved to be the simplest, least costly, most accurate for practical purposes, and most rapid in operation.

The economic importance of the Babcock test was threefold: (1) It revolutionized the dairy industry by putting it upon a business basis, (2) it hastened and made possible the rapid development of the factory system of dairy products manufacture, and (3) it provided a rapid and accurate method of selecting individual cows upon their ability to produce butterfat and thus was a stimulus to better breeding.

## BABCOCK TEST PRINCIPLES

Essentially this method of determining the percentage of butterfat in certain dairy products consists in transferring a definite weight of the product to be tested into a specially constructed and graduated test bottle. Sulfuric acid is then added and mixed with the material in the test bottle. The bottles are then centrifuged or whirled three times in succession, at a definite speed and for a definite time. Hot water is added to the contents of the bottle after the first two whirlings. After the last whirling the percentage of fat is measured directly with a pair of dividers.

The Babcock test is based on the following principles: that a strong acid will curdle and then dissolve or digest the curd in milk, thus freeing the butterfat; that heat which is developed from the action of the acid upon the water and milk solids melts the butterfat; that difference in the weight or specific gravity tends to cause the separation of liquids; and that the application of centrifugal force (whirling) hastens the separation of the fat from the other constituents of the milk.

Milk fat or butterfat has a specific gravity (compared with water, which equals 1.00) of 0.93, while whole milk has a specific gravity of about 1.032. This means that one cubic centimeter (1 cc.) of butterfat would weigh 0.93 gram and 1 cc. of milk would weigh 1.032 grams. The globules of butterfat in milk, being lighter than the surrounding fluid, tend to rise but are retarded by the interference of the other milk solids. Commercial sulfuric acid ($H_2SO_4$) first curdles and then digests the proteins in the milk. This frees the fat, and since heat is generated by the action of sulfuric acid on the water and solids of the milk, the fat is melted and tends to rise to the top. The sulfuric acid, being heavier than the milk serum, increases the specific gravity of the mixture, thus

[2] Dr. S. M. Babcock was chief chemist at the Wisconsin Agricultural Experiment Station. The test was patented and given free to the world in 1890.

making it easier for the fat to rise. In whirling, the test bottle is in a horizontal position with the bottom to the outside. Whirling produces centrifugal force which causes the heavier material to go to the bottom of the test bottle and in consequence forces the lighter fat to the top. With the addition of water, the fat is raised into the graduated neck of the bottle where it can be measured.

The Babcock test is based upon the use of a definite weight of milk or cream in the test bottle. In the case of cream, 9 grams are weighed directly into the test bottle, which is graduated to be read direct in percentage of fat. In testing milk the 17.6-cc. pipette is used for measuring the milk into the test bottle. This pipette delivers 17.5 cc. of milk (0.1 cc. of milk sticks to the inside of the pipette). With milk of an average specific gravity of 1.032 the 17.5 cc. will weigh 18.06 grams (ordinarily regarded as 18 grams.) The milk test bottle is so graduated that it can be read direct in percentage of fat when 18 grams of milk is used.

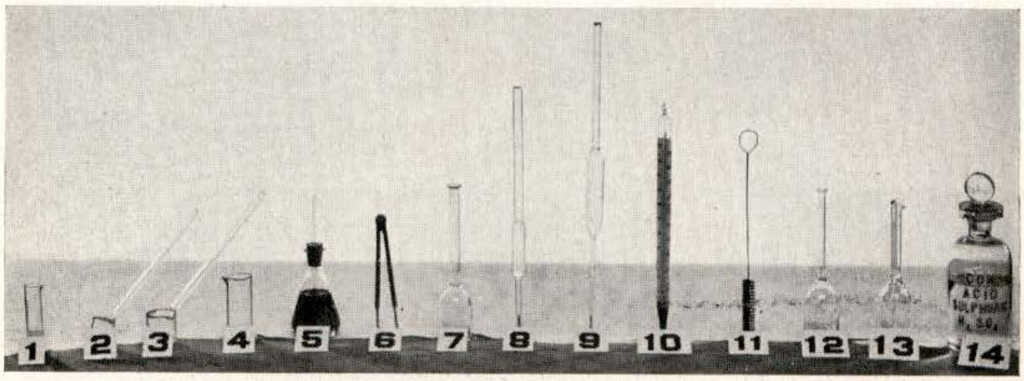



FIG. 1.—(1) 9-cc. acid measure; (2) 9-cc. acid dipper; (3) 17.5-cc. acid dipper; (4) 17.5-cc. acid measure; (5) glymol; (6) dividers; (7) cream-test bottle, 9-gram, 50 per cent; (8) 9-cc. cream pipette; (9) 17-6-cc. milk pipette; (10) floating dairy thermometer; (11) test-bottle brush; (12) whole-milk test bottle; (13) double-neck skim milk or buttermilk test bottle; (14) sulfuric acid.

## EQUIPMENT FOR BABCOCK TESTING

### Milk Testing Equipment

Centrifuge or Babcock tester—hand, steam, or electric.

Sample jars with tight covers—four-ounce size are very convenient.

Milk test bottles [3]—either 8 or 10 per cent total graduation, in 0.1 per cent intervals.

Milk pipette [3]—17.6-cc. capacity for measuring milk.

Acid measure or dipper—17.5-cc. capacity.

Thermometer—floating dairy type, with Fahrenheit graduation to 220°.

Dividers—for measuring the fat column.

Sulfuric acid (commercial grade), specific gravity 1.82 to 1.83 at 60°-70° F.

[3] See Nebraska Standard Dairy Law, Bul. No. 3, State of Nebraska, Department of Agriculture, State Capitol, Lincoln.

Water bath—a vessel that will hold hot water in which all completed tests are placed before measuring the fat column.

Washing powder—any commercial alkali powder, for cleaning glassware.

Test bottle brush—a small, wire-handled brush for cleaning bottles and pipettes.

**Additional Equipment Required for Testing Cream**

Cream test bottle [3]—9-gram 50 per cent total graduation in 0.5 per cent intervals.

Cream test balance or scale[3]—a balance or scale sensitive to 25 milligrams (0.025 gram), one-bottle type (Fig. 2.).

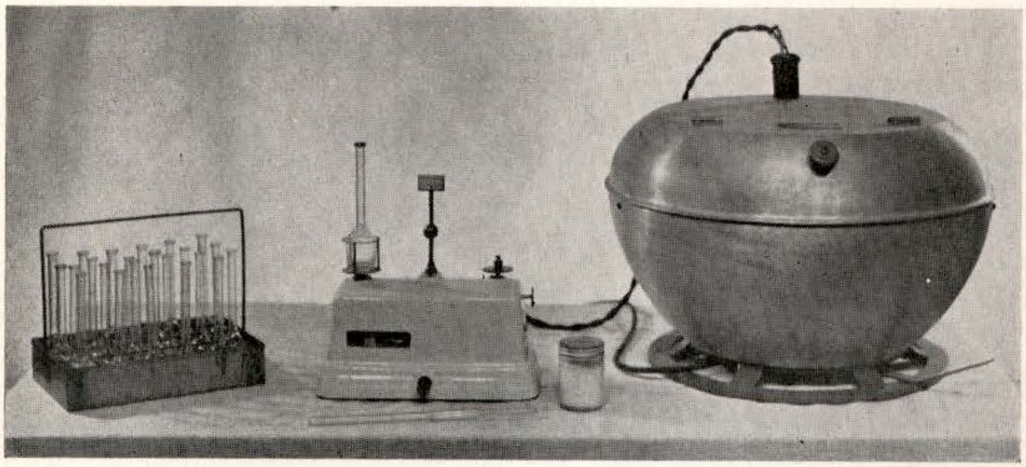


FIG. 2.—Left to right: cream-test bottles and bottle rack; cream-test scale, 9-gram weight, 9-cc. pipette, and sample bottle; electric centrifuge with heating element in cover.

Weight [3]—a 9-gram weight tested as accurate.

Pipette—a 9-cc. pipette may be used for convenience but must be used with a balance or scale sensitive to 25 milligrams.

Acid measure or dipper—9-cc. capacity.

Glymol—"red reader"—to eliminate meniscus or curved surface at top of fat column.

**Additional Equipment Required for Testing Skim Milk, Buttermilk, and Whey**

Skim milk test bottles—double necked—0.25 to 0.50 per cent total graduation in 0.01 per cent intervals.

## SAMPLING MILK AND CREAM

The accuracy of testing depends to a great extent upon the care used in sampling. The sample must be uniform in composition and representative of the material from which it has been taken. Careful testing will not correct inaccuracies in sampling. It is impossible to be too careful in sampling.

### Milk

To sample the milk of a cow, pour the complete milking from one vessel to another at least three times. Then dip out a sample of about four ounces for testing, cover tightly to prevent evaporation, and set in a cool place. Milk should not be tested until at least one hour after milking because of the air incorporated during milking, which would affect the weight of milk delivered by the pipette. If the milk has stood long enough for the cream to rise, it should be poured back and forth at least six times instead of three times. In pouring do not agitate unduly so as to cause churning. Milk can be sampled satisfactorily only when sweet.

### Cream

Cream is thick and viscous as compared to milk and consequently does not mix as readily. However, as the fat content increases above 35 per cent, there is less separation of the fat from the serum. It should be poured or thoroughly stirred, after which the sample should be taken with a recognized cream sampler (slotted openings in the side throughout the entire length of the tube). If thoroughly mixed, an accurate sample may be procured with a dipper.

### Abnormal Milk and Cream

**Sour milk.**—An accurate sample of curdled milk is difficult to obtain. Pour back and forth until thoroughly mixed; then take sample as with sweet milk.

**Sour cream.**—Thorough mixing of sour cream is not difficult because cream does not contain as much curd as milk does. Accurate samples depend only upon thorough mixing. If properly sampled, cream will test the same whether sweet or sour provided it has been kept in a closed container to prevent evaporation of water.

**Churned milk or cream.**—If particles of butter appear on the surface of milk or cream, the vessel containing either should be placed in a bath of water at a temperature of 105°–115° F. When the butter particles have melted, the milk or cream should be poured back and forth several times from one vessel to another and sampled immediately. Even then such a sample may be inaccurate.

**Frozen milk or cream.**—When milk or cream freezes, ice starts to form at the outer edge next to the container. This ice is very largely water, the other constituents being more concentrated in the soft, mushy center of the container. An accurate sample cannot be taken from the frozen material. To thaw, place in a water bath at 80° to 85° F. or at room temperature until melted, then mix well and sample as usual.

### Composite Sampling

A sample composed of proportionate quantities by weight of different lots of milk or cream is called a composite. A composite sample of milk is readily and accurately taken with a pipette graduated to 0.5 cc. with

a total graduation of not less than 25 cc. The number of cubic centimeters taken per pound of milk depends upon the total quantity represented by the composite. There should be not less than 100 cc. in the completed composite sample. For each pound of milk, use a number of cubic centimeters large enough to insure a composite of at least 100 cc. Suppose a cow is producing about 40 pounds of milk a day in two milkings. On the day the samples were taken, she produced 16 pounds in the morning and 22 pounds in the evening. Take 3 cc. of milk for each pound of milk produced; $16 \times 3 = 48$ cc. from the morning milk and $22 \times 3 = 66$ cc. from the evening milk or a total of 114 cc. for the day. Mix together and the 114 cc. represents a composite of the milk of the cow for one day. Accurate composite samples may be taken from containers of the same diameter with commercial sampling devices available for that purpose.

Since cream will not drain clean from a pipette, the composite sampling of cream is advised only when the lots of cream are in containers of equal diameter, in which case a sample may be taken by means of a cream sampler.

If composite milk samples are to be kept for any length of time some preservative should be added. Composite cream samples should be tested soon after they are taken.

Bichloride of mercury (corrosive sublimate) may be obtained from creamery supply houses in tablet form and is usually the most convenient preservative for common use. Directions for the use of these tablets are on the container. Other preservatives are potassium dichromate and formalin (40 per cent formaldehyde). In using the former, which is a powder, add just enough to give the milk a lemon-yellow color. One cubic centimeter of formalin to a pint of milk will usually be sufficient. Each time milk is added to the composite sample, it should be thoroughly stirred or mixed. A glass jar for keeping composite samples should have a wide mouth and a tight-fitting cover or stopper. Cork stoppers are not advisable as they are somewhat porous. When using a preservative that does not color the milk, some coloring matter should be added to indicate that the milk is unfit for food. All the milk preservatives mentioned above are poisonous.

## BABCOCK TEST FOR MILK

### Preparing the Sample

Milk samples for testing should be at a temperature of between 60° and 70° F. as determined by a thermometer. They may be warmed or cooled by means of a water bath. To prevent melting the fat, keep the temperature of the water bath below 85° F. After having reached the proper temperature, the sample should be poured slowly from one container to another at least 6 times to insure thorough mixing. Rapid pouring will incorporate air bubbles, making the succeeding measurement inaccurate. Care should be taken that no cream is left upon the lid or sides of the sample jar.

### Measuring the Sample

Immediately after mixing, insert the tip of a 17.6-cc. pipette into the prepared sample of milk, holding it with the thumb and second finger of the right hand and then draw in the milk by suction with the lips placed at the upper end until the pipette is filled well above the graduation mark on the stem. Quickly place the dry, fleshy pad of the first finger of the right hand tightly over the upper end of the pipette. Holding the pipette perpendicular and with the graduation on the level with the eye, release the pressure slightly on the finger applied to the upper end of the pipette and allow the milk to run back into the sample until the surface of the milk is level with the graduation, disregarding the upper edges of the meniscus (the curved surface at the top of the milk column). Insert the tip of the pipette into the milk test bottle and allow the milk to run out. If the neck is too small to allow the pipette stem to be inserted, the milk test bottle should be held at an angle to allow air to escape and to prevent splashing of milk (Fig. 3). Blow the last drop of milk from the pipette. To insure accuracy, all tests should be run in duplicate.

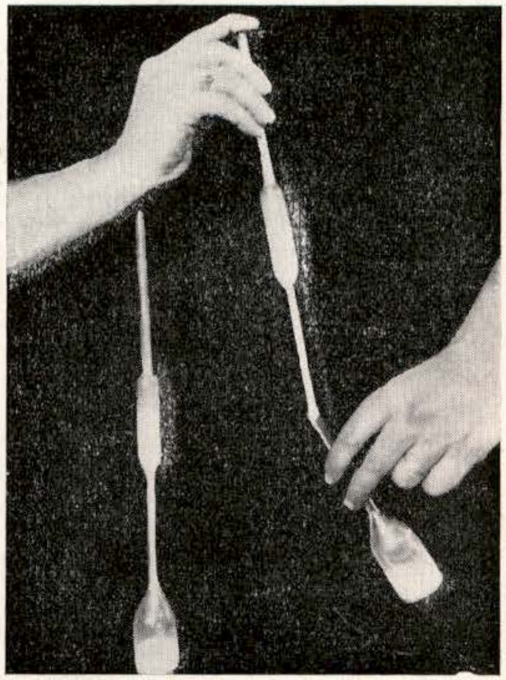


FIG. 3.—Two methods of transferring the milk to the test bottle with the 17.6-cc. pipette.

### Adding Acid

Measure 17.5 cc. of commercial sulfuric acid (specific gravity 1.82-1.83) into an acid measure or dipper. The acid should be at a temperature between 60° and 70° F. Holding the test bottle at an angle of 45 degrees (Figs. 4 and 5), rotate it between the fingers, and pour in the acid very slowly. This will wash all the milk out of the neck of the bottle, and, what is more important, will prevent the charring of the curd. Variations in the temperature or strength of the acid will necessitate the use of a slightly greater or smaller quantity. It is advisable, therefore, to add the last third of the acid in three portions, mixing the contents of the bottle after each addition with an even rotary motion. Acid should be added until the mixture, after mixing and upon standing for a minute, has a dark chocolate-brown color. In mixing milk and acid, rotate the test bottle slowly until all the curd has been dissolved, always keeping the mouth of the bottle pointed away from yourself and others to prevent

FIG. 4.—Correct procedure in adding sulfuric acid with the 17.5-cc. acid measure.

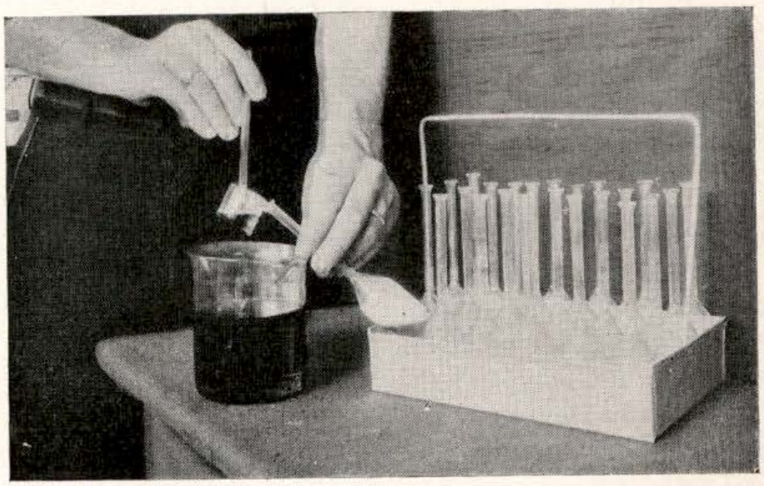
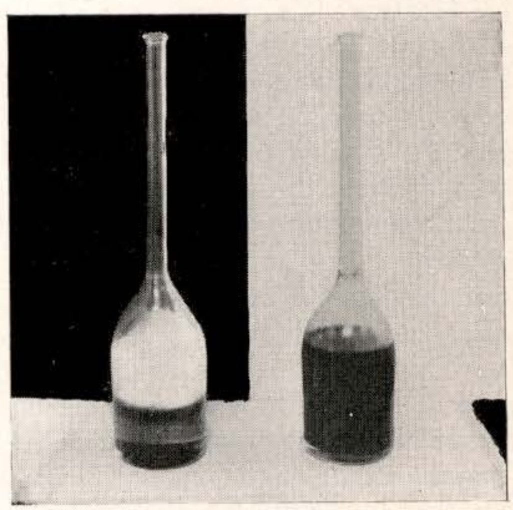


FIG. 5.—Adding sulfuric acid with the 17.5-cc, acid dipper. Also bottle rack for 24 bottles.

FIG. 6.—Left—immediately after acid has been added. Right—after mixing milk and acid.



any possibility of injury from spurting acid. Sulfuric acid is very corrosive in action, will burn the flesh and will destroy cloth, wood, etc. Plenty of cold water followed by water in which alkali washing powder has been dissolved will stop its action.

### Centrifuging (Whirling)

**First time.**—After the correct color has been obtained in the acid-milk mixture, place the bottle in the centrifuge. Always place the bottles opposite each other so that the revolving disk carrying the buckets or pockets for the bottles will be balanced. Use a bottle filled with water to balance if you have an uneven number of bottles. In centrifuges with double pockets, use the outside pockets if both are not filled. Revolve the bottles at the proper speed, as indicated on the machine, for five minutes after that speed has been attained. Stop the centrifuge gradually to prevent breaking the bottles. Always be sure that the centrifuge is level, securely fastened to a firm foundation to prevent vibration, and is well oiled, clean, and free from foreign material.

After stopping the centrifuge, add water at a temperature of not less than 180° F. until the bottle is filled to within one-fourth to one-half inch of the base of the neck. It is impossible to have this water too hot. Soft or distilled water is preferable because sulfuric acid often forms gas bubbles in its action on lime salts in hard water, which collect at the surface of the fat column and make it difficult to measure accurately. If hard water must be used, it may be desirable to add a small amount of sulfuric acid to the water before it is added to the contents of the test bottles. Approximately a teaspoonful of acid to a gallon of water will be sufficient. A pipette or a small glass nozzle attached to a container by means of a rubber hose may be used to add hot water.

**Second time.**—Centrifuge the test bottles for three minutes at the proper speed, then add water at a temperature of not less than 180° F. until the lower extremity of the fat column is well above the zero mark of the graduation or scale on the neck of the test bottle. Add water carefully to prevent overflowing, and if using a pipette do not let the tip reach the fat column.

**Third time.**—Centrifuge the test bottles at the proper speed for one minute, then place the test bottles in a water bath at a temperature of from 135° to 140° F. for five minutes, after which time the fat column may be measured. Any vessel of sufficient depth to hold enough water to immerse all but the upper one-half inch of the top of the neck of the test bottle can be used as a water bath. A frame of metal (Fig. 5) with compartments for individual bottles is a great convenience. Fat columns can be measured directly from a steam or other heated centrifuge, provided the temperature of the air within the centrifuge can be maintained between 135° and 140° F. during the time required to measure the fat column.

## Reading the Tests

Remove only one bottle from the water bath at a time. Hold the bottle in the hand with the fat column perpendicular and on a level with the eye. With the other hand place one point of a pair of dividers on the lowest point of the curve or meniscus at the bottom of the fat column, and the other point at the highest point of the fat column, or where the extreme upper edge of the fat comes in contact with the neck of the bottle (Fig. 7). The curved surfaces at the top and bottom of the fat column are called the menisci (plural of meniscus). Hold the dividers without changing the distance between the points and place one point on the zero mark of the scale of the test bottle (Fig. 8) and take the reading on the scale as indicated by the other point. Always read to the nearest mark or graduation on the scale. The scale on the milk test bottle is marked in percentage of butterfat, being graduated to 8 or 10 per cent in tenths of one per cent.

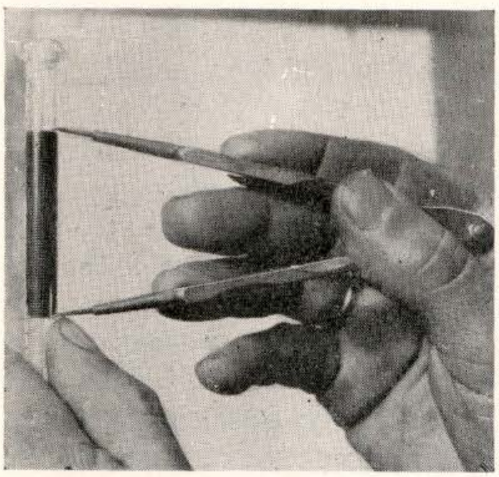


FIG. 7.—First position of the dividers when measuring the fat column of the whole-milk test. The extremes of the fat column are included in the measurement. Note the position of the thumb in holding the lower point of the dividers.

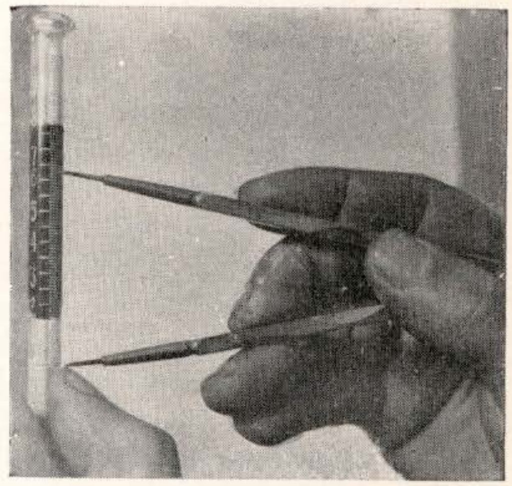


FIG. 8.—Second position of the dividers when reading the percentage of butterfat in the whole-milk test. This sample tested 6.3 per cent butterfat.

If the test bottle is held toward the light the extremities of the fat column may be seen distinctly. Readings should be made rapidly as the temperature of the fat column will change, causing an incorrect reading. The dividers should be tight enough at the joint so they will hold any position in which they are placed, but they should move freely. Duplicate tests should check within 0.1 per cent.

## Emptying the Test Bottles

Empty the bottles into a stone or glass jar or on ashes. The acid in the test bottles should be carefully handled as it will attack wood, iron, steel, tin, and most metals except brass and lead. The test bottles are easier to clean if vigorously shaken during emptying in order to dislodge the white

sediment (calcium sulfate) in the bottom of the bottle and then washed at once.

### Cleaning Glassware

Test bottles and sample bottles should be rinsed out in warm water. They should then be filled with a solution of hot water in which an alkali washing powder is dissolved. Soap and soap powders are undesirable. Shake the test bottles vigorously, and clean the inside of the necks with a small brush. Then empty and rinse thoroughly with clean, hot water. If this method is ineffective, add a little sulfuric acid, shake thoroughly, and if necessary heat the contents of the bottle by holding it in a vessel of hot water, shake again thoroughly, and then empty and rinse with clean water. A pipette should be rinsed out with water immediately after measuring the milk and then cleaned with the other glassware.

## BABCOCK TEST FOR CREAM

### Weighing the Sample

The sample of cream for testing should be prepared the same as with milk, except that greater care should be taken in mixing to insure uniform composition. Cream must be weighed into the test bottle instead of measured, as in the case of milk, for the following reasons: (1) the same volume of cream may vary much in weight because of the difference in the percentage of butterfat,[4] (2) sour cream or freshly separated cream may contain gas or air bubbles that increase the inaccuracy of a measured sample, and (3) the viscosity or thickness of cream causes it to stick to the inside of the pipette.

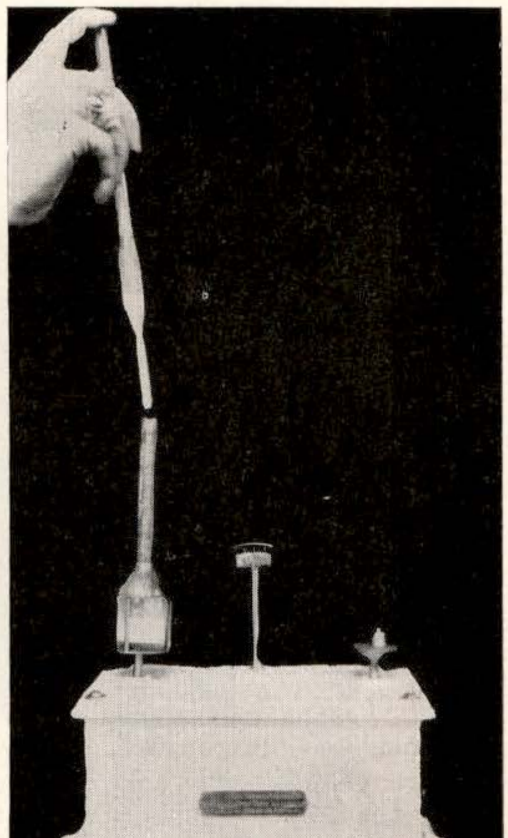


FIG. 9.—Using the 9-cc. pipette to transfer the cream from the sample bottle to the cream-test bottle previously balanced on the scale.

For weighing the cream sample, different types of balances or scales may be used. With a common type the bottle is placed on the left-hand pan of the balance and balanced by means of an adjusting screw on the right-hand end of the cream-test scale. It is properly balanced if the

[4] See table, page 38.

pointer when swinging free swings an equal distance to either side of the center mark of the graduated scale. A 9-gram weight is then placed on the right-hand pan of the cream-test scale. With a 9-cc. or other pipette, transfer enough cream to the test bottle so that the pointer again swings an equal distance to either side of this mark. Add the last bit of cream slowly, drop by drop. If too much cream is added to the cream test bottle it may be removed by pouring it from the test bottle, inverting the test bottle on the finger and removing the cream that sticks to the finger, or by inserting a stick or pencil into the neck of the test bottle and removing the cream that adheres to it.

After the cream test scale is once balanced, it must not be moved until the desired amount of cream is weighed into the test bottle. Each bottle must be balanced separately on the test scale, as bottles are not of equal weight. If cream is spilled on the test scale pan or on the outside of the bottle, it must be removed before the final weight is taken. To insure accuracy all tests should be made in duplicate and should check within 0.5 per cent of each other.

### Adding the Acid

Measure out 9 cc. of commercial sulfuric acid (specific gravity 1.82-1.83), which should be at a temperature between 60° and 70° F., into the acid measure or dipper, and add this acid to the cream in the test bottle, holding the test bottle neck at an angle to prevent the acid from charring the curd. Add enough acid to produce a chocolate-brown color when thoroughly mixed with the cream. (Cream with a high percentage of butterfat will require slightly less acid than that with a low butterfat content). Then add 10 to 12 cc. of water at a temperature of at least 180° F. to retard the action of the acid; since cream contains a higher percentage of fat and a lower percentage of other solids and water than does whole milk, the acid is more likely to cause charring.

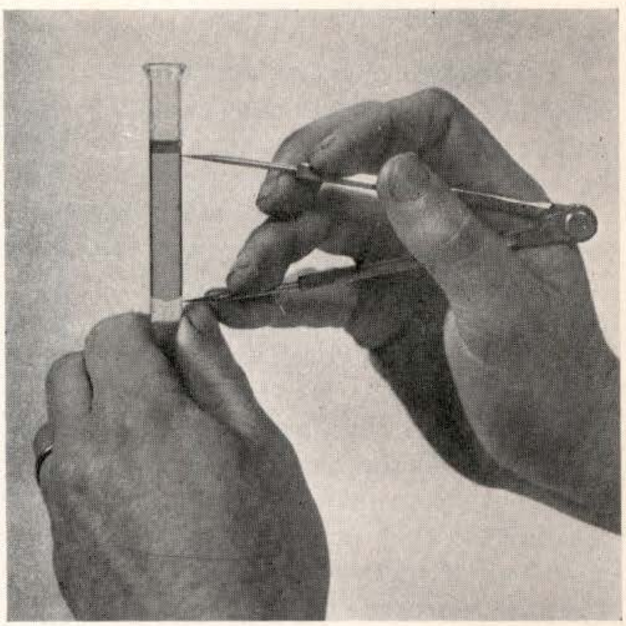


FIG. 10.—Position of the dividers in measuring the fat column in the completed cream test after glymol has been added. The measurement includes the portion between the bottom of the lower meniscus and the line between the glymol and the fat at the top.

The test bottles are centrifuged for the same length of time and water added in the same way as in the milk test.

### Reading the Tests

The completed tests are read from a water bath at a temperature of between 135° and 140° F. In the case of cream, glymol or red reader is usually added to the upper surface, after which the fat column is measured from its lower extremity to the juncture or union of the glymol and fat at the top of the column. If the fat columns are to be measured without the use of glymol, only one-third of the upper meniscus is included. The graduated scale on the cream test bottle is marked in percentage of butterfat from 0 to 50, the smallest graduation being 0.5 per cent. After being read, the test bottles are emptied and cleaned the same as milk test bottles.

## BABCOCK TEST FOR SKIM MILK AND BUTTERMILK

In general the same procedure is followed in testing skim milk as in testing whole milk, but there are certain exceptions. Double-necked test bottles having a large filling neck and a small graduated neck are used because of the small amount of fat contained in skim milk. More acid is required for skim milk and buttermilk because of the greater percentage of water and solids not fat. If 17.5 cc. of the available acid is required for the whole-milk test, then from 19 to 20 cc. of that acid will be required for the skim-milk test. The contents of the bottle can be more easily mixed without splashing curd particles into the small graduated tube if only approximately three-fourths of the required amount of acid is added at first. When this has been mixed with the milk, the remainder of the acid is added and mixing completed. It is desirable to hold the bottle with the small graduated tube uppermost when mixing the acid with the skim milk.

Skim-milk tests should be centrifuged 10 minutes the first time instead of 5 minutes to insure the most complete separation of the very small butterfat globules found in skim milk. The skim-milk test bottles should be placed in the centrifuge with the filling neck toward the center, so that the passage of the fat into the small graduated neck will not be obstructed by the filling tube. The reading of the test after tempering to between 135° and 140° F. may be made direct or with a pair of dividers. The graduated scale of the skim-milk bottle has a range from 0 to 0.25 or 0.50 per cent, the smallest graduation being 0.01 per cent.

It sometimes saves time in testing skim milk, buttermilk, or whey if two whole-milk bottles are used together with the skim-milk bottles, since the percentage of fat in the sample may be too large to be measured in skim-milk bottles.

## BABCOCK TEST FOR WHEY

The Babcock test procedure for fat in whey is the same as that for skim milk and buttermilk except that less sulfuric acid is used. If 19 or 20 cc. of the available acid has been satisfactory in the skim milk test, then 8 to 12 cc. will be sufficient for the whey test, since whey has a smaller quantity of solids to dissolve in order to liberate the fat.

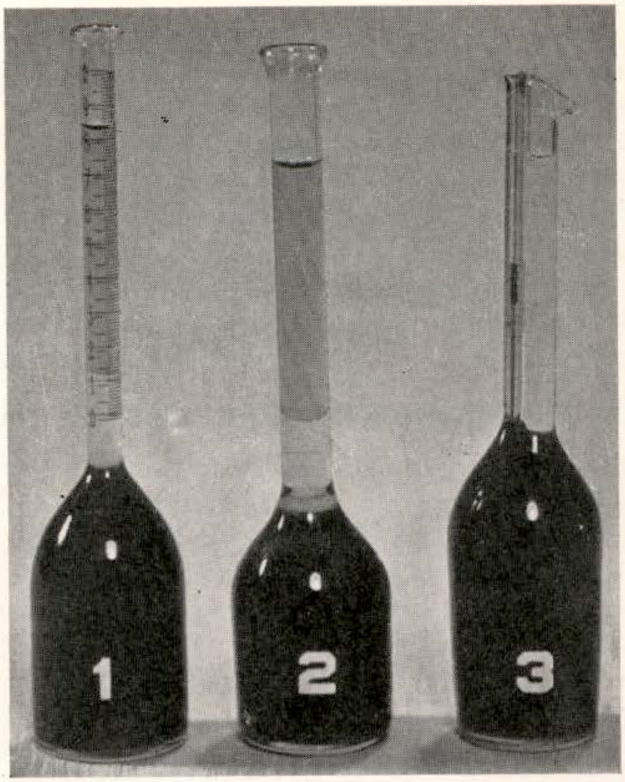



FIG. 11.—(1) Completed whole-milk test, (2) completed cream test, (3) completed skim-milk test.

## PRECAUTIONS AND SUGGESTIONS

Keep sulfuric acid of the correct specific gravity tightly covered, since it will absorb moisture from the air and become weaker.

If too strong (too high specific gravity), sulfuric acid may be weakened by allowing it to be exposed to the air. **Do not add water** to sulfuric acid, as it will splash and spatter and may cause much damage. If sulfuric acid is to be diluted with water, pour the acid carefully into the required amount of water in a suitable heat-resistant container.

Make all tests in duplicate to insure accuracy. Milk-test duplicates should check within 0.1 per cent; cream-test duplicates to 0.5 per cent; and skim-milk, buttermilk, or whey duplicates to 0.02 per cent.

If foreign matter appears in the fat column or directly below it, repeat the test.

Glymol or red reader is a white mineral oil colored red with alkanet root so as to produce a contrast with the fat column and is used only in cream testing. Since a lower-grade oil may be used which tends to mix with the fat and make the upper line indistinct, it is advisable to add the "reader" carefully just before measuring the fat column.

Determine all temperatures with a thermometer. Accuracy is necessary.

Hard water may be used if it has been boiled, or if a few drops of

sulfuric acid have been added to it and it has been allowed to stand long enough for all gas to escape.

Sharp-pointed dividers which will move readily but which will remain in any position in which they are placed are necessary in making an accurate measurement of the fat column.

If possible, centrifuge tests immediately after the correct amount of acid has been added and mixed with the contents of the bottle; otherwise they must be reheated to 180° F. by placing them in a water bath for at least 10 minutes.

Small shot used with hot water and alkali will help clean dirty glassware.

Sulfuric acid spilled on hands, clothing, or elsewhere should be washed off immediately with ample quantities of cold water.

Empty the finished test on ashes or in a hole in the ground where the acid mixture may be covered.

## DEFECTS OF FAT COLUMNS—CAUSES AND REMEDIES

The perfect finished test should show a clear fat column varying from straw to golden yellow in color with upper and lower surfaces clear and distinct. A dark fat column or one that has dark specks within or directly below it may be due to any of the following causes:

| Cause | Remedy |
| --- | --- |
| 1. Acid too strong. | 1. Use less acid or the same quantity of weaker acid. |
| 2. Too much acid. | 2. Use less acid. |
| 3. Pouring acid directly into milk. | 3. Pour acid down side of bottle held at an angle. |
| 4. Uneven mixing of acid and milk. | 4. Mix milk or cream with acid with an even rotary motion. |
| 5. Acid too warm. | 5. Temper to between 60° and 70° F. |
| 6. Milk too warm. | 6. Temper to between 60° and 70° F. |
| 7. Failure to mix milk with acid promptly after addition of acid. | 7. Mix acid and milk soon after the addition of the acid. |
| 8. Failure to add water before centrifuging in a cream test. | 8. Add proper quantity of water before whirling or centrifuging for first time. |

A light-colored fat column or one that has light specks within or directly below it may be due to any of the following causes:

| Cause | Remedy |
| --- | --- |
| 1. Acid too weak. | 1. Use more acid or the same quantity of stronger acid. |
| 2. Too little acid. | 2. Use more acid. |
| 3. Milk too cold. | 3. Temper to between 60° and 70° F. |
| 4. Acid too cold. | 4. Temper to between 60° and 70° F. |
| 5. Curd not dissolved before centrifuging. | 5. Mix milk and acid thoroughly before centrifuging. |
| 6. In cream testing—adding the check water too soon. | 6. Contents of bottle should be dark coffee brown in color before check water is added. |

A milky-colored fat column in cream testing is sometimes caused by the use of either a large excess of acid or too-strong acid, together with the failure to add water before centrifuging. A smaller quantity of standard acid, or the same quantity of weaker acid, together with the addition of water before centrifuging, will prevent the trouble.

## Summary of Procedures in Babcock Tests

**Always run duplicate tests.**

| | WHOLE MILK | CREAM | SKIM MILK OR BUTTERMILK | WHEY |
|---|---|---|---|---|
| Test bottles to use | 8% or 10% whole-milk bottles [1] | 9-gm. 50% cream bottles [1] | Double-necked skim-milk bottles | Double-necked skim-milk bottles |
| Amount of sample to use in each test bottle | Measure 17.5 cc. | Weigh 9 gms. | Measure 17.5 cc. | Measure 17.5 cc. |
| Approximate amount of acid to use (sp. gr. 1.82-1.83) (60°-70° F.) | 17.5 cc. | 9 cc. | 19-20 cc. | 8-12 cc. |
| Centrifuge (whirl) first time | 5 min. | Add 10-12 cc. 180° F. water, then centrifuge 5 min. | 10 min. | 10 min. |
| Adding water, first time, 180° F. or warmer | Enough to raise the butterfat column to within about one-half inch of the base of the neck of the bottle. | | | |
| Centrifuge (whirl) second time | 3 min. | 3 min. | 3 min. | 3 min. |
| Adding water, second time, 180° F. or warmer | Enough to raise all of the butterfat above the zero of the graduated scale on the neck of the test bottle. | | | |
| Centrifuge (whirl) third time | 1 min. | 1 min. | 1 min. | 1 min. |
| Water bath 135°-140° F. | 5 min. | 5 min. | 5 min. | 5 min. |
| Reading—Remove only one bottle from water bath at a time | Use dividers | Add a few drops of glymol and use dividers. | Read direct or use dividers. | |

[1] See Nebraska Standard Dairy Law, Bul. No. 3, Department of Agriculture, State Capitol, Lincoln.

## CAUSES OF BUTTERFAT VARIATIONS IN SEPARATED CREAM

### Richness of the Milk

Milk from a herd of cows varies in butterfat percentage from day to day as has been explained. The cream or skim-milk screws of the separator are set to divide the milk into a definite proportion of cream to skim milk. If, for example, the separator is adjusted to deliver 15 pounds of cream and 85 pounds of skim milk from each 100 pounds of milk separated, and the milk tested 4.5 per cent butterfat, the 15 pounds of cream would contain 4.5 pounds of butterfat or the cream would test 30 per cent ($4.5 \div 15 \times 100 = 30$). If the milk tested only 4 per cent, then the 15 pounds of cream would contain 4.0 pounds of butterfat. The cream in that case would test $4.0 \div 15 \times 100 = 26.67$ per cent. These illustrations assume no loss of butterfat in skimming.

### Variation in Separator Speed

Cream separators are adjusted to skim efficiently at a certain speed. If run faster, more skim milk is run through and consequently less cream, and the resulting cream contains a higher percentage of butterfat. Such operation sometimes causes clogging of the cream outlet and a consequent loss of fat in the skim milk. If operated slower than the proper speed, the proportion of cream to milk is increased and the cream contains a lower percentage of butterfat. Slow running is likely to cause incomplete skimming.

### Temperature of the Milk

Milk should be separated at temperatures between 90° and 98° F. At those temperatures the separation is usually most complete. Cold milk causes a smaller quantity of richer cream, since the cream is heavy and viscous and does not readily flow through the cream opening, and consequently a larger quantity of skim milk is obtained. Because of the reduced flow through the cream opening, some fat may be carried out with the skim milk.

### Rate of Milk Flow into Separator Bowl

The valve on the supply tank is adjusted with the float to deliver the proper quantity of milk when the supply tank is full. When the valve is not opened completely, or when the supply tank is only partially filled, there is less pressure forcing milk into the bowl. Under such conditions, the centrifugal force in the bowl acts upon a smaller quantity of milk and consequently produces a smaller quantity of cream with a higher percentage of butterfat. Any condition that increases the inflow tends to decrease the percentage of butterfat in the cream.

### Adjustment of Cream or Skim-Milk Screws

The cream or skim-milk screws regulate the proportion of skim milk to cream, and thus affect the quantity and percentage of butterfat in the cream. The larger the quantity of cream from a given volume of milk, the lower it will test, and the smaller the quantity of cream the higher it will

test. The cream screw when turned farther toward the center of the bowl produces a smaller quantity of higher-testing cream and when adjusted toward the outside produces a larger quantity of lower-testing cream. In the case of the skim-milk screws, the effect is exactly opposite.

### Cleanliness of the Bowl

If a separator bowl is not washed thoroughly after each separation, the cream outlet may become clogged, thus causing higher-testing cream and probably a loss of butterfat in the skim milk.

### Quantity of Flush Water

In order to prevent the waste of cream that sticks to the various parts at the completion of the separation, it is a good practice to run a quart or two of clean, lukewarm water or separated milk through the separator to flush out the bowl and cream spout. As soon as the liquid flowing from the cream spout becomes watery or thin in appearance, turn it so that the excess flush material flows into the skim milk. If the excess flush material is allowed to flow into the cream, the test will be lowered.

### Vibration of Separator Bowl

Any vibration of the separator bowl is likely to cause incomplete separation and a loss of butterfat in the skim milk. Vibration may be caused by an improperly balanced bowl, a bent spindle, improper adjustments, worn parts, or an unsteady separator.

## CAUSES OF VARIATION IN MILK AND CREAM TESTS

A true and representative sample of the total quantity of milk or cream is essential to an accurate test. The milk sample must be at the proper temperature, and milk or cream samples must be thoroughly mixed at the time a portion is transferred to the test bottle. This portion must be accurately measured in the case of milk or weighed in the case of cream. Carelessness in any particular may produce inaccurate results.

The temperature at which tests are read is an important factor in their accuracy. At the time of reading, the fat column should be at temperatures between 135° and 140° F. A low temperature tends to lower the reading and a high temperature tends to raise the reading, especially with cream tests. A few actual examples will illustrate the effect of temperatures upon the readings of the same tests:

| MILK TESTS | | CREAM TESTS | | |
|---|---|---|---|---|
| Correct temperature 135°–140° F. | Low temperature 115° F. | Correct temperature 135°–140° F. | Low temperature 115° F. | High temperature 157° F. |
| *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* |
| 5.1 | 5.0 | 24.5 | 24.0 | 25.0 |
| 4.1 | 4.0 | 30.0 | 29.5 | 30.5 |
| 3.8 | 3.7 | 34.5 | 34.0 | 35.0 |
| 7.9 | 7.8 | 24.0 | 23.5 | 24.5 |

Tests may be read differently by different persons. This is illustrated by the following examples where four tests were made by one person and were read independently at the proper temperature by four persons.

| Chemical Röse-Gottlieb [5] | Person No. 1 | Person No. 2 | Person No. 3 | Person No. 4 |
|---|---|---|---|---|
| *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* |
| 3.58 | 3.6 | 3.6 | 3.4 | 3.5 |
| 3.57 | 3.6 | 3.6 | 3.6 | 3.5 |
| 3.96 | 4.1 | 4.1 | 4.0 | 4.0 |
| 3.96 | 4.0 | 3.9 | 3.8 | 3.9 |

Failure to read the fat column correctly is quite common and is usually due to not having the tests level with eyes, to the indistinctness of the menisci, or the presence of foreign material (curd or char) in or directly below the fat column.

## MODIFIED BABCOCK TEST FOR BUTTERMILK

A practical method for the determination of the fat in buttermilk has been given. Although used extensively the results of this method do not compare favorably with official ether-extraction methods. A method known as the "normal butyl alcohol," "American Association," or "Mitchell method" gives results comparing quite favorably with ether-extraction methods. The "normal butyl alcohol" procedure for the determination of the fat content of buttermilk is as follows:

1. Measure 2.0 cc. of normal butyl alcohol into a skim-milk test bottle graduated to 0.5 per cent.

2. Add 9 grams of buttermilk and mix the contents of the bottle thoroughly.

3. Add 7 to 9 cc. of the Babcock testing acid, a few cubic centimeters at a time. The exact amount of acid will need to be determined by experience, since sufficient acid must be used to produce a golden yellow fat column in the finished test.

4. Mix the contents of the bottle thoroughly.

5. Centrifuge 6 minutes at the regular speed.

6. Add sufficient water (180° F. or above) to fill the bottle to within ¼ to ½ inch of the base of the neck.

7. Centrifuge 2 minutes at the regular speed.

8. Add sufficient water (180° F. or above) to bring the fat column well into the graduated neck of the bottle.

9. Centrifuge 2 minutes at the regular speed.

10. Place the bottles in a water bath at 135° to 140° F. for 5 minutes and include both menisci when measuring the fat column.

11. Multiply the reading by 2 to obtain the percentage of fat.

[5] Approved method of the Association of Official Agricultural Chemists.

## MODIFIED BABCOCK TEST FOR ICE CREAM

It is impossible to determine the fat content of ice cream accurately by the regular Babcock procedure because of the charring action of the acid on the sugar of the ice cream. The following outline of the "Nebraska procedure" or "Crowe test" is based upon the results of experimental work reported in Nebraska Agricultural Experiment Station Bulletin 246.

Two reagents are needed. They are designated for convenience as A and B. Reagant A is a mixture of normal butyl alcohol and concentrated ammonium hydroxide made up in the following proportions: 9 parts of normal butyl alcohol and 1 part chemically pure ammonium hydroxide by volume. This reagent is stable when kept in a tightly stoppered bottle. Reagent B is a mixture of equal parts by volume of sulfuric acid (sp. gr. 1.82-1.83) and ethyl alcohol (95 per cent). This mixture is prepared by pouring the acid slowly into the alcohol in a glass beaker or other glass container which will withstand high temperature. After all the acid has been added, the mixture should be stirred with a glass rod and finally cooled to room temperature before using. This reagent may produce unsatisfactory results when more than two months old.

The procedure is as follows:

1. Nine grams of a properly prepared sample of ice cream or ice-cream mix is weighed into each of the two 8-per-cent whole-milk test bottles [6] or 20-per-cent 9-gram ice-cream test bottles.

2. Add 5 cc. of reagent A to each bottle and mix the contents of the bottle thoroughly.

3. Add 30 cc. of reagent B (at room temperature) and again mix the contents of the bottle thoroughly until all the curd is dissolved. (If the volume of the base of the bottle permits adding only 28 to 29 cc. of reagent B, the results are usually satisfactory although it is advisable to select bottles which will hold the full 30 cc.)

4. Place the bottles in a water bath at a temerature of from 175° to 180° F. and heat for 15 minutes. It is important that the temperature of this water bath should not vary more than 5° F. as indicated. The contents of the bottles must be mixed at least three times during this heating period.

5. Centrifuge at the regular speed for 5 minutes.

6. Shake the bottle thoroughly, and if the contents of the bottle are not up to the base of the neck add sufficient water (180° F. or above) to raise the contents to within about ¼ inch of the base of the neck.

7. Centrifuge at the regular speed for 3 minutes.

8. Again mix the contents of the bottle thoroughly and then add sufficient water (180° F. or above) to raise the fat well into the graduated portion of the neck of the bottle.

9. Centrifuge at the regular speed for 1 minute.

[6] A milk-test bottle with a large base is best adapted for this procedure.

10. Place the bottles in a water bath at 135°–140° F. for 5 minutes and measure the fat columns after adding glymol.

11. The percentage of fat is read direct from the bottle if a 9-gram 20-per-cent ice-cream test bottle has been used, but the reading from the neck of the 8-per-cent whole-milk test bottle must be multiplied by 2 to obtain the percentage of fat. The test should always be made in duplicate, and the results from the two bottles should check within 0.2 per cent fat in the sample.

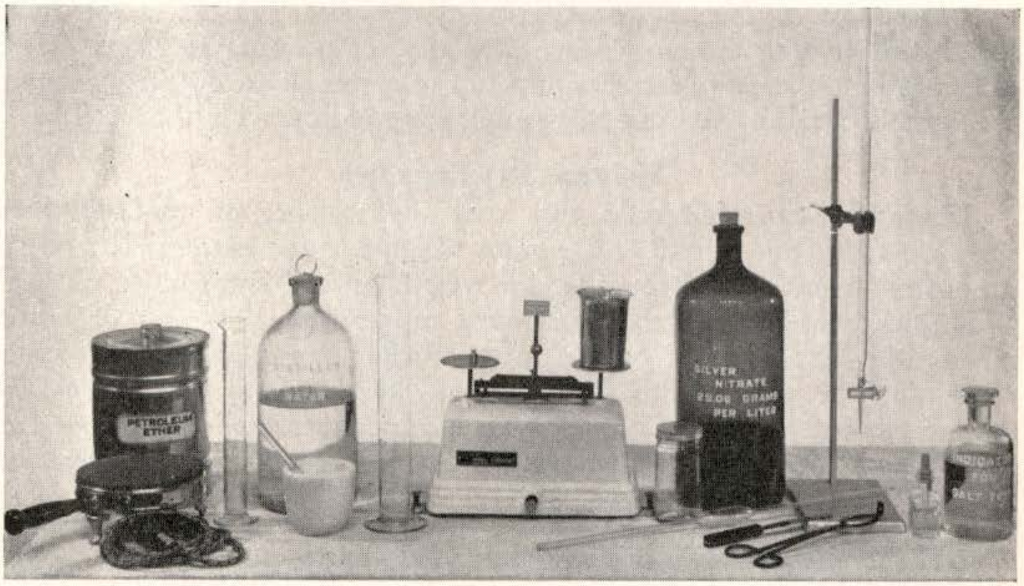



FIG. 12.—Equipment and reagents for making a complete analysis of butter.

## COMPLETE BUTTER ANALYSIS
### (Modified Kohman Procedure)

The following equipment is needed:

Sample jar—4- to 6-ounce capacity with tight-fitting lid.

Spatula or similar device (an ordinary table or case knife may be used).

Aluminum cup—200 cc. to 250 cc. capacity and at least 3 inches tall.

Moisture test scale and 10-gram weight and a 1-gram or a 9-gram weight.

Tongs.

Alcohol lamp, gas flame, or electric hot plate.

Graduate—100 cc. capacity.

Volumetric flask—250 cc. capacity.

Burette—25 to 50 cc. capacity or an automatic-type flask.

Silver nitrate solution—29.06 grams silver nitrate per liter or 14.53 grams per liter.

Pipette—17.6 cc. or 25 cc.

White cup.

Potassium chromate indicator—10-per-cent solution in distilled water.

Distilled water.

Petroleum ether. Cleaner's naphtha or even a very high-grade gasoline has been found to be satisfactory.

### Sampling

After scraping aside the surface, remove at least five portions of 10 to 15 grams from different parts of the churn and transfer to sample jar; or cut a slice about one inch in thickness from the center of a pound print; or with a trier remove three portions from the tub, one portion from the center, another near the edge, and the third half-way between these two.

If necessary to procure a heavy, creamy consistency of the sample, place the closed jar with the sample in water at a temperature of 90° to 95° F. (Do not heat the sample sufficiently to cause the fat to oil off.) Remove the sample jar lid and mix the sample thoroughly with the spatula.

### Moisture Determination

Heat the clean aluminum cup, cool, and balance on the right-hand scale pan with the 1-gram and 2-gram weights at the extreme left on the graduated beams. Place the 10-gram weight on the left pan of the scale and quickly weigh into the aluminum cup exactly 10 grams of butter, placing the butter on the bottom of the beaker if possible. Hold the cup containing the sample with the tongs and lower it into a small colorless gas or alcohol flame, or set it on an electrically heated plate (not over 300° F.). As the sample is heated, rotate the cup gently and take care that none of the sample boils or spatters over the edge.

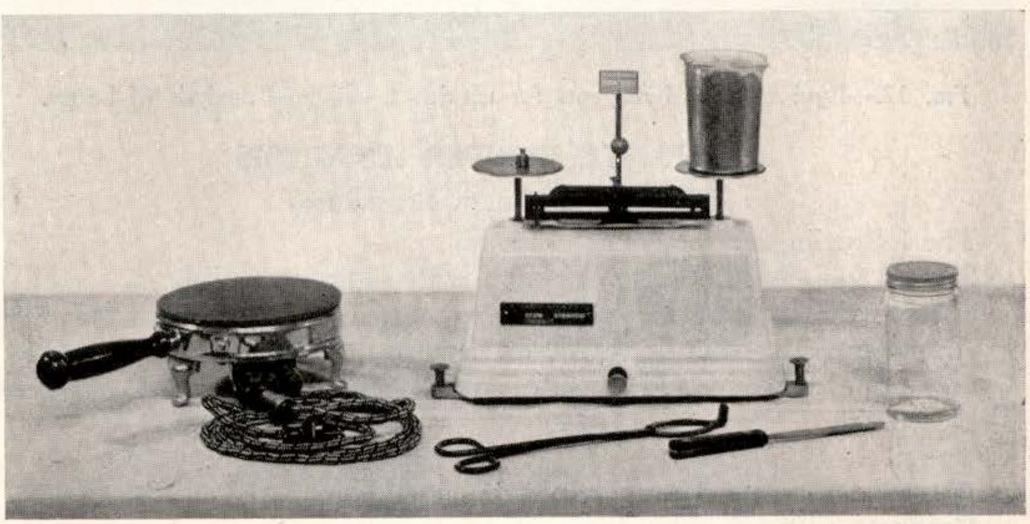


FIG. 13.—Equipment and reagents for determining moisture in butter.

Continue the slow heating until the sample stops sputtering and a golden brown color appears in the curd (without any great amount of browning of the fat itself) and a faint odor of burned butter is detected.

Cool the cup and sample at once. For greatest accuracy this should be done by allowing the cup to stand on a clean table or metal plate. If the result must be reported quickly, the cup may be immersed part way in

a pan of clean, cold water until cool, and then carefully and thoroughly dried with a clean, dry, lintless towel. For greatest accuracy, the cooling of the cup in water is not recommended.

Replace the cooled cup containing the water-free butter on the right-hand pan of the scales (which should not be disturbed in the meantime). Move the 2-gram weight on the 20-per-cent beam and the 1-gram weight on the 10-per-cent beam to the right until the cup is again in balance. Read the percentage of moisture directly from the beam. Read to the nearest 0.1 per cent.

### Fat Determination

Use the residue from the moisture determination. Do not disturb the scales. Pour about 100 cc. of petroleum ether or high-test gasoline over the residue in the cup. Rotate gently to mix, then let the cup stand undisturbed for not less than 4 minutes. Then carefully pour off the ether or gasoline containing the dissolved fat as completely as possible without losing any of the curd. Complete the removal of fat by adding another 100 cc. of petroleum ether or gasoline and pouring it off as before.

Dry off the rest of the ether or gasoline by warming the cup on a heated electric plate or over the flame. (Ether and gasoline are highly inflammable and must be heated carefully if over an open flame.) Heat until the residue in the cup appears as a fine, dry powder which does not stick together or stick to the cup. In case the residue is dark colored and sticky, add another 50 cc. of the petroleum ether or gasoline and pour off as before. This difficulty is experienced more often with gasoline than with ether but may be due to failure to pour off a sufficient quantity of the solvent.

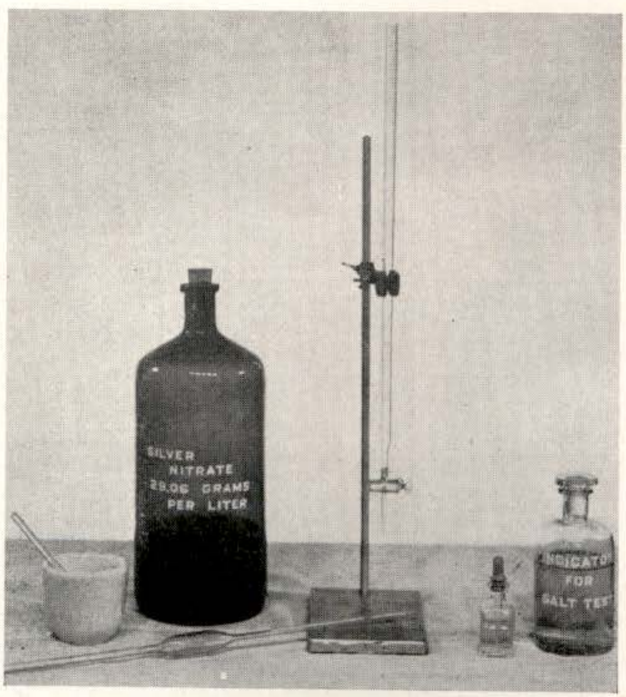



FIG. 14.—Equipment and reagents for determining the salt content of butter.

Allow the cup to cool and replace it on the right-hand pan of the moisture scales. Substitute the 1-gram weight for the 10-gram weight or place a 9-gram weight on the pan with the cup. Adjust the 1-gram and 2-gram weights on the graduated beams to bring the scale to a balance again. The readings on the graduated beams subtracted from 10 give the per cent of salt and curd. The per cent of salt and curd plus the per cent of moisture subtracted from 100 gives the per cent of fat.

### Salt Determination

The residue from the fat determination is rinsed from the beaker and made up to exactly 250 cc. in the volumetric flask with distilled water. Twenty-five cc. of the solution is placed in a white cup and 2 or 3 drops of the potassium chromate solution added. Then with rotating the cup constantly or stirring the contents of the cup with a stirring rod, run in the silver nitrate solution from the burette until a flesh or light orange color appears throughout the mixture in the cup.

Read from the burette the number of cubic centimeters of silver nitrate solution used, to the nearest 0.1 cubic centimeter. Each cubic centimeter of silver nitrate solution used represents 1 per cent of salt in the sample when the silver nitrate solution contains 29.06 grams per liter or 0.5 per cent when 14.53 grams per liter is used.

### Curd Determination

The curd is determined by difference. The percentage of salt and curd has been determined. Likewise the percentage of salt has been determined. The difference between these figures is the percentage of curd.

## DETERMINING THE ACIDITY OF DAIRY PRODUCTS

Normal milk when first drawn from the cow will show a titratable acidity of 0.10 to 0.14 per cent, which is due to the carbon dioxide, casein, and acid-reacting salts contained in the milk. As the milk stands, especially if not kept cold, the acidity increases as a result of normal bacteria of the milk acting upon the lactose or milk sugar and changing it to lactic acid. The final amount of acid produced usually does not exceed 1.0 per cent. Milk as delivered at the factory or to the consumer will usually have 0.15 to 0.18 per cent titratable acidity. Milk containing a higher per cent of fat as produced by the cow will have a higher titratable acidity due to the higher percentage of solids not fat in such milk. An acidity of 0.26 to 0.30 per cent can be detected by taste. In determining the

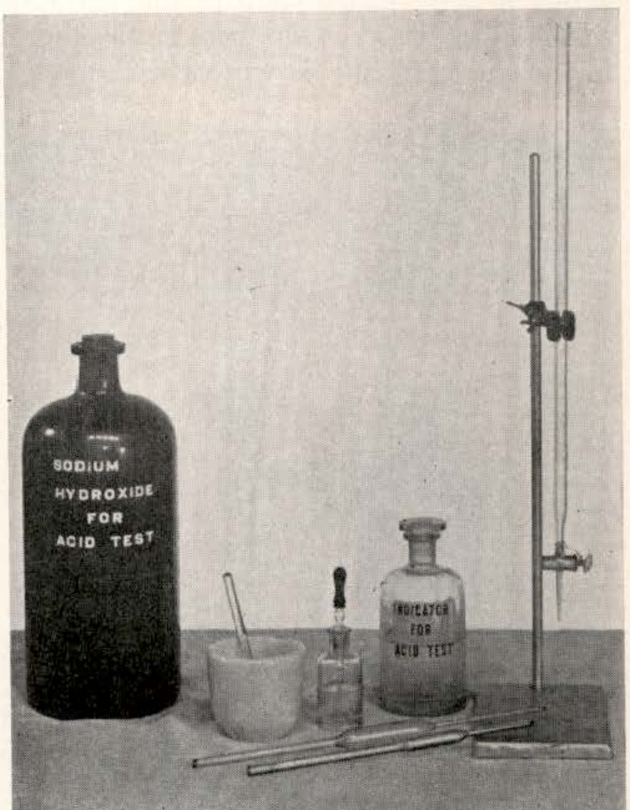



FIG. 15.—Equipment and reagents for determining the percentage of acid in dairy products.

acidity of milk, the chemical principle that acids and alkalis will neutralize each other and produce water and a neutral substance called a salt is used. A definite quantity of the alkali will always neutralize or combine with a definite quantity of the acid; thus, by knowing the strength of the alkali and the amount used in neutralizing the acid in a known quantity of milk, we can readily calculate the amount of acid present. An "indicator," which by a change of color indicates that all the acid-reacting substances in the sample have been neutralized by the alkali, is used. This indicator is phenolphthalein.

### Equipment and Reagents Needed

An alkali (sodium hydroxide) solution of a definite concentration known as tenth normal. This solution contains 4.0 grams of the pure alkali per liter (1000 cc.) and should be procured from a supply house. One cc. of this solution will neutralize 0.009 gram of lactic acid.

Phenolphthalein indicator—1 per cent solution in alcohol.

A white cup.

A 17.6-cc. and a 9-cc. pipette.

A 25-cc. or 50-cc. burette with clamp and support. An automatic burette attached directly to the alkali bottle may be obtained from a supply house.

### Procedures

**For milk, skim milk, and whey.**—Transfer 17.5 cc. of the sample to the white cup. Add 0.5 cc. of the indicator. While mixing the contents of the cup with a rotary motion or with a stirring rod, add the alkali from the burette drop by drop until the first pink color develops that does not fade in 30 seconds. Read from the burette the number of cubic centimeters of alkali used. This divided by 20 will equal the percentage of acid.

**For cream and ice-cream mix.**—Transfer 9 grams of the sample to the white cup and add 9 cc. of distilled water. Proceed as in the case of milk. The number of cubic centimeters of alkali used divided by 10 is the percentage of acid.

**For condensed milk.**—Use 9 grams of the sample and add a sufficient amount of distilled water to bring the sample to about the same consistency as whole milk. Proceed as in the case of milk. The number of cubic centimeters of alkali used divided by 10 is the percentage of acid.

### Calculations and Suggestions

Since it has been indicated that 1.0 cc. of the alkali exactly neutralizes 0.009 gram of lactic acid, it follows that the following formula applies to all cases of acidity determinations for milk products when using a tenth normal alkali.

$$\frac{\text{Cubic centimeters of alkali used} \times 0.009}{\text{Weight of sample used (grams)}} \times 100 = \text{per cent acid.}$$

Dilution of the sample with distilled water has an effect upon the titratable acidity but the above procedures are outlined to give comparable results with various products. Clean equipment and careful following of the directions are essential if dependable results are to be obtained.

## DETERMINING TOTAL SOLIDS IN MILK PRODUCTS BY GRAVIMETRIC METHODS

This method of determining the solids in dairy products consists in evaporating the water from a definite quantity of the product by the application of heat.

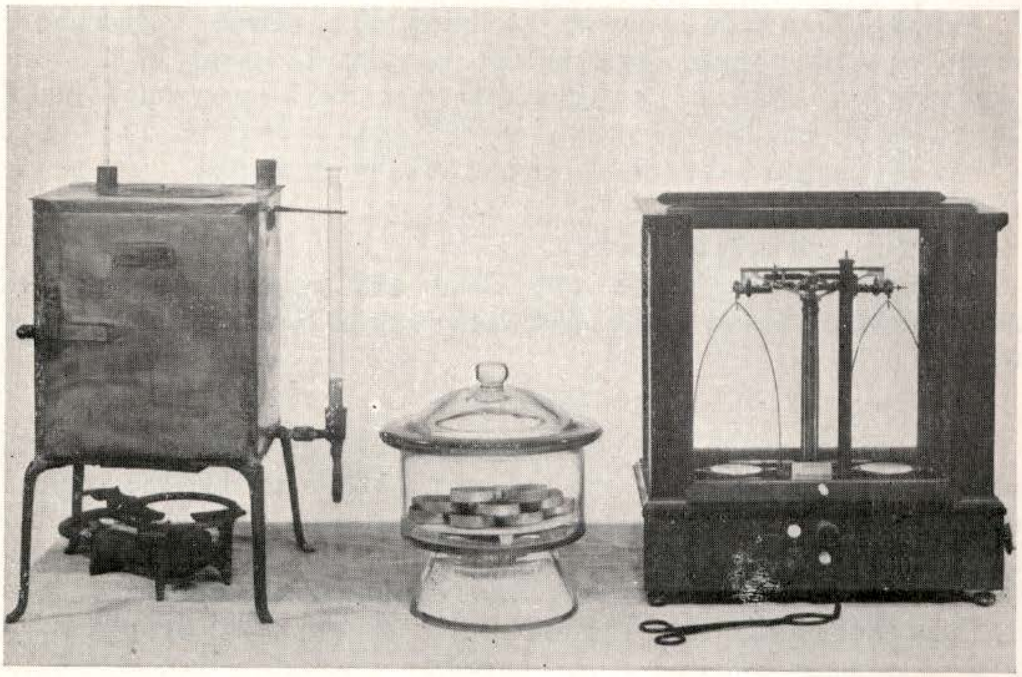


FIG. 16.—Equipment for determining the moisture or total solids in dairy products. Water oven (left), usually heated by a gas burner, in which weighed samples are dried to constant weight. Desiccator (middle) with aluminum dishes in which the weighed samples are cooled previous to reweighing after drying. Analytical balance (right) for weighing dishes and sample.

### Equipment Necessary

Balance or scale. For most accurate work an analytical balance must be used; however, results which may be satisfactory for use in regular dairy plant procedure may be obtained when using the torsion moisture test scale or a scale of equal sensitivity.

A set of analytical weights ranging from 1 milligram (0.001 gram) to 100 grams.

An aluminum, flat-bottom dish about 3 inches in diameter and about ½ inch high.

A cover for the aluminum dish.

A water-jacketed oven which may be heated to and maintained at the temperature of boiling water.

A desiccator—a glass vessel with a drying agent (calcium chloride is commonly used) in the base and a tight fitting cover.

### Procedure for Milk, Skim Milk, Buttermilk, and Whey

1. Heat the aluminum dish in the oven at the temperature of boiling water for at least one hour.
2. Cool the dish in the desiccator.
3. Weigh dish and cover and record weight.
4. Transfer 3 to 5 cc. of the milk product to the dish, replace cover, reweigh, and record weight.
5. Place the dish and contents without cover in oven and dry to constant weight, i.e., until there is no further loss in weight when the results of two successive weighings (at half-hour intervals) are compared.
6. Cool dish and contents in desiccator.
7. Weigh dish and cover and dried contents.
8. Calculate the percentage of moisture and percentage of total solids.

Example:

Weight of dish and cover, plus milk product ............ 20.05 grams
Weight of dish and cover ............ 16.01 grams
Weight of milk product ............ 4.04 grams
Weight of dish and cover and dried-milk product ............ 16.55 grams
Weight of dish and cover ............ 16.01 grams
Weight of dried milk product ............ 0.54 grams
4.04—0.54 = 3.50 grams evaporated moisture.
3.50 ÷ 4.04 × 100 = 86.63% moisture.
100—86.63 = 13.37% solids.

### Procedure for Cream, Evaporated Milk, Condensed Milk, and Ice-Cream Mix

Proceed in the same manner as described for milk, skim milk, etc., except that because of the viscosity of these products it may be desirable to add 1 to 2 cc. of distilled water to the sample after it is weighed into the dish; this causes a more even distribution of the sample over the bottom of the dish for drying.

## CALCULATION OF TOTAL SOLIDS OF WHOLE MILK BY FORMULA

For this calculation it is necessary to determine the lactometer reading and the percentage of butterfat of the sample of milk. A lactometer is a hydrometer graduated especially for determining the specific gravity of milk. Either the Quevenne or the New York Board of Health lactometer is commonly used. The first is graduated from 15 to 40, and the latter from 0 to 120. Readings may be made when the milk is between 50° F. and 70° F., but a correction factor must be applied to a reading at any temperature other than 60 °F. The correction factor for the Quevenne

lactometer is 0.1 for each degree. With temperatures above 60° F. the correction is added to the reading, but for temperatures below 60° F. it is subtracted. A correction factor of 0.3 is applied in the same way with the New York Board of Health lactometer.

In obtaining a lactometer reading, the temperature of the milk is first adjusted to nearly 60° F., the milk is mixed thoroughly but carefully to avoid incorporation of air, and then it is transferred to a glass cylinder of sufficient depth and diameter to allow the lactometer to move up and down freely. The lactometer is inserted and after about a half minute the point and the temperature at which the milk meniscus (curved surface) intersects the stem are recorded. The butterfat determination of the sample is also made, using the regular Babcock procedure.

The following is an example of the calculations to be made: Quevenne lactometer reading is 32 at 66° F., and the butterfat content of the sample is 4.3 per cent. Since the lactometer reading was made at a temperature other than 60° F., the correction factor must be applied. The above figures are used in the formula, 0.25 L + 1.2 F = per cent total solids (L = the corrected Quevenne lactometer reading and F = the percentage of butterfat).

$$32 + 0.6 = 32.6$$

$$32.6 \div 4 + (1.2 \times 4.3) = 8.15 + 5.16 = 13.31\% \text{ total solids.}$$

The New York Board of Health lactometer may be used, but the reading obtained with it must be converted to its Quevenne value. This is accomplished by correcting the lactometer reading for temperatures other than 60° F. and then multiplying this corrected reading by 0.29; the result will be the corresponding Quevenne reading. The procedure is then followed as outlined above.

## PROBLEMS IN DAIRY ARITHMETIC

The following examples are selected to illustrate calculations more commonly encountered in dairy work.

1. What is the amount of butterfat in each of the following?

| | | |
|---|---|---|
| 120 lbs. | milk containing | 3.2 % butterfat |
| 1,140 lbs. | milk containing | 3.9 % butterfat |
| 12 lbs. | cream containing | 42.5 % butterfat |
| 340 lbs. | cream containing | 27.0 % butterfat |
| 62 lbs. | skim milk containing | 0.04% butterfat |
| 12,057 lbs. | buttermilk containing | 0.25% butterfat |
| 3,048 lbs. | whey containing | 0.55% butterfat |

Procedure:

$120 \times 0.032$ (3.2%) = 3.84 lbs. butterfat
$1{,}140 \times 0.039$ (3.9%) = 44.46 lbs. butterfat
$12 \times 0.425$ (42.5%) = 5.10 lbs. butterfat
$340 \times 0.27$ (27.0%) = 91.80 lbs. butterfat
$62 \times 0.0004$ (0.04%) = 0.0248 lb. butterfat
$12{,}057 \times 0.0025$ (0.25%) = 30.1425 lbs. butterfat
$3{,}048 \times 0.0055$ (0.55%) = 16.7640 lbs. butterfat

2. If the cream, the whole milk, and the skim milk in the above example are all mixed together, what will be the percentage of butterfat of the mixture?

Use the following formula:

$$\frac{\text{Total pounds of butterfat}}{\text{Total pounds of mixture}} \times 100 = \% \text{ of butterfat in mixture.}$$

Then

$120 + 1140 + 12 + 340 + 62 = 1{,}674$ pounds in the mixture.

$3.84 + 44.46 + 5.10 + 91.80 + 0.0248 = 145.2248$ pounds of butterfat in the mixture.

$$\frac{145.2248 \text{ lbs. butterfat}}{1{,}674 \text{ lbs. mixture}} \times 100 = 8.675\% \text{ butterfat in the mixture.}$$

3. If a farmer separates an average of four 10-gallon cans of milk daily and the skim milk from the separator contains 0.12 per cent butterfat, what is the value of the butterfat lost in the skim milk in 60 days if butterfat is worth 28 cents per pound?

Procedure:

One gallon of milk weighs 8.6 lbs. This may be calculated from the weight of a gallon of water (weight 8.34 pounds) and the average specific gravity of milk, thus $8.34 \times 1.032 = 8.6$.

Then $8.6 \times 10 \times 4 = 344$ lbs. milk in four 10-gallon cans. Since the separator may be assumed to deliver approximately 10 lbs. cream and 90 lbs. of skim milk from each 100 lbs. milk separated, then $344 \times 0.90 = 309.6$ lbs. skim milk $\times$ 60 days $= 18{,}576$ lbs. of skim milk. $18{,}576 \times 0.0012 = 22.2912$ lbs. butterfat, or approximately 22.3 lbs. and $22.3 \times \$0.28$ equals \$6.244 or \$6.24.

4. If in the above example the farmer separated milk testing 4.2 per cent butterfat and the fat loss in the skim milk was so small as to be negligible, (a) What would be the percentage of butterfat in the cream? (b) How many pounds of cream would be procured? (c) What would be the value of the fat in the cream?

Procedure:

(a) 100 lbs. milk = 10 lbs. cream and 90 lbs. skim milk.
100 lbs. milk contains 4.2 lbs. butterfat; therefore, 10 lbs. cream contains 4.2 lbs. butterfat and $4.2 \div 10 \times 100 = 42\%$ butterfat in the cream.

(b) 344 lbs. milk daily $\times$ 60 days $= 20{,}640$ lbs. milk.
$20{,}640 \times 0.10$ (pounds of cream from each pound of milk) $= 2{,}064$ lbs. cream.

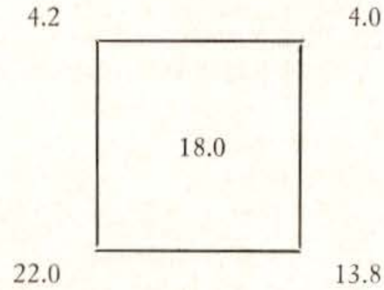
(c) 2,064 lbs. cream $\times$ $0.42 = 866.88$ lbs. butterfat.
$866.88 \times \$0.28 = \$242.73$.

## PROBLEMS IN THE STANDARDIZATION OF THE FAT CONTENT OF MILK AND CREAM

The various types of problems in the standardization of milk and cream which may be encountered are illustrated below. In the first problem the details of the method are given, while in the later problems these are omitted. The Pearson Square method is used.

1. How much 4.2-per-cent milk must be added to 103.5 pounds of 22-per-cent cream to reduce the fat content to 18 per cent?

First draw a rectangle or square and place at its left-hand corners the figures designating the percentage of butterfat in the products to be mixed together, then place in the center of the square the percentage of butterfat desired in the final product. Now subtract diagonally across the square, and always the smaller number from the larger, placing the result in the diagonally opposite corner.




The figures on the right-hand corners now represent the proportion in which the two products must be mixed. That is, 4 lbs. of 4.2% milk must be mixed with 13.8 lbs. of 22.0% cream to produce 18.0% cream, consequently

$103.5 \div 13.8 \times 4 = 30$ lbs. of 4.2% milk needed

or

$13.8 : 103.5 :: 4 : X$

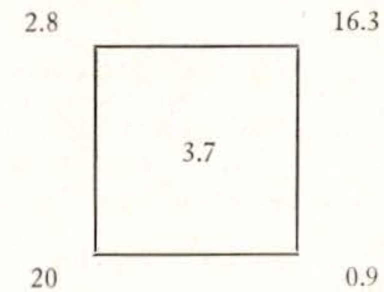
$13.8X = 414$

$X = 30$ lbs. 4.2% milk needed.

Then 30 lbs. of 4.2% milk when mixed with 103.5 lbs. of 22% cream will make 133.5 lbs. of 18% cream.

2. How much 20-per-cent cream must be added to 120 lbs. of 2.8-per-cent milk to increase the fat content to 3.7 per cent?

The figures are now placed on the square according to the plan illustrated in the preceding problem and we have




Then since 0.9 lb. of 20% cream must be added to each 16.3 lbs. of 2.8% milk

$120 \div 16.3 \times 0.9 = 6.6$ lbs. of 20% cream required

or

$16.3 : 120 :: 0.9 : X$

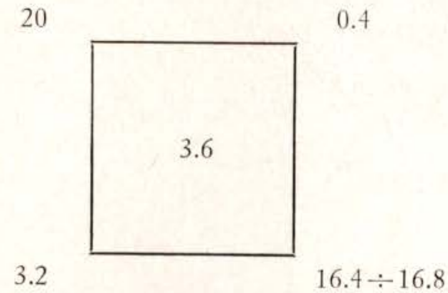
$16.3X = 108$

$X = 6.6$ lbs. of 20% cream required.

3. How much 20-per-cent cream and 3.2-per-cent milk will be required for 120 quarts of 3.6-per-cent milk?

These calculations must always be in pounds, and since a quart of milk weighs 2.15 lbs., then $120 \times 2.15 = 258$ pounds of 3.6% milk wanted.

Proceeding as before,




Here is a slight variation from the procedures previously illustrated, since a definite quantity of the final product is desired. According to previous illustrations when 0.4 lb. of 20% cream and 16.4 lbs. of 3.2% milk are mixed together, 16.8 lbs. of 3.6% milk will be the result. Therefore

$258 \div 16.8 \times 16.4 = 251.86$ lbs. of 3.2% milk required
$258 \div 16.8 \times 0.4 = 6.14$ lbs. of 20% cream required

or by proportion

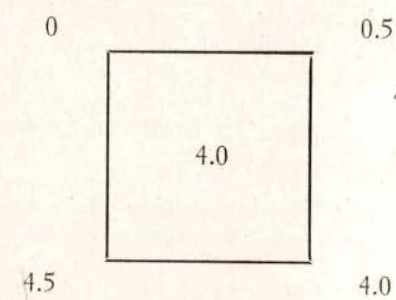
$16.8 : 258 :: 16.4 : X$
$16.8X = 4231.2$
$X = 251.86$ lbs. of 3.2% milk required

and $16.8 : 258 :: 0.4 : X$
$16.8X = 103.2$
$X = 6.14$ lbs. of 20% cream required

4. How much skim milk must be added to 400 lbs. of 4.5-per-cent milk in order to reduce the fat to 4.0 per cent?

This problem may be worked in one of two ways, only one of which makes use of the square. It is asssumed that the percentage of the fat in the skim milk is so small that it may be considered as 0.

With the square




$400 \div 4.0 = 100 \times 0.5 = 50$ lbs. skim milk to add

or by proportion

$4.0 : 400 :: 0.5 : X$
$4.0X = 200$
$X = 50$ lbs. skim milk to add.

Without the square,

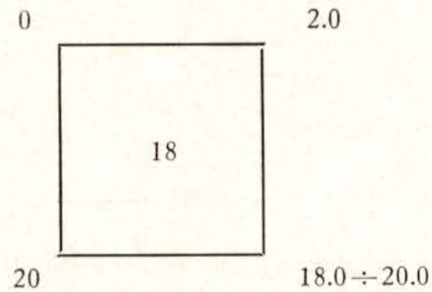
400 lbs. 4.5% milk contains 18.0 lbs. butterfat.
Each pound of 4.0% milk contains 0.04 lb. butterfat

Then

$18 \div 0.04 = 450$ lbs. of 4.0% milk can be made by adding skim milk to 400 lbs. 4.5% milk, or 50 pounds of skim milk would be needed.

5. How much skim milk and 20-per-cent cream are needed to make 210 lbs. of 18-per-cent cream? This problem may likewise be worked with and without the use of the square.

With the square




Thus 2 lbs. of skim milk and 18 lbs. of 20% cream will make 20 lbs. of 18% cream.

Then

$210 \div 20 \times 18 = 189$ lbs. 20% cream needed

and

$210 \div 20 \times 2 = 21$ lbs. skim milk needed

or by proportion

$20 : 210 :: 18 : X$

$20X = 3780$

$X = 189$ lbs. 20% cream needed.

and

$20 : 210 :: 2 : X$

$20X = 420$

$X = 21$ lbs. skim milk needed.

Without the square,

210 lbs. of 18% cream will require

$210 \times 0.18 = 37.8$ lbs. butterfat

37.8 lbs. butterfat will be supplied by

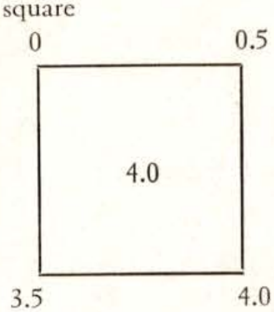
$37.8 \div 0.20 = 189$ lbs. of 20% cream

189 lbs. 20% cream + 21 lbs. skim milk = 210 lbs. 18% cream.

6. How much skim milk must be removed from 200 lbs. of 3.5-per-cent milk to increase the fat to 4.0 per cent?

It is understood that only the skim milk will be removed and that the cream produced will be poured back into the original milk.

With the square




For every 4.0 lbs. of 3.5% milk 0.5 lb. of skim milk must be removed.

$200 \div 4 = 50 \times 0.5 = 25$ lbs. of skim milk to be removed.

or by proportion

$4.0 : 200 :: 0.5 : X$

$4.0X = 100$

$X = 25$ lbs. of skim milk to be removed.

Without the square

200 lbs. 3.5% milk contains $200 \times 0.035 = 7.0$ lbs. butterfat.

Each pound of 4.0% milk will require 0.04 lb. butterfat or there is sufficient butterfat to produce $7.0 \div 0.04 = 175$ lbs. of 4.0% milk. Since there are 200 lbs. of milk, then 25 lbs. of skim milk must be removed.

## OTHER USEFUL INFORMATION

### From Centigrade to Fahrenheit

Changing a temperature reading in centigrade to its equivalent in Fahrenheit is illustrated as follows:

Since 5 degrees on the centigrade scale is equivalent to 9 degrees on the Fahrenheit scale and 32° F. and 0° C. are equivalent, we may multiply the centigrade reading by 9/5 and add 32 if the reading is above 0° C. or deduct 32 if the reading is below 0° C.

60° C. = what temperature on the Fahrenheit scale?

(Formula: $9/5\ C. + 32 = {}^\circ F.$)

$60 \times 9/5 = 108$

$108 + 32 = 140^\circ$ F.

### From Fahrenheit to Centigrade

Changing a temperature reading in Fahrenheit to its equivalent in centigrade can be illustrated by the following example:

140° F. = what temperature on the centigrade scale?

(Formula: ${}^\circ F. - 32 \times 5/9 = {}^\circ C.$)

$140 - 32 = 108$

$108 \times 5/9 = 60^\circ$ C.

### Weights and Measures

Liquid measures:

1 cubic centimeter (milliliter) = approximately 20 drops.

1,000 cubic centimeters = 1 liter = 1.056 quarts.

29.57 cubic centimeters = 1 liquid ounce.

473.2 cubic centimeters = 1 liquid pint.

Dry measures:

1 gram = 15.432 grains = 0.035274 ounce.

1,000 grams = 2.2046 avoirdupois pounds.

453.6 grams = 1 avoirdupois pound.

## Weight and Specific Gravity Table

| Material | Specific gravity at 60° F. | Weight of 17.5 cc. in grams | Weight of one gallon in pounds |
|---|---|---|---|
| Water | 1.0000 | 17.500 | 8.34 |
| Milk (average 4 per cent fat) | 1.0320 | 18.060 | 8.60 |
| Skim milk (average) | 1.0360 | 18.130 | 8.64 |
| Cream: 18 per cent butterfat | 1.0152 | 17.766 | 8.47 |
| 20 | 1.0129 | 17.726 | 8.45 |
| 22 | 1.0107 | 17.687 | 8.43 |
| 24 | 1.0085 | 17.649 | 8.41 |
| 26 | 1.0062 | 17.608 | 8.39 |
| 28 | 1.0040 | 17.570 | 8.37 |
| 30 | 1.0017 | 17.530 | 8.35 |
| 32 | 0.9995 | 17.491 | 8.33 |
| 34 | 0.9973 | 17.453 | 8.32 |
| 36 | 0.9952 | 17.416 | 8.30 |
| 38 | 0.9930 | 17.377 | 8.28 |
| 40 | 0.9908 | 17.339 | 8.26 |
| 42 | 0.9886 | 17.300 | 8.24 |
| 44 | 0.9864 | 17.262 | 8.23 |
| 46 | 0.9843 | 17.225 | 8.21 |
| 48 | 0.9821 | 17.187 | 8.19 |
| 50 | 0.9801 | 17.152 | 8.17 |
| Butterfat | 0.9300 | 16.275 | 7.76 |

## Distribution of Constituents of Milk[1]

| | Constituent | Amount | Description | Subtotal | Group total | Total solids |
|---|---|---|---|---|---|---|
| Milk fats—emulsions—globules 0.004″ to 0.00006″ in diam. | Olein | 33.95[2] | Glycerides of insoluble volatile acids | 3.40 | 3.70 | Total solids 12.35 |
| | Palmitin | 40.51[2] | | | | |
| | Stearin | 2.95[2] | | | | |
| | Myristin | 10.44[2] | | | | |
| | Laurin | 2.57[2] | | | | |
| | Butyrin | 6.23[2] | Glycerides of soluble volatile acids | 0.30 | | |
| | Caproin | 2.32[2] | | | | |
| | Caprylin | 0.53[2] | | | | |
| | Caprinin | 0.34[2] | | | | |
| Milk serum | Casein | 2.60 | (Nitrogen-containing substances) Solution and colloidal suspension | 3.25 | Solids not fat 8.65 | |
| | Albumin | 0.60 | | | | |
| | Globulin, trace | | | | | |
| | Fibrin, trace | | | | | |
| | Lecithin | 0.05 | | | | |
| | Milk sugar | | | 4.50 | | |
| | Citric acid | | | 0.20 | | |
| | Potassium oxide | 0.175 | Ash 0.70 solution and colloidal suspension | | | |
| | Sodium oxide | 0.070 | | | | |
| | Calcium oxide | 0.140 | | | | |
| | Magnesium oxide | 0.017 | | | | |
| | Iron oxide | 0.001 | | | | |
| | Sulfur trioxide | 0.027 | | | | |
| | Phosphorus pentoxide | 0.170 | | | | |
| | Chlorine | 0.100 | | | | |
| | Water | | | | | 87.65 |
| | | | | | Total | 100.00 |

[1] By Mojonnier and Troy, "Technical Control of Dairy Products."
[2] Percentage of total fat.

## Federal and State Standards for Milk, Cream, Butter, and Ice Cream [1]

| State | Milk | | Light cream, fat | Butter, fat | Plain ice cream, fat | Fruit and nut ice cream, fat |
|---|---|---|---|---|---|---|
| | Fat | S. N. F. | | | | |
| | *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* |
| Alabama | 3.25 | 8.5 | 18 | 80 [2] | 10 | 8 |
| Arizona | 3.25 | 8.5 | 18 | 80 [2] | 10 | 8 |
| Arkansas | .. | .. | .. | .. | 8 | 6 |
| California | 3.3 | 8.5 | 20 | 80 | 10 | 8 |
| Colorado | 3.2 | .. | 18 | 80 | 12 | 10 |
| Connecticut | 3.25 | 8.5 | 16 | 80 [2] | 10 | 8 |
| Delaware | 3.25 | 8.5 | 18 | .. | 12 | 10 |
| Florida | 3.25 | 8.5 | 18 | 80 | 10 | 8 |
| Georgia | 3.25 | 8.5 | 18 | 80 | 10 | 8 |
| Idaho | 3.2 | 8.0 | 18 | 80 | 10 | 8 |
| Illinois | 3.0 | 8.5 | 18 | 80 | 12 | 10 |
| Indiana | 3.25 | 8.5 | 18 | 80 | 10 | 8 |
| Iowa | 3.0 | 8.5 | 16 | 80 | 12 | 10 |
| Kansas | 3.25 | .. | 18 | 80 | 10 | 10 |
| Kentucky | 3.25 | 8.0 | 18 | 80 [2] | 10 | 10 |
| Louisiana | 3.25 | 8.5 | 18 | 80 | 10 | 8 |
| Maine | 3.25 | 8.5 | 18 | .. | 14 | 12 |
| Maryland | 3.5 | .. | 18 | 80 | 12 | 8-10 |
| Massachusetts | 3.35 | .. | 16 | 80 | 10 | 8 |
| Michigan | 3.0 | 8.5 | 18 | 80 [2] | 12 | 10 |
| Minnesota | 3.25 | .. | 20 | 80 [2] | 12 | 10 |
| Mississippi | 3.0 | 8.5 | 18 | 80 | 10 | 8 |
| Missouri | 3.25 | 8.5 | 18 | 82.5 | 8 | 8 |
| Montana | 3.25 | 8.5 | 20 | 80 | 10 | 9 |
| Nebraska | 3.0 | .. | 18 | 80 | 14 | 12 |
| Nevada | 3.25 | 8.5 | 22 | 80 | 14 | 12 |
| New Hampshire | 3.35 | .. | 18 | 80 [2] | 14 | 12 |
| New Jersey | 3.0 | .. | 16 | 80 [2] | 10 | 8 |
| New Mexico | 3.25 | 8.5 | 18 | 80 [2] | 12 | 10 |
| New York | 3.0 | .. | 18 | 80 | 10 | 8 |
| North Carolina | 3.25 | 8.5 | 18 | 80 [2] | 10 | 8 |
| North Dakota | 3.0 | .. | .. | 80 [2] | 12 | 10 |
| Ohio | 3.0 | .. | 18 | 80 | 10 | 8 |
| Oklahoma | 3.5 | 8.5 | 18 | 80 [2] | 12 | 10 |
| Oregon | 3.2 | 8.5 | 18 | 80 | 12 | 10 |
| Pennsylvania | 3.25 | .. | 18 | 80 [2] | 10 | 8 |
| Rhode Island | 3.25 | .. | 18 | 80 | 8 | 8 |
| South Carolina | 3.0 | 8.5 | .. | .. | 10 | 10 |
| South Dakota | 3.25 | 8.5 | 18 | 80 | 12 | 10 |
| Tennessee | 3.5 | 8.5 | .. | 80 | 8 | 6 |
| Texas | .. | .. | 18 | .. | 8 | 6 |
| Utah | 3.2 | 8.3 | 18 | 80 | 12 | 9 |
| Vermont | 3.25 | 8.5 | 18 | 80 [2] | 14 | 12 |
| Virginia | 3.25 | 8.5 | 18 | 80 | 10 | 8 |
| Washington | 3.25 | 8.5 | 18 | 80 | 10 | 10 |
| West Virginia | 3.0 | 8.5 | 18 | 80 [2] | 8 | .. |
| Wisconsin | 3.0 | 8.5 | 18 | 82.5 [3] | 13 | 11 |
| Wyoming | 3.0 | 8.5 | 18 | 80 | 10 | 10 |
| Federal | .. | .. | 18 | 80 | .. | .. |

[1] From "Legal Standards for Dairy Products," Bureau of Dairy Industry, U. S. Department of Agriculture, 1936.
[2] Sixteen-per-cent water.
[3] Allowable tolerance of 2.5 per cent.