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ERRATA.

Page 7, read "Total solids for Jersey breed 15.40."
Page 20, line 7, read "less" in place of "more."
Page 23, line 14, "composite sample," not "compositive."
Page 43, in the example, read "$32 \div 4 = 8$."
Page 44, "Total solids $= \frac{L + 0.7f}{3.8} + f$."
Page 56, reference 30, "Hoard's Dairyman."
Page 133, fifth line from bottom, "1860" not "18.60."
Page 143, "timothy hay" read "pea hay." On the same page the figures for total fat should read, beginning with clover hay: "2.97, 2.75, 3.91, 1.50, 2.40, 2.80, 3.25, 2.93, 0.97, 1.40, 0.95, 1.57." Digestible fat, sugar beets, and mangels, "0.1" not "1."
Page 146, the corrected reading for lactometer, No. 32, temperature 70, is "33.4" not "34.4."

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CHEMISTRY OF DAIRYING

An Outline of the Chemical and Allied Changes Which Take Place in Milk, and in the Manufacture of Butter and Cheese; and the Rational Feeding of Dairy Stock.

—BY—

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PREFACE.

These notes on Dairy Chemistry were originally prepared for classroom use in the School of Agriculture of the University of Minnesota. They are based on a course of lectures which have been given by the author, twice a year, for several years past.

The increased interest in dairy literature, together with the scarcity of works of this nature, has led to the belief that this work might be of sufficient value to warrant its publication. In its preparation free use has been made of the bulletins and reports of the agricultural experiment stations of the various states, and of the standard works dealing with milk and its products.

These notes have been prepared with the object of furnishing useful information to a class of young men who intend to become farmers and dairymen rather than scientific experts.

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October 31, 1896.

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The Chemistry of Dairying.

INTRODUCTION.

Dairy Chemistry is that part of agricultural chemistry which treats of the chemical and allied changes that take place in milk, and in its manufacture into butter and cheese. Each operation in the dairy, as creaming, ripening the cream, churning, cheese-making, etc., involves chemical, physical, and bacteriological changes, a knowledge of which is essential in order to understand and properly control many of the operations of both cheese-making and butter-making. The chemical, bacteriological, and physical changes which take place in butter- and cheese-making are so closely allied that it is difficult to treat of one without also considering the others. Our present knowledge of many of the changes which milk and its products undergo in their preparation for the market, is incomplete; there are, however, many facts which are known and understood, and if they were carefully observed and properly made use of by the butter- and cheese-maker, a better quality of products could be more generally produced. Before taking up the study of milk and its products, it is first necessary to obtain a clear conception of the nature and composition of milk, and then the separate operations in the dairy may be studied in detail.

CHAPTER I.

The General Composition of Milk.

Milk is a very complex material. It is, in fact, one of the most complex of the animal fluids. Milk is composed of a number of solid substances dissolved and suspended in water. The substances in solution are: casein, ash, sugar, and albumin. These substances, together with the water in which they are dissolved constitute the *milk serum*. The fat in the milk is not dissolved, but is suspended in the milk serum. The fat is present in the form of globules, like little rubber balls.

1. Total Solids.—The total solids of milk are what remain after all of the water has been removed. The term *dry matter* is sometimes used instead of total solids. The solids are obtained by evaporating a portion of milk to complete dryness at the temperature of boiling water.

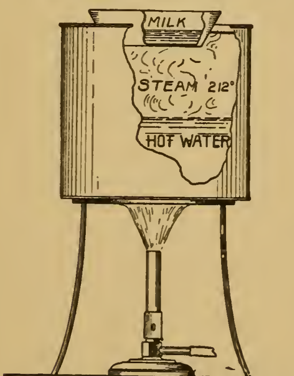


Fig. 1.

In the illustration observe that the milk is placed in the dish which is supported over boiling water. The milk is heated, by the steam, to a temperature of 212° F., when the water in the milk is expelled as steam. The residue left in the dish, known as the milk solids, is a shiny, brittle mass composed of fat, milk-sugar, ash, casein, albumin, and many other compounds. When all of the water is removed from 100 pounds of milk, about thirteen pounds of solid matter will be left. The milk of some cows contains more solid matter than that of others. There is rarely less than twelve pounds or more than sixteen pounds of solids in 100 pounds of milk. In tables of analyses this is usually stated as per cent. of total solids, that is, pounds of solid matter in 100 pounds of milk.

2. Ash.—The ash is what remains after the solid matter of milk has been burned. It is a grayish white material. The ash in the milk is very valuable for the formation of bones. 100 pounds of milk will yield about three-fourths of a pound of ash. or seventy-five hundredths per cent. ash. The ash in milk is very constant and varies but little from three-quarters of one per cent.

In order to obtain the ash, the little flat-bottomed dish "a" is placed on the triangle "b" over the gas flame. The sugar, fat, casein, and albumin are burned and converted into volatile (smoke-like) products, while the ash is left as a grayish white powder in the dish.

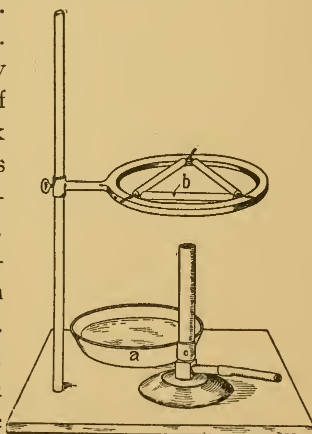


Fig. 2.

When the milk is analyzed in the laboratory the little dish, which is used for determining the solids and ash, is carefully weighed on a very delicate pair of scales. A small quantity of milk, after it has been carefully weighed, is put into the dish. The water is expelled from the milk in the way explained, and after careful drying, the dish with the milk solids is weighed. The increase in weight is that of the milk solids obtained from the milk used, which was also weighed. That is, a weighed quantity of milk has given a weighed quantity of milk solids. The corresponding amount of solids in 100 parts of milk is then obtained by a simple proportion.

Example.—Dish weighs 12.850 grams, milk used weighs 10.51 grams. The dish and milk solids weigh 14.195 grams. The dish and milk ash weigh 12.925 grams. What is the per cent. of solids in this milk? What is the per cent. of ash?

	Grams.
Dish and solids	14.195
Dish	12.850
Solids in 10.51 grams milk	1.345

	Grams.
Dish and milk ash	12.925
Dish	12.850
Milk ash in 10.51 grams milk	0.075

In 100 grams of milk, how many grams of solids?

$1.345 : 10.51 :: x : 100$

$x = 12.80$ or 12.80 per cent. solids in the milk.

In 100 grams of milk, how many grams of ash?

$0.075 : 10.51 :: x : 100.$

$x = 0.71$ or 0.71 per cent. ash in the milk.

3. **The Casein in Milk** is generally known as the curd, and when obtained from the milk in a pure state, it is a

grayish white powder. Casein takes a very important part in cheese-making and other dairy operations. The chemical and physical properties of casein will be studied in detail further on. Casein is very valuable as food. There is not as much casein in milk as there is fat. One hundred pounds of milk will ordinarily contain about three pounds of casein. The per cent. of casein in milk is quite constant, ranging from two and nine-tenths to three and six-tenths per cent.

4. **Albumin,** which is nearly identical with the white of the egg, is also found in milk. Albumin has about the same general composition as casein. The "scum" which forms when milk is boiled is albumin. There is from a half to three-quarters of a pound of albumin in every 100 pounds of milk.

5. **Milk Sugar.**—There is present in milk a material called milk sugar, which, in general appearance, resembles confectionary sugar. Milk sugar possesses no sweet taste. Indirectly, the milk sugar takes a very important part in both butter- and cheese-making. There is from four and three-fourths to five pounds of milk sugar in every 100 pounds of milk.

6. **Milk Fats.**—The fat in milk is familiar as the product obtained as butter from the churn. Milk fats and butter, however, are not the same. By milk fats is meant the pure dry fat, free from water, salt, or casein, while butter contains all three of these materials. One hundred pounds of butter contain about eighty-three pounds of pure dry fat.

Each one of these separate compounds in milk will be studied in detail. In beginning the study of this subject, the student should aim to obtain first a general idea of the composition of milk, and then later to study the separate compounds in detail.

Milk varies in composition according to the special peculiarities of the cow as to the breed, nature of the food, and period of lactation.

The average composition of 3000 samples of milk compiled from analyses reported in the agricultural experiment station reports and bulletins of the various states, gives approximately:

	Per cent.
Water	87.50
Total solids	12.50
Fats	3.60
Solids not fat	8.90
Casein and Albumin	3.40
Milk sugar	4.75
Ash	0.75

As an example of milk from a good herd, the average analyses of 112 samples from the dairy herd of the Minnesota Experiment Station in 1893, gave:

	Average. Per cent.	Highest. Per cent.	Lowest. Per cent.
Water	86.32	87.82	84.76
Total solids	13.68	15.24	12.18
Fat	4.74	6.50	3.45
Solids not fat	8.94	9.74	8.73
Casein and albumin	3.42	4.20	3.00
Milk sugar	4.85	5.25	4.30
Ash	0.67	0.78	0.60

Inasmuch as the per cent. of fat as given in the preceding table is somewhat greater than is usually produced by an ordinary herd, the average of the analyses of 43 samples of milk from different herds in the same state are given:

	Per cent.
Water	87.20
Total solids	12.80
Fats	3.65
Solids not fat	9.15
Casein and albumin	3.57
Milk sugar	4.85
Ash	0.71

The composition of the milk from different breeds, as given by the New York Experiment Station for one year, was:

Breeds.	Total solids. Per cent.	Fat. Per cent.	Casein. Per cent.	Milk sugar. Per cent.	Ash. Per cent.
Holstein-Fresian	12.39	3.46	3.39	4.84	0.74
Ayrshire	13.06	3.57	3.43	5.33	0.70
Jersey	10.40	5.61	3.91	5.15	0.74
Am. Holderness	12.63	3.55	3.39	5.01	0.70
Guernsey	14.60	5.12	3.61	5.11	0.75
Devon	13.77	4.15	3.76	5.07	0.76

These figures are not necessarily true for all cases, because there is frequently as great a difference in the composition of milk from cows of the same breed as between the cows of different breeds. These figures are given mainly for illustration. The student should remember the general figures as:

Solids, twelve to thirteen per cent., occasionally as high as fifteen per cent.

Fat, three to four per cent., occasionally as high as five or six per cent.

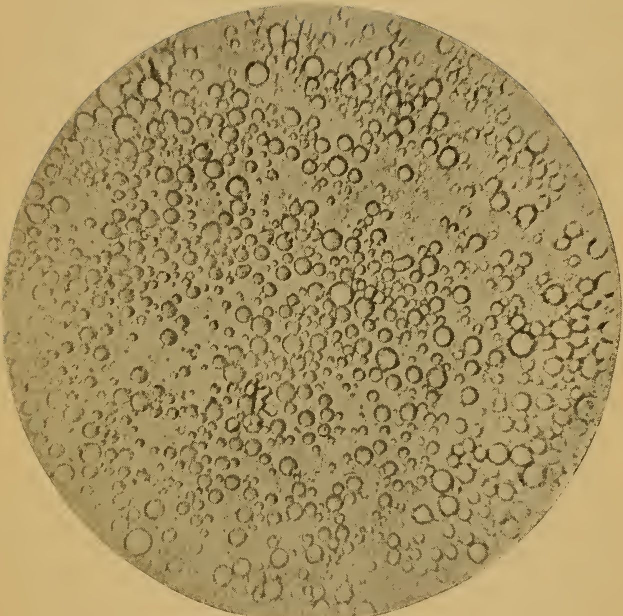
Casein and albumin, three and one-fourth to three and three-fourths per cent.

Sugar, four and three-fourths to five and one-fourth per cent.

Ash, 0.75 per cent.

7. The Fat Globules.—The fat globules in milk are very small. It would require on an average about 5,000 of them to measure an inch. A cubic millimeter of milk is estimated to contain from 2,000,000 to 4,000,000 fat globules. Under the microscope the fat globules appear grouped together in small colonies. The size of the fat globules varies with (1) the breed and the individuality of the animal, and (2) according to the length of time that the animal has been in milk. When a cow is fresh there is a smaller number of large globules; when the cow is well along in her milking period the globules are smaller, and at the same time they are more numerous. These small bodies are the bodies which must be massed together and collected when butter is made. The more completely they are recovered the greater will be the amount of butter produced. The globules are simply solid masses of fat. At one time it was supposed that the fat globules were surrounded by a membrane, and in churning it was supposed the membrane had to be broken before the globules would mass. Recent chemical investigations have shown that there is no membrane surrounding the fat globules.

8. Surface Tension.—The fat globules are lighter than any of the constituents of the milk serum. The globules retain their form and individuality on account



THE FAT GLOBULES OF FRESH MILK × 300.

of the surface tension. The surface tension is the pressure that is exerted on the surface of the globules, and is equal on all sides, hence the spherical form of the globules.

The illustration (Fig. 3) shows the composition of milk.

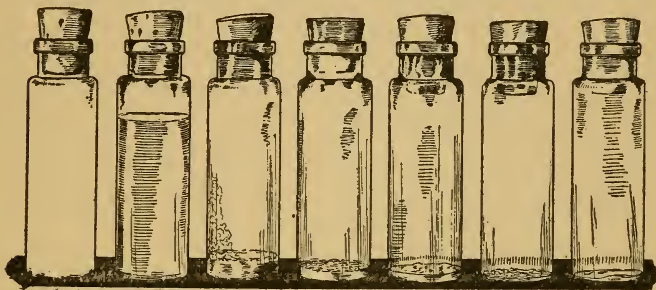


Fig. 3.

If the first tube were filled with milk, the corresponding amounts of the other constituents would be as represented.

9. Total Yield in Pounds, and Percentage Composition.—The total yield, in pounds, of milk solids, and fat produced in a given time is of more importance than the percentage composition, and it is the basis on which all comparisons are usually made. The total yield in pounds of each constituent is obtained by multiplying the percentage composition by the total weight of milk. For example, two cows gave, for one week, an average yield of thirty-three and thirty-five and two-tenths pounds respectively of milk. The average composition of the milk for this period was as given below. The pounds of each of the constituents are found by multiplying the percentage composition by the weight of the milk.

Cow No. 1.

	Composition.		Pounds milk.		Total pounds given.
Total solids	0.1344	×	33	=	4.44 total solids.
Fats	0.0466	×	33	=	1.54 fats.
Ash	0.0068	×	33	=	0.22 ash.
Casein, etc.	0.0334	×	33	=	1.10 casein, etc.
Milk sugar	0.0475	×	33	=	1.56 milk sugar.

Cow No. 2.

	Composition.		Pounds milk.		Total pounds given.
Total solids	0.1256	×	35.2	=	4.42 total solids.
Fats.......	0.0406	×	35.2	=	1.43 fats.
Ash	0.0064	×	35.2	=	0.23 ash.
Casein, etc.	0.0304	×	35.2	=	1.07 casein.
Milk sugar	0.0478	×	35.2	=	1.68 sugar.

10. First Milk and Strippings.—As is well known, the first portion of milk given by any cow, at any milking, is poor in fat, while the last portion, or strippings, is very rich in fat; the amount of casein, ash, and sugar is about the same in both cases. The composition of the first pint and the last pint, in the case of the two cows previously mentioned, well illustrates this point.

	Cow No. 1.		Cow No. 2.	
	First pint. Per cent.	Last pint. Per cent.	First pint. Per cent.	Last pint. Per cent.
Total solids......	9.42	19.49	10.10	18.47
Fat	0.71	10.84	1.02	9.49
Solids not fat....	8.71	8.65	9.08	8.98
Ash	0.68	0.72	0.70	0.74
Casein, albumin..	3.44	3.51	3.35	3.65

11. Milk Serum, Constancy of Composition.—The solids of the milk serum are fairly constant in composition. This is well illustrated in the case of the composition of the first milk and the strippings. The solids of the milk serum, also known as the solids not fat, are never less than 8.25 per cent. and rarely more than 9.75 per cent. The average is about nine per cent. The greatest difference in the composition of various milks is observed in the amount of fat that is present. Any material increase in the total solid matter of milk is due mainly to an increase of the fat. The solids not fat are subject to but slight variations compared with the fluctuations of the fat.

Nearly all of the important fluids of the body, like the blood, etc., are normally quite constant as to chemical composition. With milk, the constancy of its composition is confined to the solids of the milk serum.

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[Note.—The references given at the end of each chapter are not intended as a complete index of the literature. They are given as a guide for those who desire to make a more thorough study of the subject.]

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CHAPTER II.

Milk Testing.

A knowledge of the amount of fat in milk is essential in order to determine: (1) Any unnecessary waste in the manufacture of butter and cheese; (2) to determine the value of individual cows; (3) to serve as a basis for the purchasing of milk; and (4) to determine the cost of production of milk.

A number of simple methods have been proposed for testing milk; some of them require a more extended knowledge of chemical operations than others. The method which is most generally used, on account of its accuracy and simplicity, is the Babcock centrifugal method.

12. Reliability of the Babcock Method.—This method has been carefully tested by many chemists, and in all cases has been found to be a reliable test. There is a tendency to read the results too low; this will be spoken of more in detail when dealing with that part of the operation. In the case of skim-milk and buttermilk, when the fat present is less than two-tenths per cent. (one small division), the method does not always give reliable results. This does not impair its usefulness, because frequently the losses are greater than this, and so far as the whole milk is concerned the method is perfectly reliable. When the Babcock test shows only a trace of fat in the skim-milk or buttermilk, the losses are very small.

13. **Sampling Milk.**—Every lot of milk, whether a large or small one, should be weighed before sampling. The milk as it comes from the cow, and when it has been standing, is not in a condition to sample until it has been thoroughly mixed, either by pouring from one pail to another, or by stirring with a long-handled dipper. Two ounces of the well mixed milk, and even less, put into a convenient wide-mouth bottle is a sufficient quantity to serve as a sample.

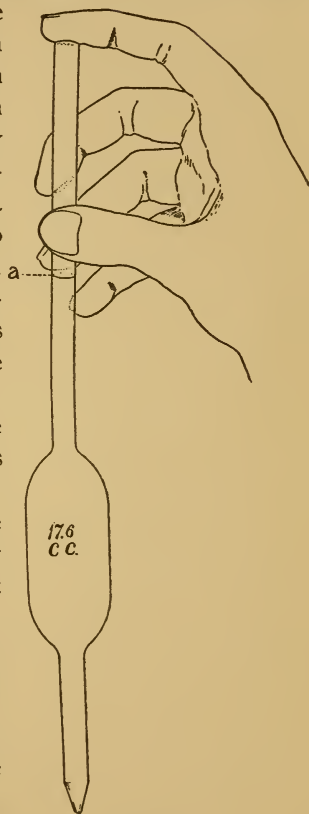

Fig. 4.

The milk should not be measured into the test-bottles until it has cooled to 70° F. At a higher temperature the milk is expanded and may contain an abnormal amount of dissolved air.

When the milk has been standing some time in the sample bottles, it is necessary to mix it. Pour the milk from the bottles down the sides of another bottle or dish and not in the center of the vessel. This prevents the formation of foam and insures the thorough mixing of all particles of cream.

14. Measuring the Milk.—The apparatus used for measuring the milk is called a pipette (see Fig. 4). In order to fill the pipette put the pointed end into the milk, apply suction with the mouth until the milk rises above the point *a* on the stem; then close the end with the index finger of the right hand, holding the pipette in the way shown in the cut. The second and third fingers are opposite the thumb, while the little finger rests against the stem. When held in this way the pipette is prevented by the little finger from swaying sidewise, while the firm grasp by the thumb with the second and third fingers on the opposite sides secures a good hold and leaves the index finger free to properly control the flow from the pipette and to make rapid measurements. If the pipette is wet, rinse it with a little of the milk before using it; remove the last few drops by blowing. In passing from one milk to another, clean the pipette by rinsing it with a little of the milk that is to be tested. Be sure to give the pipette a thorough cleaning, first with cold water, then with hot water at the close of the work.

The pipette holds 17.6 cc. of water, and delivers eighteen grams of milk. When the milk is delivered into the test-bottles, hold the test-bottle in the left hand at an angle of about 60°. Allow the tip of the pipette to just touch one side of the neck of the test-bottle. This is necessary in order to allow air to pass out of the test-bottle, otherwise the milk will spatter when it is delivered. Allow plenty of time for the pipette to drain.

15. Making the Test.—The test-bottle is shown in

Fig. 5, and is provided with a neck which has a graduated scale from 1 to 10. Each larger division is in turn divided into five smaller divisions. Each test-bottle is usually provided with a copper collar bearing a number. Fill the acid measure, Fig. 6, up to the 17.6 cc. mark, with sulphuric acid. More will be said about the sulphuric acid in another paragraph. Pour the sulphuric acid from the acid measure into the test-bottle which contains the milk.

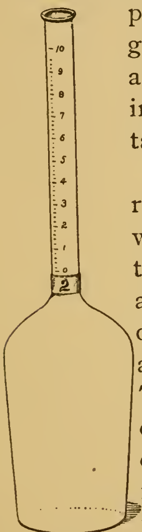

Fig. 5

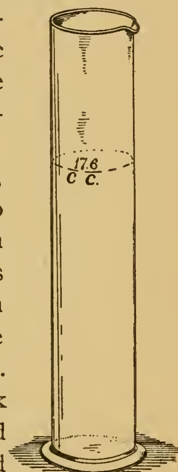

Fig. 6.

When the acid is poured in, rotate the test-bottle so as to wash all of the milk down from the stem. After the acid is added, take hold of the stem of the test-bottle, and mix the acid and milk by rotating. The solution takes on a dark coffee color, due to the acid charring the sugar. The acid first precipitates the casein and then dissolves it. The acid does not act on the fat.

The fat is separated from the milk serum by centrifugal action. There are a number of different makes and sizes of centrifugal machines on the market, but they all act on the same principle. The test-bottles are placed into the pockets of the centrifugal machine. In case there are not enough bottles to fill the machine, arrange the bottles so that there will be an even number on each side. If this is not done the machine is unbalanced, and the bearings will soon become badly worn. The bottles are to be whirled five minutes at the rate of 900 revolutions per minute. Directions for speeding the machine will be found in another paragraph. The starting and stopping of the machine should be done gradually.

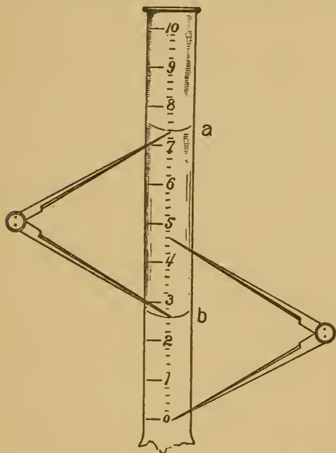

Fig. 7.

After whirling five minutes the test-bottles are filled with hot water up to about the eight mark on the stem. The air bubbles which are sometimes caught in the neck, should be allowed to escape. The bottles are then whirled two minutes in order to collect all of the fat in the graduated stem. In using the machine always close the cover so as to prevent any accident.

None of the apparatus used in this test is patented, and a good home-made centrifugal machine will answer every purpose. The bottles and all of the glassware can be purchased separately.

16. Reading the Fat.—When the test is completed, the fat in the stem presents the appearance shown in Fig. 7. Read from the lowest point *b* to the highest point *a*. Each large division, as 1 to 2, represents a whole per cent. of fat. Each of the smaller divisions is one-fifth or two-tenths of a per cent. Suppose the top register seven large and one small divisions, then $a = 7.2$ per cent. If *b* register two large and three small divisions, $b = 2.6$. $7.2 - 2.6 = 4.6$, the per cent. fat in the milk.

Do not read from any other points except *a* and *b*, otherwise the results will be too low. The bottles are made to read in just this way. The reading should be done before the fat cools, and streaks down the sides. In case a number of readings are to be made, the test bottles should be set into a pan of hot water, or hot water can be run into the pan of the machine, so as to prevent the bottles from cooling. A pair of sharp pointed dividers can be used in the way indicated in the figure. (See Fig. 7.)

All test-bottles should be rejected when the inaccuracy of the divisions can be detected with the eye. In the most careful work they should be calibrated with mercury. Each small division is equal to about 0.04 cc., or as usually made, one and one-half millimeters. For ordinary work the bottles can all be tested with one sample of milk, and all bottles rejected that show a greater difference than one small division. Accurately graduated test-bottles can usually be obtained from supply houses that deal in chemicals and glassware. Other pieces of apparatus can be obtained from the same sources. Poor test-bottles are frequently the cause of much trouble and dissatisfaction in the factory.

17. Speeding the Machine.—Count the number of revolutions that the test-bottles make for every revolution of the crank wheel. Suppose the test-bottles make twelve revolutions while the crank makes one. In order that the bottles may make 900 revolutions in a minute, the crank must be turned seventy-five times in a minute. ($900 \div 12 = 75$). In case the machine is more than fifteen inches in diameter a greater number of revolutions is necessary.

18. Centrifugal Action.—As previously stated, the fats are lighter than the milk serum, and when the milk is whirled in the test-bottles, there is a separation of milk fats (lighter particles), from the milk serum (heavier portions). The serum goes to the outside of the circle of revolution, while the fats will mass in the center where they are finally collected in the graduated stem. The sulphuric acid, which is one and eight-tenths heavier than water, also aids in the separation both by increasing the specific gravity of the milk serum and by its chemical action upon the albumin and casein. The cream separator also works on this same principle. Centrifugal action is well illustrated by whirlpools, where all of the foam and light materials, as leaves, collect at the center. In the case of the separator, provision is made for the escape of the fat into a tube as it collects at the center.

19. The Acid.—Commercial sulphuric acid (sp. gr. 1.82), about ninety per cent. strength, can usually be obtained for two and one-half cents per pound when purchased in carboy lots; one pound of acid will make about twenty tests. When the acid is too strong, the fat presents a blackened and charred appearance, if too weak, particles of undissolved casein appear immediately below the fat line. When just right, the fat separates in a distinct and well defined layer, and looks like butter. The acid as well as the washings and contents of the test-bottles can be handled only in glass or earthenware. The acid should never come in contact with a tin or metallic dish of any kind. If any acid is spilled on the floor or desks, wash it up immediately, using plenty of water. If a large quantity is spilled, absorb it with sawdust, bran, or fine clay. In case any is spilled on the clothing rinse with water

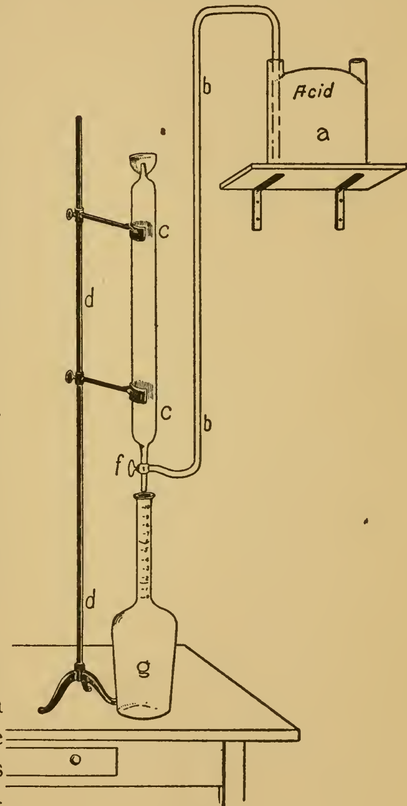

Fig. 8.

and then apply ammonia to the spots. Never throw the acid waste near a tree or where a person or animal is obliged to walk.

A convenient form of apparatus for measuring the acid is shown in Fig. 8. *a* is the acid bottle connected with glass tube *bb* to a 100 cc. pipette *cc*. The stopcock *f* can be turned so as to allow the acid to run into the test-bottle *g*. The automatic pipette is fastened to an iron stand *dd*, which rests upon the table. Other forms of apparatus are also in use, but in ordinary practice a good strong glass vessel with a good lip for pouring is the cheapest and best arrangement for the acid. A white tile is excellent to have on the table under the acid bottle.

20. Composite Test.—In actual creamery practice the daily testing of each patron's milk, or in the dairy, the testing of both morning's and evening's milk from each cow, is too expensive and consumes too much time. To obviate this daily testing, a composite or compound sample is made up by saving a little of the milk from each milking, in a pint fruit can. At the end of the week or two weeks the compound sample is carefully mixed and tested. Inasmuch as this test represents a proportional part of each lot of milk, it gives the average amount of fat in the milk for that period. In creameries and factories where milk is paid for by test, the composite test, when properly carried out, gives good results.

The composite sample should be kept covered so that the surface of the cream will not become dry and leathery. The sample should also be kept in a cool place to prevent fermentation. Various chemicals are used to keep the milk fresh.

Potassium bichromate has been found to give the best satisfaction. About as much potassium bichromate as will lay on the end of a pen knife blade will be a sufficient amount to use in each sample can. Put in the bichromate when the sample cans are empty, then no more need be added until a new composite sample is started. It imparts its characteristic yellow color to the milk.

In case corrosive sublimate or any poisonous material is used in the composite sample, it is best to color the milk with aniline so as to prevent the milk from being used, and accidental poisoning resulting therefrom.

Small four or six ounce wide-mouth bottles may be used for holding the compositive samples. Bottles with glass stoppers are the best. Rubber stoppers may be used but cork stoppers should never be used. They are difficult to clean and they cause the milk to sour. When the composite sample becomes "lumpy" and is difficult to sample, a very small piece of caustic potash may be added before mixing the milk. The potash will dissolve the lumps. A few drops more than 17.6 cc. of acid should then be used.

When there are only a small number of cows, the following plan may by followed: Save about two ounces of each cow's milk separately in glass bottles or cans; at the next milking add the same quantity or a proportional quantity. A composite sample of the day's milk is thus obtained, and while still fresh is mixed and then by means of a small pipette, 5.9 cc. are measured into a test-bottle twice the size of those ordinarily used, or test-bottles made for thirty-five cc. of milk. The milk of six days can then be measured directly into the test-bottles, and then tested. The milk is measured while sweet and fresh and will not harm if it sours in the test-bottles. No preservatives need be used. The milk sample of four ounces can then be saved and there is no loss through the taking of large samples.

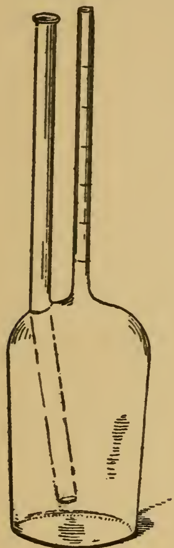

Fig. 9.

In testing skim milk, the special bottles, with the small neck and the side tube for the addition of the acid, should be used. It must be remembered that even the small amount of fat that is obtained in the neck is not necessarily all of the fat in the skim-milk because some of it may be present in such a fine state of division that it is not brought up into the neck. This, however, does not seriously impair the test. When the test shows only a trace of fat, the butter-maker can feel satisfied that he is doing good work.

21. Frozen Milk.—When a can of milk freezes the ice forms on the outside and there is a central part that does not freeze. The unfrozen part is richer in fat and solids than the frozen part. The ice in the center of the can is also richer in milk solids than the ice of the outer portions. When frozen or partially frozen, milk is not in a condition to sample.

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CHAPTER III.

Milk Fats.

The fat which is present in milk is not a single chemical compound, but is a mixture of various separate fats, all intimately mixed together. Each separate fat has its own name and special characteristics. Each fat, when finally separated into the materials of which it is composed, shows the presence of only three elments, or building materials: Carbon, hydrogen and oxygen. The various fats differ from each other, chemically, in two ways: (1) In the proportion in which these elements or building materials are present, as one fat may contain more or less carbon than another; and (2) the way in which these elements are united, just as a pile of bricks may be put together in a number of different ways. The fact that the butter-fat is composed of various separate fats, shows itself in various ways. At certain seasons of the year the butter is naturally harder, at other times it is softer; then again the butter from some cows is hard and firm, while from other cows, even upon the same food, it is naturally soft and salve-like. Chemical analysis has shown that this is due to the difference in the proportions in which the various fats are present. The quality of the butter, as hard or soft, is influenced by the quality of the separate fats which compose the butter. The different fats present in milk, according to Blyth, are:

	Per cent. of butter.
1. Palmitin } [1] 2. Stearin }	50
3. Olein	40
4. Butyrin	7
5. Caproin, caprylin and others	3

22. Palmitin is a white solid fat found in butter and also obtained from palm oil, and other sources. Human fat is very rich in palmitin. When chemically pure it is tasteless. Palmitin forms crystals like snow flakes. This fat has a high melting-point, 145.4° F.

23. Stearin is a white solid fat like palmitin and has a high melting-point, 157° F. It also crystallizes in the same way as palmitin. For a long time these two fats, palmitin and stearin, were thought to be one fat, to which was given the name margarine. Among the fats that are particularly rich in stearin are beef and mutton tallow. These substances melt at a much higher point than butter, and they are the materials used in the adulteration of butter, forming the product known as oleomargarine, which is a mechanical mixture of the fats palmitin and stearin (margarine) with olein. The larger the proportion of either stearin or palmitin in any fat, the higher its melting-point. When one butter has a higher melting-point than another, it is due to the presence of a larger amount of palmitin or stearin. These two fats make up about half of the weight of the milk fats.

24. Olein is quite different from either palmitin or stearin. This fat makes up about forty per cent. of

[1] The palmitin and stearin also include the myristic acid of butter.

the weight of butter. At medium temperatures, olein is a liquid or oil. It solidifies at a temperature of 40° F. It is a liquid at the ordinary temperature of the cold deep setting of milk, that is, the setting of milk in ice water. Olein has the property of readily and copiously dissolving palmitin and stearin. The larger the per cent. of olein in a butter or fat, the softer it is. Sperm oil, cod liver oil, and many of the vegetable oils are rich in olein.

25. **Butyrin,** the fourth fat in milk, melts at a temperature of 77° F.; milk fats contain from six to seven per cent. of butyrin. Although butyrin forms such a small proportion of milk fat, it is the characteristic fat of butter. It is the butyrin which gives to butter its individuality, and its presence or absence is the distinguishing point between butter and oleomargarine. Butyrin, when decomposed, forms butyric acid. In rancid and stale butter, the rank odor is due to butyric acid.

26. **Caproin and Caprylin** comprise only a small part of the fats of milk, and they do not require any special consideration.

27. **Glycerine a Part of all Fats.**—All fats have one point in common: when they are broken up into simpler products, glycerine is one of the products always formed; the other product is an acid with an "ic" ending in place of the "in" ending of the fat. By the action of superheated steam,

Palmitin yields palmitic acid and glycerine.
Olein " oleic " " "

Stearin	yields	stearic	acid	and	glycerine.
Butyrin	"	butyric	"	"	"
Caproin	"	caproic	"	"	"
Caprylin	"	caprylic	"	"	"

Milk fats are frequently defined as glycerides of the fatty acids. They are neutral bodies. All of the fats are lighter than water. The mixed butter-fats are insoluble in water; all are soluble in ether, chloroform, gasoline, and other similar solvents. Butyrin, caproin, and caprylin, when exposed to the air and light for any length of time undergo decided changes in composition, which finally result in the production of the corresponding fatty acids, and the product is rancid butter. Milk fats compared with starch contain but little oxygen in their composition. When the fats are acted upon by the air and some chemicals, they are oxidized. The drying of paint is an oxidation of some of the fats.

28. Food Value of Fats.—Fat is a very concentrated form of heat-producing food, because it contains such a large amount of carbon. In very small seeds, like flax, the fat is one of the main reserve forms of food. One pound of fat when burned will produce about two and one-fourth times more heat than a pound of starch. Starch contains forty-four per cent. carbon, and fat contains seventy-six per cent. carbon.

29. Saponification and Other Properties of Fats.—When certain chemicals known as alkalies, such as potash and soda, are heated with the fats they form soaps; the process is called saponification. When saponification takes place, part of the alkali unites with the fatty acid of the fat and forms soap, while the glycerine part of the fat unites with the remainder of the alkali and forms glycerine. Fat + alkali = soap + glycerine.

Butter-fats have a less power of taking up iodine than the fats which are used for making oleomargarine. Butter has an iodine number of about thirty, while that of oleomargarine is forty-five to fifty.

The main differences in composition between butter and oleomargarine is illustrated in the following table:

	Butter.	Oleomargarine.
Butyric acid, etc..........	4.50 per cent.	0.25 per cent.
Iodine number...........	30	45
Melting point............	85 to 95°	98 to 100°
Insoluble fatty acids.....	88.5 per cent.	90 to 95 per cent.

Simple methods for detecting adulterated butter will be given in another part of the work.

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CHAPTER IV.

Milk Sugar and Lactic Acid.

30. **Physical Properties.**—When milk sugar is obtained from milk and is in a pure state, it is in appearance, quite like ordinary confectionary sugar, but it does not possess any marked sweet taste. It is not as easily soluble in water as cane sugar. Ordinary sugar dissolves in less than a third of its own weight of cold water, while milk sugar requires six times its own weight of cold water for solution. Milk sugar is not as heavy as ordinary sugar; its specific gravity is 1.53, while that of cane sugar is 1.60. *Milk sugar takes a very important part in butter- and cheese-making.*

31. **Fermentation of Milk Sugar.**—Under favorable circumstances, milk sugar undergoes fermentation. In milk, one kind of fermentation is brought about by the action of minute organisms known as the lactic acid ferments. These organisms may be considered as microscopic vegetable bodies. These minute plant-like bodies live, develop and die in milk, just as any higher plant develops in the soil. Milk is a perfect food for the development of the lactic acid organisms. It contains a substance, milk sugar, capable of undergoing fermentation. The necessary amount of water for fermentation is also present, and as soon as the "spores" or seeds of the lactic acid organisms find their way into the milk, and the proper temperature is reached, fermentation takes place.

In winter, milk keeps sweet much longer than in summer. This is because the ferment does not develop at a low temperature.

A temperature of 70° to 90° F. is the most favorable for its growth. Below zero and above the boiling point of water, the ferment is killed. Not only milk but all of its products which contain a small amount of milk sugar, as cream, cheese, and even butter are capable of undergoing the lactic acid fermentation to a greater or less extent.

32. Chemistry of the Process.—When milk sours, the milk sugar is partially converted into lactic acid by the lactic acid ferment. The acid has a very sour taste. The chemical name of milk sugar is lactose. When the ferment begins to act, lactose is split up into two bodies, galactose and dextrose. The galactose that is formed is still farther acted upon by the ferment and forms two parts of lactic acid.

Lactose, (milk sugar) forms galactose and dextrose.

$$C_{12}H_{22}O_{11},H_2O = C_6H_{12}O_6 + C_6H_{12}O_6$$

Galactose forms two parts of lactic acid

$$C_6H_{12}O_6 = 2C_3H_6O_3.$$

The dextrose part may undergo a similar change. Hence, one part of milk sugar, when fermented, is finally split up and produces two or four parts of lactic acid. When the lactic acid is formed from the milk sugar, the milk changes from sweet to sour, and finally when the acid reaches a certain point the milk curdles; that is, the casein is coagulated. When milk is boiled and then curdles, it shows the presence of four-tenths per cent.

of lactic acid. The fermentation can take place only up to a certain point; it then stops and the action cannot go beyond this point, because the acid that is developed kills the ferments. Very frequently ferments are killed by their own products, just as an animal would be killed by the products of respiration if shut in a closed room.

33. **The Ripening of Cream.**—The ripening of cream is due mainly to the action of the lactic acid ferments. In the creamery, the process is hastened by warming the cream in vats, and holding it at a temperature of about 70° F., until the process is completed, and then cooling and churning the cream. In addition to the lactic acid organisms, other organisms may find their way into the milk or cream and produce undesirable products which render the cream bitter, and cause foul butter. In the ripening and handling of cream the most scrupulous cleanliness is necessary so as to prevent the action of the undesirable ferments, and to permit of the action of the desirable ones. Various attempts have been made to use pure cultures (seeds) of the lactic acid and other organisms for the ripening of the cream. It is believed by many that great improvements will be made in the ripening of cream.

34. **The Culture or Starter.**—In ripening cream the process is frequently hastened by adding a starter. A starter, or more properly culture, is a little sour skim milk that contains the spores (seeds) of the lactic acid ferment. When these spores are introduced into the cream, they

rapidly multiply and produce the desired effect. The action is checked, when the proper point is reached, by cooling the cream and churning it. In the selection of the starter, much care should be exercised; take the milk from a fresh and perfectly healthy cow so as to get a pure culture, which is as necessary as is good yeast for bread-making.

35. Determining the Acid in Milk.—For this work a burette (see Fig. 10) will be necessary, also a standard alkali solution and an indicator. Measure out twenty-five cc. of milk into a glass dish, add three to five drops of indicator (phenolphthalein). The milk or cream may then be diluted with 75 or 100 cc. of water. Add the standard alkali (tester) from a burette, until the color of the milk is changed to a faint reddish purple tinge. At this point sufficient alkali has been added to neutralize all the free acid of the milk. The standard alkali solution is sometimes spoken of as the tester solution.

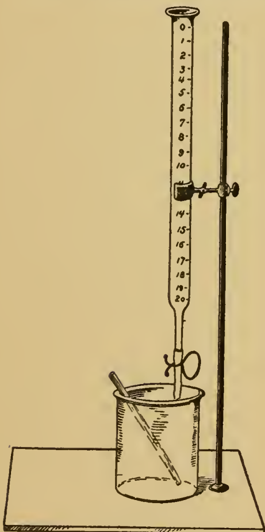

Fig. 10.

The amount of alkali used will depend upon the amount of free acid in the milk. For ripened cream butter twenty-two cc. of alkali should neutralize the acid in twenty-five cc. of the cream. In making the test, rain water should be used for rinsing and washing the dishes, as strong alkaline waters will destroy the accuracy of the test. The alkali can be prepared only by a druggist or one who has a delicate balance at hand. It is made by dissolving five and six-tenths grams of potassium hydroxide or four grams of sodium hydroxide per liter of distilled water.

Note the alkali used for sweet milk.
" " " " " sour "
" " " " " sweet cream.
" " " " " sour cream.

The object of this test is to enable the butter-maker to get his cream in about the same conditions, as to ripeness, from day to day, so as to aid in the production of a uniform article of butter.

Attempts have been made to utilize this test in determining the ripeness of milk for cheese-making purposes. The test will show the acidity of the milk but it does not necessarily follow that the acidity and the physical conditions of the casein, favorable for coagulation are identical. There is a class of bacteria which curdle milk without rendering it acid; on this account, the alkali test is not applicable for general cheese-making purposes. The test is of value in the manufacture of sweet curd cheese, to determine the fitness of the milk for use, as to whether it is too old or not, because the older the milk, the greater is the amount of lactic acid present.

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CHAPTER V.

The Lactometer and the Detection of Adulterated Milk.

The lactometer is a piece of apparatus used to determine the specific gravity of milk; that is, the weight of an equal volume of milk compared with the weight of an equal volume of water under the same conditions.

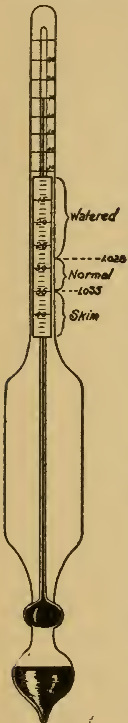
36. Specific Gravity of Milk.—The fat in milk is lighter than water; it has a specific gravity of about 0.93. This means that a given volume of fat weighs 0.93 as much as the same bulk of water, when under the same conditions as to temperature, etc. The ash, milk sugar, casein, etc., all have a higher specific gravity than water taken as 1. When a given weight of sugar or salt is dissolved in a definite amount of water, the specific gravity of the solution is increased proportionally to the amount of sugar or salt that is added. When the fat of milk is removed, the specific gravity is increased because the fat has a specific gravity of only 0.93, while all of the other constituents have a specific gravity greater than 1.

If there were but one ingredient in milk, the lactometer could tell how much there was of that ingredient, but the presence of more than one constituent complicates the problem.

The richer a sample in casein, milk sugar or ash, the greater is its buoyant power; it has a higher specific gravity. This is indicated by the lactometer stem not sinking to so great a depth as it otherwise would. On the other hand, the richer a milk in fat the greater the depth to which the spindle will sink. There is a certain point between these two opposing powers to which the spindle will sink in pure milk. Pure milk has a specific gravity of 1.029 to 1.034, skim-milk above 1.034, and watered milk below 1.029.

37. Lactometer Results Liable to Error.—The results obtained by the lactometer are liable to error, not on account of any imperfection in the principle or instrument, but because of the complex composition of milk. When sugar is mixed with water, the richness of the solution in that one substance can be as accurately and quickly determined by the hydrometer as by any other means. But when instead of one substance there are several mixed with water, and especially when some of these substances make the liquid less dense, while others make it more dense, the liability to error, in estimating with the lactometer the proportion of any one of the substances, becomes very serious. The fat might first be removed, which would result in raising the gravity; then water might be added which would lower it to almost the specific gravity of normal milk. Hence, if the milk were judged solely by the lactometer, serious errors might sometimes result.

38. Effect of Temperature on Lactometer Reading.—A difference in temperature affects the density of the milk solution and causes a difference in the depth to which the lactometer sinks. In taking a lactometer reading the temperature of the milk should also be taken



and the necessary corrections made according to the tables which usually accompany the lactometer. In case there are no tables, apply the general rule. When the temperature is greater than 60° F. (not exceeding 15°) add 0.1 for each lactometer degree greater than 60°, as specific gravity 1.032 at 70°; 70—60 = 10; 10 × 0.1 = 1 to be added to 32 makes the specific gravity 1.033 at 60° F. When the temperature is less than 60° subtract this factor from the reading. All the readings are recorded for the temperature of 60° F. [See appendix for table.]

The lactometer in most general use is known as Quévenne's lactometer. There are other forms, one known as the New York State Board of Health lactometer, which has a scale divided into 110 parts, 100 being for normal milk. In purchasing a lactometer, always get one that has a thermometer attached, as they are the most reliable ones. A lactometer reading by itself is not as valuable as when taken in connection with the Babcock test.

39. Combined Uses of Lactometer and Babcock Test.—When used jointly, the quality of the milk can be safely judged. The following general rules will aid in judging milk:

A low fat, 2.50 per cent., and a high specific gravity, 1.035, indicates skimming or fats removed.

A low fat, 3.00 per cent., and a low specific gravity, 1.027, indicates watered milk.

A low fat, 2.50 per cent., and a normal gravity, 1.029, indicates skimmed and watered.

Fat, 4.00 per cent., and a normal gravity, 1.032, indicates normal milk.

Fat, 4.50 per cent., and a normal gravity, 1.029, indicates normal milk.

40. Solids in Milk.—In order to obtain a fair idea of the solids in milk, multiply the per cent. of fat obtained

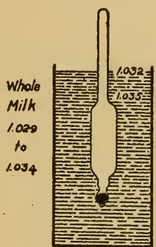


Fig. 13.

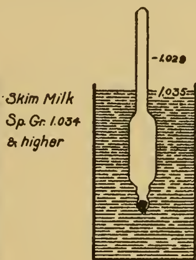


Fig. 14.

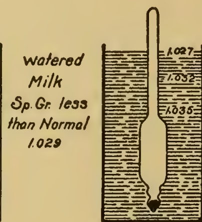


Fig. 15.

in the test by 1.2. Divide the gravity number by 4. To the sum of the two results add 0.14.

Example.—A milk tests four per cent. fat, and has a specific gravity of 1.032. Hence the gravity number is 32. $4 \times 1.2 = 4.8$. $32 \div 8 = 4$. $4.8 + 8 + 0.14 = 12.94$ per cent. solids. This milk contains approximately 12.94 per cent. solids.

This is Hehner and Richmond's formula. This formula has been found by comparison with chemical analysis to be one of the most accurate simple formulas in use.

Babcock's formula for determining the total solids, and the solids not fat, is accurate and useful. The formula is as follows:

$$\text{Solids not fat} = \frac{L + 0.7f}{3.8}$$

$$\text{Total solids} = \frac{L + 7f}{3.8}$$

L = reading of Quévenne's lactometer at 60° F., and f = per cent. of fat.

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CHAPTER VI.

Chemistry of Butter-Making.

41. Composition of Cream.—Cream is quite variable in composition. It ranges in fat content from ten to sixty per cent. Cream is known as thick or thin according to the amount of fat which it contains. Average cream contains from twenty to twenty-five per cent. fat, and has about the following composition:

AVERAGE ANALYSIS OF TWENTY-FIVE SAMPLES.

	Per cent.
Water	66.41
Solids	33.59
Fat	25.72
Casein and albumin	3.70
Milk sugar	3.54
Ash	0.63

As a rule about eighty to ninety per cent. of the solid matter of cream is fat. Cream contains casein, albumin, ash, and milk sugar, the same as milk, but in smaller proportions.

One hundred pounds of milk will produce from fifteen to twenty pounds of cream, depending upon the way in which the cream is obtained and upon the composition of the milk used.

42. Testing Cream.—In testing cream, special bottles with a bulb in the stem to accommodate the extra fat, as shown in the figure, can be used in the same way as ordinary test-bottles. The cream test-bottles are in every way capable of taking the place of the "oil-test" and will be found to give more reliable results. In testing cream the utmost care should be used to obtain a fair sample. Rinse the pipette with a little warm water so as to get all of the cream. The cream can be measured into the test-bottles by the cream gatherers, while the cream is still sweet. It is a very difficult matter to sample old and lumpy cream. The test-bottles for cream can be obtained from the supply houses which deal in chemicals and glassware.

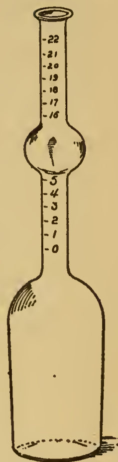

Fig. 16.

The cream should contain at least ninety-seven per cent. of the total fat in the milk. When the cream, obtained by the separator contains less than ninety-five per cent. of the total fat there is too great a loss of butter-fat. Separator cream differs in no essential way from the cream obtained by the gravity process.

43. **Loss of Fat in Butter-Making.**—In butter-making the loss of the butter-fat is one of the most important matters to consider. The greatest loss of butter-fat occurs in the skim-milk. There is a total loss of four or five times more fat in the skim-milk than in the buttermilk. Hence the necessity for the best methods of creaming and the observance of the requisite conditions for obtaining the cream.

The three methods by which the cream is usually obtained are: shallow setting, cold deep setting, and the separator. When the milk is set in shallow pans and the cream is removed by hand skimming, there may be a loss of fat in the skim-milk, amounting to from one-half to three-quarters of a pound of fat for every hundred pounds of milk used. This loss depends upon a number of conditions, such as the length of time the cow has been in milk, the season of the year, and the temperature of the room where the pans are set. It is possible to do good creaming work with shallow setting, as in pans, but ordinarily the necessary conditions for successful creaming by this method are not observed. For thorough creaming, a low temperature is very essential. The loss by shallow setting may amount to one-fifth or more of the total fat of the milk, or eighty per cent. and less of the fat being recovered in the cream.

In case the milk is set in deep pails which are immersed in water at 40° to 44° F., the loss can be reduced to about two-tenths of a pound of fat for every hundred pounds of the milk used. The skim-milk will then show from two-tenths to four tenths per cent. of fat. A loss of 0.25 per cent. of fat in the skim-milk is equivalent to a loss of five to seven per cent. and more of the total fat, depending upon the richness of the whole milk in fat.

By means of the separator the loss of fat may be reduced to one and one-half or two per cent. of the total fat.

Inasmuch as the creaming of milk by the cold deep setting process is inexpensive and within the reach of every one, it might be well to briefly state the main points of the process. When the milk is set in pails, twenty inches deep and eight inches or so in width, and the pails are placed in a trough or tank of ice water, creaming begins immediately. The milk first becomes poorer in fat at the bottom of the can, where the temperature is first lowered to the greatest extent. Within fifteen minutes after the milk is set, the temperature of the milk in the bottom section of the can will drop to 40° and will contain less fat, the fat having passed into the upper layers. The middle section of milk is next effected, and during the entire time of creaming it has an intermediate temperature and fat content.

The creaming action goes on very rapidly for the first

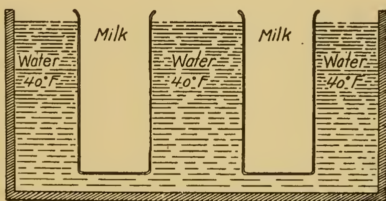

Fig. 17.

six hours when the temperature of the water is kept down. If the temperature of the tank water is not sufficiently low, below 44°, the creaming action is much slower and the milk finally becomes "clogged," and there is a heavy loss of fat in the skim-milk.

The temperature of the water at the time the milk is set is of far more importance than the temperature of the milk. A difference of 10° in the temperature of the milk when it is set does not appreciably effect the thoroughness of the creaming, while a difference of 5° in the tank water seriously affects the creaming. When a cow is fresh in milk and the temperature of the tank water is kept down to 44° or lower, the skimming can safely be done in twelve hours, provided the pails are needed for the next milking, otherwise twenty-four hours should be allowed for the creaming. A slight gain can be obtained from a prolonged setting, but in no case will this equal the loss sustained for the want of a low temperature at the beginning A prolonged setting can not make up for the want of a low temperature at the time of setting.

For the purpose of comparison, figures are given, showing the rate of creaming of two milks, one under good and the other under poor conditions:

		Good conditions. Tank water 40° Per cent.	Poor conditions. Tank water 60° Per ceut.
Fat in milk		5.00	4.45
Top below 4 inches	30 minutes	4.60	4.40
Middle	" "	4.45	4.40
Bottom	" "	3.40	4.40
Top	1 hour	4.00	4.30
Middle	"	3.85	4.30
Bottom	"	1.30	2.92
Top	2 hours	3.30	3.90
Middle	"	2.10	3.90
Bottom	"	0.75	2.40
Top	5½ hours	1.40	3.00
Middle	"	1.00	2.90
Bottom	"	0.35	2.18
Top	10 hours	0.40	2.52
Middle	"	0.30	2.40
Bottom	"	0.15	1.40
Average fat in skim-milk		0.25	1.40

Observe how much more slowly and incompletely the cream rises in the can set at 60°. Notice also the greater loss of fat in the skim-milk.

44. Losses of Milk Fats in Butter-Making.—When 100 pounds of milk are creamed, about eighty pounds of skim-milk and twenty pounds of cream are obtained. If the milk tests about four per cent. fat, and the cream is carefully churned, it will make about 4.60 pounds of butter. The following table shows how the various constituents of 100 pounds of milk are distributed when the milk is made into butter. With poor work, of course, a much smaller amount of fat is recovered in the butter, and more is lost in the skim-milk and buttermilk.

DISTRIBUTION OF MILK SOLIDS IN BUTTER-MAKING.

		Products from 100 pounds of milk.			
	100 pounds of milk.	Cream 20.	Skim-milk.	Butter.	Butter-milk.
Total solids.......	13.00	5.18	7.82	4.00	1.18
Fat...............	4.00	3.88	0.12	3.83	0.05
Casein, albumin ..	3.50	0.50	3.00	0.10	0.40
Sugar and acid....	4.75	0.75	4.00	0.05	0.70
Ash	0.75	0.05	0.70	...	0.03

The four pounds of solid matter recovered in the butter, which contains 3.83 pounds of fat, together with the salt and water which the butter contains, will make about 4.6 pounds of marketable product.

About ninety-six per cent. of the total fat of the milk is recovered in the butter. About three times more fat is lost in the skim-milk than in the buttermilk. Nearly ninety per cent. of the casein and albumin, and eighty-five per cent. of the milk sugar find their way into the skim-milk. The buttermilk is composed of constituents present in the cream, minus what has been removed in the butter. About seven per cent. of the ash of the milk goes into the cream. The buttermilk contains about ten per cent. of the original casein and albumin and about fifteen per cent. of the milk sugar. The composition and comparative food value of skim-milk and buttermilk will be considered in another part of this work.

With poor butter-making the amount of casein and foreign matter left in the butter is increased. A large amount of water and foreign matter left in the butter greatly decreases its keeping qualities, because fermentation can then proceed more rapidly than when these substances are not present. Pure fat ferments very slowly; with water and casein present, the fermentation is more rapid.

45. **Churning.**—In churning, the massing together of the fat is supposed to be due to the hardening of the fat globules; the globules lose their spherical form and appear as masses which are irregular in shape and have sharp angles. Ordinarily the fat globules are spherical, and the surface tension prevents their massing. When of angular form, the fat particles are more easily united. The large globules unite first into larger masses. The smaller globules are the last to assume irregular forms and to mass together. The agitation of churning aids the combination of the irregular masses. The agitation causes a change of the fat globules from a liquid to a solid condition. This is entirely a physical change and will take place only at the right temperature. Frozen

milk or cream churns very easily because then the globules are irregular in form and are in a solid condition, but the churning is not so complete as at a higher temperature.

The ripening of the cream is supposed to aid in rendering less resistance to the massing of the fat globules. When the cream is well ripened, the serum is reduced in specific gravity, because the casein is coagulated by the acid formed in ripening and the surface tension is thereby decreased.

The temperature of churning depends upon (1) the ripeness of the cream, and (2) size and character of the fat globules. Sweet cream churns between 50° and 55°; sour cream from 58° to 68°. Mixing sweet and sour cream is not a good practice, it being preferable to have the cream all of the same degree of ripeness, for then the butter comes more evenly and there is no overchurning of a part of the butter. The more advanced the period of lactation the smaller the globules and the higher the temperature necessary for churning.

46. The Composition of Butter.—The composition of twenty samples of butter analyzed at the Minnesota Experiment Station, is given in the following table:

	Average. Per cent.	Highest. Per cent.	Lowest. Per cent.
Water	12.00	16.20	8.21
Fat	85.00	90.20	79.42
Ash and salt	2.25	3.09	0.44
Casein and milk sugar	0.75	2.09	0.21

Butter should contain not more than fifteen per cent.

water, nor less than eighty-three per cent. fat. The amount of water that can be retained in butter depends upon the ripeness of the cream, temperature of churning, washing and working of the butter. Sweet cream butter will usually retain more casein and water than butter made from sour cream. The effects of different temperatures of churning, working and washing upon the amount of water left in the butter is illustrated in the following table :

Name of cow.	Per cent. water in butter.	Temperature of Churning.	Washing.	Working.
Beckley	8.95	66	59	59
Bess	9.75	64	54	56
Bess	8.52	62	59	59
Houston	10.22	64	55	59
Houston	10.44	63	53	59
Maria	9.75	64	55	58
Olive	9.25	62	56	58
Olive	8.71	62	56	60
Sully	8.22	62	60	62
Sweet Briar	10.42	64	55	58
Sweet Briar	8.80	..	62	63
Topsy	9.06	62	59	63
Topsy	8.00	64	58	62

It appears that the higher the temperatures reached in either churning, washing or working, the less the amount of water retained in the butter. The warmer the butter, the more easily it parts with its water, and the more thoroughly is the water worked out.

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CHAPTER VII.

The Chemistry of Cheese-Making.

47. The Nitrogenous Compounds of Milk. — The casein and albumin in milk are nitrogenous compounds and are sometimes spoken of as the proteids of milk.

The compounds previously considered as sugar and fat, contained only carbon, hydrogen and oxygen, and they are sometimes called the non-nitrogenous compounds of milk, because they contain no nitrogen. The nitrogenous compounds are those that contain the element nitrogen, and in some cases other elements together with carbon, hydrogen and oxygen. Casein and albumin are the two most important nitrogenous compounds in milk. These proteids, as they are sometimes called, are alike in their general composition, but differ in the number of their building materials or elements, and the way in which they are combined. The proteids or protein compounds are the general class, while the casein and albumin are each distinct representatives of a separate sub-class. In addition to casein and albumin there are smaller amounts of other milk proteids present, as well as smaller amounts of other nitrogenous compounds which are not proteids. For dairy purposes it is necessary to consider the main chemical and physical properties of each group, because they illustrate, to a great extent, the underlying principles of cheese-making.

48. Casein.—When milk is fresh, the casein is in a semi-soluble form, but as soon as a sufficient amount of lactic acid is formed by the fermentation of the milk sugar, curdling results, or more correctly speaking, the lactic acid precipitates the casein.

Many other acids like acetic acid (the acid in vinegar) hydrochloric acid and sulphuric acid, will produce the same result; that is, precipitate or throw down the casein.

The point to be noted is: Dilute acids added to milk in small amounts, precipitate the casein, but they do not precipitate the albumin. In precipitating the casein a part of the acid unites with the casein. Some of the ash of the milk is also combined and precipitated with the casein.

49. Albumin.—After milk has fully soured it will separate into a watery portion, whey, which contains the albumin and milk sugar, and a coagulated portion that includes the casein and fat. When this liquid or whey is poured off or filtered, and the clear solution boiled, a flake-like, yellowish-white substance will be observed, which is the albumin. The albumin may also be obtained by taking a sample of milk, adding a few drops of acetic acid, or strong vinegar, to the milk, so as to coagulate the casein, and then, after thorough mixing, filtering. The clear filtrate (filtered liquid) is heated to 157° F., when the solution turns white, due to the coagulating of the albumin. The acid that forms when the milk sours does not separate the albumin, but it does separate the casein. The albumin in milk is coagulated at 157° to 161° F.

The leathery, skin-like mass, that forms on milk when it is boiled, is albumin.

According to Blyth, there is a constant ratio between the albumin and casein in normal milk. In cheese-making, by the ordinary process, the albumin is not recovered. Albumin is coagulated by a number of chemicals, as mercuric chloride and lead acetate, both of which are poisons.

50. Rennet.—In cheese-making, the casein is coagulated by rennet. Rennet is prepared from the membrane or lining of the fourth stomach of the calf. Rennet contains various digestive fluids and organisms, chief among them being the peptic and lactic ferments from the gastric juice. Rennet imparts to the milk (1) lactic, peptic and other ferments, (2) acids produced by the ferments. In cheese-making it would not be practicable to allow the milk to become sour and curdle from prolonged fermentation, because objectionable ferments would then form in the milk along with the desirable ones. The action of rennet on milk is similar to the action of weak or dilute acids which coagulate the casein combined with the power possessed by the digestive ferments that are found in the rennet and which serve to ripen the cheese.

The temperature at which the rennet is added, 86° to 90° F., is very favorable for the full development and digestive action of the various ferments, introduced along with the rennet.

51. Rennet Test.—In cheese-making the rennet test is employed to determine when the milk is in the proper condition for adding the rennet. The test is made in the following way: Five cc. of rennet extract is put into a flask and water added until the solution measures fifty cc.; it is then thoroughly mixed. A small cup with a mark on the side, 140 cc., is floated in the center of the milk vat. The cup is filled to the mark with milk from the vat. Five cc. of the diluted rennet is then added to the milk in the cup and thoroughly stirred. The milk in the cup is closely observed, and when a knife is drawn from the milk and the proper signs of coagulating observed, the time required for curdling is noted. If the milk requires more than sixty seconds for coagulating, it is not ripe enough to add the rennet. The milk is then allowed to ripen farther or more starter is added. If milk shows signs of coagulating in less than forty-five seconds, it is over-ripe. The riper a milk is, the shorter the time required for the process of making, and the result is a quick-curing cheese.

The ripeness of the milk, as shown by the rennet test, has a great deal to do with the ripening of the cheese. The ripening of the curd in the vat also influences the ripening and keeping qualities of the cheese.

52. The Hot Iron Test is employed to determine the degree of ripeness of the curd. As soon as the casein is precipitated, or as the factory man would say, as soon as the curd has set, the rennet causes other chemical and bacteriological changes to begin, similar to the first stages of the digestion of the food in the stomach. The curd changes from a hard leathery mass to a soft, stringy consistency. The change is carefully watched by the cheese-maker, who uses for this purpose the hot iron test.

When the little threads, as shown by putting a piece of curd against the hot iron and then withdrawing it, are an eighth of an inch in length, the whey is usually drawn off, and the curd is allowed to digest still farther until the threads are about one-fourth of an inch long, when the process is stopped by grinding and salting the curd. The ferments that were added in the rennet are the agents that carry on this work. The ripening of the cheese for market is simply a continuation by the rennet ferments of this digestive process, in the curing room. Heavy salting checks the ripening process simply because the ferments can not thrive in a strong salt solution. The stringing on the hot iron is not due to the acid that is formed, but is simply due to the digestive process having reached that stage where the hot iron will show threads an eighth to one-fourth of an inch long.

53. Notes on the Process of Cheese-Making. — In order to discuss this subject it will be necessary to briefly review the more important operations of cheese-making.

The milk when it is received should be carefully weighed and a two-ounce sample taken for testing. The condition of the milk when received should be carefully noted, because a little foul milk when mixed with a large amount of good milk, will spoil all of the good milk. The taste and smell of the milk should also be noted. Tainted or bad flavored milk cannot be made into a good cheese.

The milk, after it is received and weighed, is run into the vat and thoroughly mixed. The steam is turned on, or the milk is otherwise heated in the vat until a temperature of 86° to 88° is reached. The milk should be heated gradually and stirred to prevent the separation of the fat or the unequal heating of the milk. When the milk reaches the desired temperature, 86° to 88°, the rennet test is applied. See Section 51. If the milk is found to be in the proper condition, the remainder of the rennet is added at the rate of three to five ounces of rennet per 1,000 pounds of milk. The rennet is added to a dipper nearly filled with water at 86° F. and then thoroughly mixed with the milk in the vat. When the milk is rich in fat, it is set at the higher temperature, and the larger quantity of rennet is used. The temperature of setting and the quantity of rennet depend upon the season of the year, the temperature of the room, conditions of the milk, and the time when the cheese is to be ready for market. These are factors that cannot be determined by rules, but must be known and carefully followed by the cheese-maker.

After the rennet has been added and thoroughly mixed, the milk is allowed to remain quiet, and the vat is covered until the curd is well formed. When the index finger can be removed from the curd so that the curd will break square across the finger, the mass is in the proper condition to be cut with the cutting knife into little cubes. After cutting, the mass is gently stirred with the hands for about five minutes, and as soon as the curd is in the proper condition, the temperature is gradually raised about 2° every five minutes until the thermometer shows 102°. With different kinds of milk different temperatures will be required. The stirring is to be continued at intervals until the particles will no longer mass and pack.

As soon as the curd shows the proper signs of ripening, with the hot iron test, the whey is drawn off. The curd packs into large masses, which are cut into blocks and are occasionally turned so that an even temperature will be maintained. When the threads on the hot iron are of the desired length, the curd is ground and salted and returned to the vat, and after another short stage of digestion it is put into molds and pressed. After pressing it is weighed, branded and taken to the curing room.

Two types of milk should be followed through the process. The following blank is used in making the entries required :

CHEESE REPORT.

Size of vat.
Condition of fat.
Pounds of milk in vat.
Per cent. of fat in milk.
Rennet test for ripeness.
Temperature of milk when set.
Amount of rennet used.
Rate of rennet per 1,000 pounds of milk.
Time cut.
Minutes in curdling.
Time heat is applied.
Time required to raise to 102°.
Hot iron test when dipped.
Time dipped.
Time from cutting to dipping.

Pounds of whey.
Per cent. of fat in whey.
Time ground.
Hot iron test when ground.
Time salted.
Amount of salt in curd.
Rate of salt per 1,000 pounds of milk.
Time put to press.
Time dressed.
Time pressed.
Weight of green cheese.
Weight of milk per pound of cheese.
Weight of milk per pound of cured cheese.
Remarks.

54. Where the Milk Solids Go in Cheese-Making.— As previously stated, a hundred pounds of milk ordinarily contain from 12.5 to 13 pounds of dry solid matter. This solid matter is composed of three and one-half to four pounds of fat, 3.25 to 3.75 pounds of casein and albumin, 4.75 pounds of milk sugar, 0.75 pound of ash, and at the time the rennet is added there is about 0.16 of a pound of lactic acid.

When the whey and drippings at the cheese press are analyzed, it will be found that nearly half of the solid matter of the milk is recovered in the dry matter of the cheese. Of the three to four pounds of fat in the milk, from one-quarter to one-third of a pound is lost in the whey, which amounts to from five to ten per cent. of the total fat. In good cheese-making there is about the same loss of butter-fats as in ordinary butter-making, but a greater loss than with good butter-making. The casein and albumin are not so economically recovered as the milk fats. The whey shows a loss of 0.75 to 0.90 of a pound milk proteids for every 100 pounds of milk used. This loss is mainly albumin, which is not coagulated by the rennet. But little of the milk sugar is retained in the cheese; out of the 4.75 pounds of milk sugar in the 100 pounds of milk used, from four and three-tenths to four and six-tenths pounds are recovered in the whey.

The solid matter in the cheese is composed mainly of fat and casein. When the fat in the milk is increased, the amount of fat in the cheese is also proportionally increased. With poor making this increase of fat in the milk may very easily be lost.

The following types of milk are given to show where the various constituents of milk go in the process of cheese-making:

EXAMPLE No. 1.

	100 pounds milk.	From 100 pounds of milk. Loss in whey.	Recovered in cheese.
Water, lbs	87.52	80.97	3.65
Solids "	12.48	6.23	6.25
Ash "	0.80	0.52	0.28
Fat "	3.50	0.30	3.20
Casein and albumin, lbs.	3.22	0.84	2.38
Milk sugar, lbs	4.80	4.35	...

EXAMPLE No. 2.

Water, lbs	86.79	80.89	3.59
Solids "	13.21	6.11	7.11
Ash "	0.64	0.40	0.24
Fat "	4.00	0.34	3.66
Casein and albumin, lbs.	3.71	0.81	2.90
Milk sugar, lbs	4.50	4.30	...

MILK WITH CREAM ADDED.

Water, lbs	85.87	76.01	4.56
Solids "	14.13	5.69	8.44
Ash "	0.77	0.42	0.35
Fat "	6.00	0.49	5.51
Casein and albumin, lbs.	3.12	0.52	2.60
Milk sugar, lbs	4.13	4.00	...

SKIMMED MILK.

Water, lbs	87.80	80.80	3.00
Solids "	12.20	6.19	6.01
Ash "	0.80	0.31	0.49
Fat "	2.75	0.34	2.41
Casein and albumin, lbs.	3.95	0.82	3.13
Milk sugar, lbs	4.55	4.45	...

The amount of cheese that can be made from 100 pounds of milk depends upon (1) the skill of the maker, (2) the amount of water left in the cheese, and (3) the composition of the milk used, The richer a milk in fat the greater is the amount of cheese produced per pound of milk. Experiments illustrating this point are to be found in Bulletin No. 19, Minnesota Experiment Station, from which the following is taken :

No. of trials.	Range of fat. Per cent.	Pounds milk to make pounds cheese.	Fat recovered in cheese. Per cent.
28	3.5—4.0	9.68	91.69
31	4.1—4.6	9.30	92.77
14	4.7—5.1	8.90	92.86
4	5.1—6.0	8.56	94.46

COMPOSITION OF CHEESE MADE FROM DIFFERENT MILKS.

	No. 1. 3.50 per cent. fat	No. 2. 4.00 per cent. fat.	No. 3. Creamed milk. Per cent.	No. 4. Skim-milk. Per cent.
Water	34.29	31.4	32.43	30.68
Fat	33.76	35.3	43.55	27.09
Casein and albumin.	24.47	27.7	20.00	36.00

Observe that in a cheese made from normal milk the amount of fat always exceeds the amount of casein and albumin. In the case of the skim-milk, when only a small part of the fat is removed from the milk, it is to be observed that the fat in the cheese is then *less* than the casein and albumin. Hence the difference in composition between whole-milk and skim-milk cheese: the per cent. of casein is less than the fats in whole-milk cheese, while in skim-milk cheese the per cent. of casein is greater than the fat.

The richness of a sample of cheese in butter-fat can be approximately determined with the Babcock test, aided by a delicate pair of scales.

55. Testing Cheese by the Babcock Milk Test.—If the cheese is cut, obtain a number of small pieces from different parts of the cheese. If it is not cut, take four "plugs" from different parts of the cheese. With a sharp knife and in a cool room, cut the cheese into small pieces about the size of wheat grains. Then, on a pair of well-balanced scales, weigh out five grams of cheese. In the absence of gram weights, use a five-cent piece which weighs just five grams. Then introduce the five grams of well mixed cheese sample into a test-bottle by means of a paper funnel. Add about ten or twelve cc. of hot water, and shake well so as to thoroughly break down the cheese. Add a little more water, five cc., and mix. Complete the test in the usual way as for milk testing.

In order to get the per cent. of fat in the cheese, it is necessary to multiply the per cent. of fat found by the test by 3.6, because the test-bottles are graduated for eighteen grams and only five grams have been used. If the per cent. of fat in the cheese falls much below thirty-two per cent., the cheese has not been made from normal milk.

56. Testing Whey.—In the making of cheese, both the whey and the drippings from the cheese press should be frequently tested for fat so as to determine whether there has been any unnecessary loss of fat. In testing whey, the special bottles made for testing skim-milk may be used. It is not necessary to use 17.6 cc. of acid because the casein has been removed from the milk, and the acid has less work to do. Use about eight cc. of acid.

57. The Ripening of Cheese is a continuation of the digestion process which was started in the vat by the rennet ferments. The length of time required for curing, and before the cheese is ready for market, ranges from two months to a year or more, depending upon the conditions of making and curing.

FACTORS WHICH PRODUCE A LONG-KEEPING CHEESE.

1. Rennet test showing milk to be only moderately ripe. Rennet test 50 to 60.
2. Smaller quantity of rennet and lower temperature of milk.
3. Hot iron test, short threads.
4. Heavy salting.
5. Heavy pressing.
6. Lower temperature of curing-room and lower temperature for ripening.

Factors Which Produce a Quick-Ripening and Early Market Cheese.

1. Rennet test showing milk to be over-ripe. Rennet test 45 to 50.
2. Large quantity of rennet and higher temperature of milk.
3. Hot iron test, long threads.
4. Light salting.
5. Moderate pressing.
6. Higher temperature of curing-room and more rapid ripening.

In making cheese it is sometimes necessary to balance these factors. An over-ripe milk may be given some of the treatment for producing a long-keeping cheese, such as heavy salting and slow curing, which will neutralize the effects of the over-ripe milk.

When a milk is rich in fat, a larger quantity of rennet is used and the milk is set at a higher temperature.

The two most essential conditions for curing cheese are: uniform temperature and a certain amount moisture in the air. All fermentation actions are the most complete when the range of temperature is between narrow limits. A high temperature is unfavorable to some of the ferments. Sudden changes in temperature destroy the vitality of the ferments.

The atmosphere of the curing-room should contain from eighty to ninety-five per cent. of water. The amount of water in the air is determined by the hygrometer, which is easily made. Two thermometers are fastened to a board. One is known as the *dry* bulb thermometer, the other one as the *wet* bulb thermometer. A piece of woolen cloth, *c*, wrapped around the bulb of the thermometer leads to the cup of water, *w*. The cloth is kept wet by capillarity. When the air is saturated with water, the dry bulb and wet bulb thermometer readings are the same. When the air is not saturated, the wet bulb thermometer shows a lower temperature. The greater the difference in temperature between the two thermometers, the smaller the amount of moisture in the air. The amount of water in the air is determined from the table.

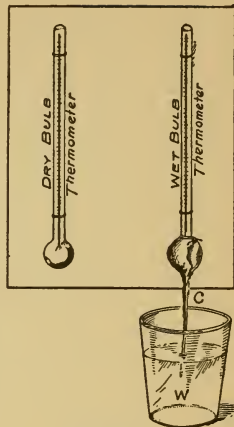

Fig. 18.

Dry bulb thermometer.	Difference between the two thermometers.	Per cent. moisture.
55°	0	100
55	1	93
55	3	81
55	5	67
60	1	93
60	3	83
60	5	70
65	1	94
65	3	84
65	5	73
70	1	94
70	3	85
70	5	74
75	1	95
75	3	86
75	5	75

There should never be a greater difference than 3° between the dry bulb and wet bulb thermometer readings. Before taking the wet bulb reading, fan away the air from around the thermometer and bulb, because the air near the thermometer may not be the same as the air of the room.

58. Paying for Milk by Test in Cheese Factories.— The paying for milk on the basis of the fat which it contains, as determined by the test, is more accurate than the usual way of paying by weight. When the milk tests between three and four-tenths, and four and one-tenth per cent. fat, the amount of cheese made from the milk is practically proportional to the amount of fat present in the milk. Inasmuch as average milk tests between these two points, the test can be used, because the butter value and the cheese value of the milk are practically the same. When the milk is poor in fat, a pound of milk fat produces more cheese.

The richer milks produce, as a rule, better cheese which commands a higher price than the cheese made from poorer milks. One pound of milk fat will make, on the average, about two and six-tenths pounds of cured cheese, depending upon the richness of the milk in fats.

When the milk tests	One pound of fat makes
3.2 per cent. fat	2.8 pounds cheese.
3.4 " " "	2.7 " "
3.6 " " "	2.6 " "
3.8 " " "	2.6 " "
4.1 " " "	2.5 " "
4.5 " " "	2.4 " "

The fat test should be used in cheese factories for the making out of the dividends, the same as in the creamery. In order to calculate approximately the amount of cheese that can be made from a certain amount of milk, it is first necessary to determine the total fat in the milk and then to multiply by the amount of cheese that can be made from one pound of fat of that kind of milk.

Exercise.—5000 pounds milk testing 3.6 per cent. fat $= 5000 \times 0.036 = 180$ pounds fat. As: 1 pound of fat in 3.6 per cent. milk will make 2.6 pounds cheese; hence, $180 \times 2.6 = 468$ pounds of cheese produced from 5000 pounds of 3.6 per cent. milk.

59. Comparative Amounts of Butter and Cheese Made from the Same Milk.—Using this as an example, it is an easy matter to calculate the comparative gross proceeds from the sale of cheese and butter, at current market prices.

As a rule, one pound of fat will make about a sixth of its weight more of butter, because of the water which is added to it in making. In order to get the butter equivalent from the total fat, add one-sixth to the weight of fat taken, as: $180 \div 6 = 30$; $180 + 30 = 210$; or 180 pounds of fat will produce about 210 pounds of butter. If the butter sells at eighteen cents and cheese at eight cents per pound, the gross proceeds from the butter will be $37.80 and from the cheese $37.44.

Instead of using the factors as given here, the cheese-maker or the butter-maker should use the factors obtained from his own work. A butter-maker finds from his records that

One week,		484	pounds	fat	by	test	make	581	pounds butter.
"	"	612	"	"	"	"	"	732	" "
"	"	316	"	"	"	"	"	370	" "
	Then	512	"	"	"	"	should make ?	"	"

In three weeks 1412 pounds of fat produced 1683 pounds butter, or one pound of fat produced 1.19 pounds butter, or one pound of butter is made from 0.83 pound of fat. The 512 pounds of fat would then make about 609 pounds of butter.

In making out the dividends in either the cheese factory or the creamery, the calculations should all be made entirely upon the basis of the total fat and the net proceeds. The total amount of fat found by test is sold in the form of butter or cheese for a certain sum of money. After deducting the cost of making, etc., the net receipts for so many pounds of fat are to be divided among the patrons according to the amount of fat which they have brought to the factory or creamery.

Every pound of fat found by test is then worth a certain amount of money.

Exercise.—Make out the following dividends, first on the basis of the total fat, and second, by the total weight only.

Patron.	Pounds milk.	Fat found by test.	Dividend. Test.	Dividend. Weight.
1	1512	4.0	——	——
2	1700	3.6	——	——
3	1200	4.8	——	——
4	2100	3.4	——	——
5	1400	4.5	——	——

370 pounds of butter are produced. The butter is sold for eighteen cents per pound. Cost of making, etc., $7.50.

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CHAPTER VIII.

Ash and Miscellaneous Compounds in Milk.

60. Ash of Milk.—The ash of milk, as previously stated, is that portion of the milk solids which cannot be converted into smoke or volatile products by burning. The fat, casein and milk sugar are substances that will burn, and they are called organic compounds, while the ash, which is the product left from burning, is called the mineral or inorganic portion.

One hundred pounds of milk will yield about 0.75 of a pound of ash, which is composed of:

	Per cent.
Potash	21.11
Soda	8.08
Lime	24.19
Magnesia	2.57
Iron oxide	0.34
Phosphoric acid	32.11
Sulphuric acid	2.16
Chlorine	8.51

The most abundant compounds in the ash of milk are: Phosphates of lime, potash and common salt.

The ash of milk supplies materials for bone growth, such as bone phosphate of lime.

61. Citric Acid in Milk.—In milk, the lime is combined largely with citric acid and forms citrate of lime. Citric acid is the same acid or sour principle found in lemons. The taste of citric acid in milk is not observed because of its combination with the calcium. There is about one-tenth per cent. of citric acid in milk. About as much citric acid as is found in a good-sized lemon, is present in a quart of milk. The presence of this acid in milk was recently discovered by Henkel. How it is produced and the part it takes in dairy operations are not known.

62. Colostrum Milk.—The milk given by a cow for the first three or four days after calving is quite different in color, taste, and appearance from milk in its normal condition. Such milk is called colostrum milk, and has a different chemical composition from ordinary milk. Colostrum milk has a yellow color and a sweetish taste and a characteristic oily feeling. It coagulates on boiling on account of the large amount of albumin which is present. Pour hot water into colostrum milk and it curdles. Colostrum milk has a higher specific gravity than normal milk, frequently reaching 1.064.

COMPOSITION OF COLOSTRUM MILK.[1]

	Per cent.
Water	71.50
Solids	28.50

Solids contain:

	Per cent.
Fat	6.04
Casein	3.50
Albumin	12.67
Sugar	4.85
Ash	1.35
Undetermined	0.09
	28.50

[1] Analysis made by the author.

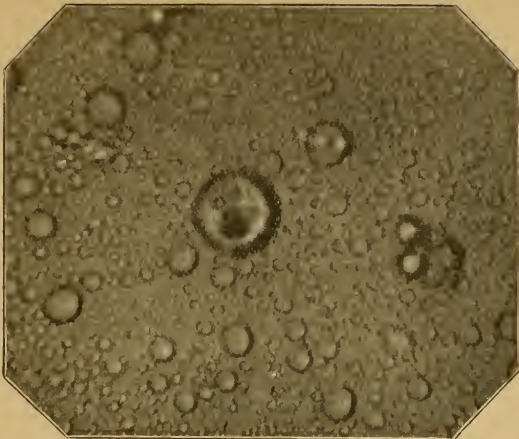
The term colostrum is used because of the presence of circular bodies in the milk, larger than the fat globules, and known as colostrum cells. These colostrum cells are similar in structure to white blood corpuscles, from whence it is supposed they are derived. When examined under the microscope, while the milk is still warm, they will produce the amoeboid movement, common to white blood corpuscles.

These colostrum cells begin to make their appearance in milk about a week before the calf is born. Four or five days after calving the albumin decreases and the milk gradually reaches its normal condition. The colostrum acts as a purge upon the young calf.

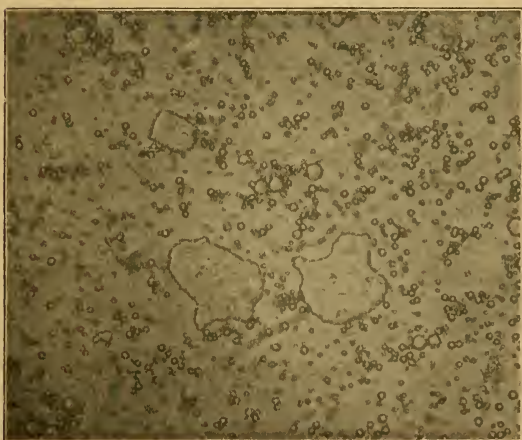
The creaming of colostrum milk is very imperfect on account of the albumin which is present in such large quantities. Colostrum milk should never be mixed with other milk, because it will prevent creaming by clogging the separator as well as produce an inferior product.

In cheese-making, colostrum seriously interferes with the curing and keeping qualities of the cheese. Colostrum is not so objectionable, for sanitary reasons, as it is on account of its affecting the quality of the products.

63. **Tyrotoxicon** is a poisonous chemical compound which is sometimes found in stale milk and old cheese. The tyrotoxicon, when separated and examined with the microscope, appears in long needle-shaped crystals. This poisonous compound is produced by bacteria, and is a ptomaine, or poisonous compound formed from decomposing animal matter. When tyrotoxicon is present in milk in small quantities it produces diarrhoea,



Colostrum Cells in Cow's Milk × 300.



Detached Membranes in Colostrum Milk × 150.

and symptoms similar to those of cholera. It proves fatal when injected into the veins of small animals. This is the material which causes the trouble from eating old cheese. It is most apt to be present in the rind. The tyrotoxicon is sometimes developed in ice-cream. When the cream becomes old and when gelatin is used the conditions are favorable for its formation. The so-called ice-cream poisoning is due to this compound.

Inasmuch as this material is produced by bacteria which feed upon decomposing products, the utmost cleanliness is absolutely necessary to prevent its forming. It is the tyrotoxicon which causes the scouring of calves and pigs. Hence, keep the whey and skim-milk barrels clean.

64. **Urea in Milk.**—When muscular tissues of the body are broken down, a part of the waste materials are separated and carried off by the kidneys, in the form of urea, a white crystalline compound dissolved in the urine. There are traces of this compound in nearly all of the fluids of the body. It is present in milk to the extent of 0.001 per cent., and any more than this amount is due to some diseased condition of the animal.

65. **Fibrin in Milk.**—Another nitrogenous compound, present in milk, is fibrin, the compound present in blood which forms the "clot." The best proof of the presence of fibrin in milk is the microscopic appearance of the fat globules. It has previously been stated that the fat globules always appear in little groups or colonies. It is supposed that the globules are held together by the bands or meshes of fibrin and are

thus prevented from coming to the surface in the gravity creaming process. The amount of fibrin in milk is about the same as that of urea, 0.001 to 0.0001 per cent. Fibrin is produced by the action of the fibrin ferment. The chemical proofs for the determination or even the detection of its presence in milk, are very unsatisfactory. In Bulletin No. 29, Cornell Experiment Station, it appears from the tests that the amount of fibrin in milk from cows advanced in their lactation period is not related or proportional to the thoroughness of the creaming of milk by the gravity process.

66. Gases in Milk.—The gases which are dissolved in milk as it comes from the cow are: Nitrogen, oxygen, and a small amount of carbon dioxide. The nitrogen and oxygen are dissolved in the milk in about the same proportion as in pure spring water. When milk gets older, the oxygen in the milk decreases and the carbon dioxide increases. The carbon dioxide is the same gas that is given off in respired air; the oxygen in the milk has been used up to form carbon dioxide.

At the end of four or five days ninety per cent. of the gas in milk will be carbon dioxide. There is always more gas in old than there is in fresh milk. When the milk becomes saturated with gas, the gas is given off. When the gas escapes from the surface of cream or thick milk, it leaves small holes on the surface. When milk or a starter shows these openings, sometimes called "eyes" by the cheese-maker, it will cause much trouble if used for cheese-making.

In addition to carbon dioxide, other gases of a different character may be present in milk and cause the curd to float: such as hydrogen, which is given off in butyric acid fermentation, and also derivatives of the marsh gas series of gases.

The gases in milk are a part of the products produced by bacteria, and hence the milk may cause trouble, not only from the gases present, but also from the bacteria.

67. The Color of Milk.—The color of milk is imparted by a chemical compound, and is not due to either a high or low per cent. of fat. The coloring matter which imparts to milk its yellow color and also gives the color to butter, whey, etc., is a nitrogenous compound called, by Blyth, lactocrome. The amount of this coloring matter is influenced by the food consumed and also by the special peculiarities of the cow. There is a marked difference in the color of milks from cows fed on the same food. Frequently a yellow tinged milk will show a smaller per cent. of fat than a milk of a lighter shade.

Milk dealers sometimes take advantage of the popular idea in regard to the color of milk as indicating a rich milk, and add a little annatto or other coloring matter to impart the desired yellow tinge.

Butter colors are nearly all made from the seeds of Bixa Orellana and are harmless vegetable materials. The use of butter colors does not come under the head of adulterating butter, because the natural color of butter is yellow and butter without this color is unnatural butter. The public demands a uniform color, hence, in certain seasons of the year, when butter does not possess the requisite color, it is considered justifiable to use butter colors.

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CHAPTER IX.

Dairy Salt and Commercial Problems Relating to Milk.

68. Dairy Salt.—There is great difference in the quality of dairy salt, due both to a difference in chemical composition and to the physical properties of the salt. The salt particles range in size from large blocks, known as rock-salt, to a fine powder that gives a smooth surface when a knife is pressed upon it. The coarse salts are much slower in dissolving and require longer working of the butter to work in the salt, which injures the grain of the butter. Salt that is too fine is also open to as serious objections. If the butter is worked too dry and a large amount of fine salt used, the salt will separate and form a crust on the surface of the butter.

A salt that cakes or becomes quite moist when exposed to the air is not a good salt for dairy purposes. Such a salt usually contains impurities in the form of lime and magnesia. A tablespoonful of salt should dissolve in an ordinary glass of water, when it is well stirred. Any insoluble residue is due to materials not salt. When salt is examined with the microscope the crystals appear as cubes. Sometimes the crystals are not clear, due to impurities in the brine solutions from which the salt was made.

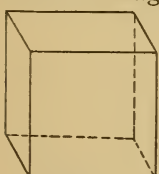

Fig. 19.

In chemical composition salt ranges from 97 to 99 per cent., or more, pure sodium chloride. Impure salt containing lime or magnesia will impart an unpleasant caustic taste to any dairy product. In a good dairy salt the crystals should be clear, neither too coarse nor too fine, with a good taste, and should show no tendency to cake or to become moist, and should be entirely soluble in water.

69. Changes during Transportation.—The effect of transportation upon the chemical composition of milk has also been studied. In court the question is frequently raised, does milk change in composition during transportation, and when milk is peddled in cans does the last purchaser get as much fat in his milk as the first purchaser?

In England very extensive experiments on this point have been made. In one season over 7,000 samples of milk were taken and analyzed at three different times: (1) before the milk was sent out, (2) then again during the delivery, and (3) finally at the end of the route. In another season, 11,000 samples were taken in the same way and analyzed. This work was performed so as to prevent the drivers from watering the milk and making a profit for themselves. The chemical work was done by Dr. Vieth in the interest of a large dairy firm. The average of each season's work was:

AVERAGE OF 7,000 SAMPLES.

	Milk.	Cream.
1. Before starting....	12.75 per cent. solids.	49.0 per cent. fat.
2. During delivery...	12.74 " "	.... " "
3. At close..........	12.81 " "	49.1 " "

AVERAGE OF 11,000 SAMPLES.

1.	Before starting....	12.84 per cent. solids.	48.3 per cent. fat.
2.	During delivery...	12.88 " "	.... " "
3.	At close...........	12.92 " "	48.4 " "

The differences for both seasons are very small. The last milk is equally as rich in solid matter, including fat, as the first milk sold. If it were not, the solids would not be so nearly alike. The variations are no more than would occur through loss of water caused by evaporation.

At the Cornell University Station it was shown that when the milk was taken from the can with a long-handled dipper, the milk was practically of the same composition throughout the entire route. The excuse that the fat separates and is dipped off in the first part of the route, is not a valid excuse for poor milk. If the milk were originally unadulterated it would show itself to be unadulterated through the entire course of delivery.

70. Effects of Delay and Cooling upon Creaming.— When milk is creamed by the cold deep setting process a little delay in setting the milk does not necessarily affect the creaming. It was believed at one time that the very moment the milk was taken from the cow it should be hurried off to the tank. This undue haste is not necessary. With a small herd, it is safe to complete the milking and then put the cans in the tank all at one time. A delay is not advisable because it is not wise to let the milk be about too long exposed to the odors of the barn before putting it into the water tank. Experiments at the Maine and Cornell Experiment Stations have shown that with the mixed milk of the entire herd there is but little loss of fat when the milk has been delayed in its setting for a half to three-quarters of an hour. At the Wisconsin Station the herd was divided into five lots; with three of the lots there was no appreciable effect caused by a delay, but with two lots a delay showed a serious loss of creaming power. When the milk of the five lots was mixed there was but little effect from a delay in setting the milk in water. With some individual cows there may be a loss of fat when the milk is not set immediately, but when the milk of the entire herd is considered there is much less danger of imperfect creaming by a little delay. Unnecessary delays should be avoided, but undue haste is not necessary. With the centrifugal there is no loss of creaming power following a delay, provided the milk is at a proper temperature when separated.

71. Aerating Milk is simply exposing it in fine streams to a pure atmosphere, so as to substitute pure air for the impure air and gas in the milk. When the milk is aerated while warm it materially reduces its temperature, and hence improves its keeping qualities. In case milk is taken to the factory only once a day, aerating is an excellent practice in order to keep the milk sweet. It also improves the quality for cheese-making. In butter-making aerating the milk has not been extensively tried, because it was believed that any delay or cooling of the milk injured the creaming qualities; but, inasmuch as these factors are not nearly so serious as was once supposed, there is no particular reason why aeration cannot be successfully practiced in butter-making. Aerating milk improves its quality, but it does not make a bad milk good.

72. Effects of One Cow's Milk upon that of Another in Creaming.—In case a cow's milk creams imperfectly on account of her being far along in the period of lactation, the creaming is frequently improved by mixing her milk with some from a fresh cow. The test should be used to detect any unusual losses. It is always well to combine the milk from different cows, so that one milk may have a beneficial effect upon another in regard to creaming. The milk test is the only safe guide to follow in each case.

73. Cream Raising by Dilution.—The effect of the addition of hot and cold water on the creaming of milk by the gravity process has received much attention. In the absence of ice the use of water, either hot or cold, has been recommended in order to secure more rapid and perfect creaming. Experiments on this line, conducted in Germany some years ago, showed that the addition of water, either hot or cold, was not a successful practice; in fact, it rather prevented perfect creaming.

Since 1890, extensive experiments conducted in this country have given the same results. At the Cornell University station it was shown that the addition of either hot or cold water under any circumstances, was always followed by heavy losses of fat in the skim-milk; much greater, in fact, than when no water was used.

At one time, the use of hot water was advocated, but later experiments have shown it to be very objectionable. The use of hot water is impracticable, because it produces a rapidly souring cream; in fact, a cream that is over-ripe before it is skimmed, and the result is a very poor quality of butter. Furthermore, diluting milk with water requires additional pails, cans, and vats, which increases the labor. The diluted skim-milk is far less valuable for food.

74. Effect upon the Volume of Cream.—The diluted milk produces a larger volume of cream than the undiluted milk. But the cream from the undiluted milk is more concentrated than the cream from the diluted milk. The addition of water results in the production of a larger volume of thinner cream. In general, it can be said that anything which interferes with the normal creaming of milk results in the production of a larger volume of poorer cream.

Hot or cold water added to the milk does not improve the creaming and it may cause a serious loss of fats. The use of water in gravity creaming is not advisable.

Example.—One hundred pounds of milk undiluted produces eighty pounds of skim-milk testing 0.40 per cent. fat, while, if diluted, 160 pounds of skim-milk yields 0.30 per cent. fat. Loss in undiluted skim-milk 0.32 pounds fat, in diluted 0.48 pounds fat. The increased weight of the skim-milk causes a greater total loss of fat.

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CHAPTER X.

The Sanitary Condition of Cows' Milk and the Milk of other Domestic Animals.

75. The Sanitary Condition of Milk.—The milk given by a diseased cow is generally different in composition from that of a healthy cow. Milk should be fairly constant in composition. When the fat, shown by the test, suddenly rises as high as eight per cent., while usually it is about four per cent., there is something wrong about the cow. Normal health is followed by a fairly constant composition of the milk. Limited variations are to be expected, but not abnormal ones.

MILK FROM COW WITH MAMMITIS.[1]

	Per cent.
Fat	2.80
Casein	4.02
Albumin	0.56
Sugar	5.54
Ash	0.92
Cholesterine	....
Peptones	....
Urea	....

Note the low fat and high casein and sugar.

MILK FROM COW WITH PNEUMONIA.

	Per cent.
Fat	2.96
Casein	3.86
Albumin	0.44
Sugar	3.88
Ash	0.80
Cholesterine	0.58
Galactin	0.09
Urea	0.01

[1] From Blyth: Foods.

Note the low fat and high sugar and casein.

MILK FROM COW WITH TUBERCULOSIS.

	Deposits in lungs.[1] Per cent.	Deposits in udder.[1] Per cent.
Fat	2.77	0.49
Casein	3.65	1.21
Albumin	0.87	2.39
Milk sugar	2.82	0.47
Ash	0.87	0.77

MILK FROM COW WITH INFLAMMATION OF UDDER.[2]

	Per cent.
Fat	1.35
Ash	0.92
Albumin	5.79
Sugar	0.32
Undetermined	1.38
	10.76

The microscope is frequently employed to determine the presence of foreign matters in milk. With inflammation of the udder the microscope shows pieces of detached membranes, which appear as small pieces of meat. Pus and colostrum cells can also be observed with the microscope. Milk from unhealthy cows becomes sour much more readily than healthy milk, when both are subjected to the same treatment. When milk sours very easily and rapidly something is wrong.

The sanitary condition of milk, that is, its quality, is equally as important as its composition. Milk has frequently caused the spreading of germ diseases, such as scarlet fever, diphtheria, and typhoid fever. The germs of these diseases find their way into the milk, which is a perfect food for their nourishment and development,

[1] From Blyth : Foods.

[2] Analysis by author.

and they are then distributed through the milk. The purity of the water supply and the condition of the stables are the two most important factors for the production of good milk. Neither cattle nor other animals should be allowed or compelled to drink stagnant water. In fact, no animal should be given water to drink which we would hesitate about drinking ourselves. Impure water is frequently the cause of the production of unwholesome milk. In the analyses of milk, given on preceding pages, observe how the different samples vary in composition from normal milk. Not only is the quality of milk affected by disease but the quantity or yield is also affected.

Animals may, however, be laboring under a poisonous or fatal disease and yet give apparently wholesome milk. Such milk, however, will show the presence of ptomaine compounds when it is given a careful chemical and bacteriological examination.

Dirt, disease germs, and many forms of bacteria from foul sources find their way into the milk from the cow's udder, and are the cause of serious trouble in both the cheese factory and the creamery. In one case in particular, noted by Mr. Willard, a pioneer American cheesemaker, a factory was having much trouble from the rapid decomposition of milk. The cause was traced to one herd and an extended examination showed that the cows, in passing to and from the milking shed, walked through a marshy place that contained much green pond scum and other decomposing matters, particles of which adhered to the udder, dried, and then fell off into the milk pails and fouled the milk. As soon as the cows were excluded from this place the trouble in the factory ceased.

In another case, Soxhlet observed that when milk was placed on a particular shelf in a milk room, the milk soon became offensive and indicated butyric acid fermentation. An examination of the milk rack showed that at some time a pan of milk had been spilled on the shelf above the one causing this trouble. The lower side of the shelf had not been thoroughly cleaned; hence, whenever a fresh pan of milk was placed on the shelf, spores or seeds fell off into the milk from the shelf above and immediately fouled it. These cases are mentioned simply to show the care and cleanliness which are necessary in the handling of milk.

MILK OF OTHER DOMESTIC ANIMALS.

76. Mare's Milk resembles cow's milk in general characteristics, except that it is not quite so rich in fat and is correspondingly poorer in solid matter. Mare's milk is subject to variations in composition, due to breed and individuality, the same as cow's milk.

COMPOSITION OF MARE'S MILK.[1]

	Per cent.
Water	88.49
Fat	2.86
Sugar	4.75
Ash	0.55
Casein and albumin	3.35

77. Sow's Milk is quite rich in casein and albumin

[1] Analysis by author.

(proteids), in fact there is about twice as much of these compounds as in cow's milk.

COMPOSITION OF SOW'S MILK.

	Per cent.
Water	4.00
Fats	4.60
Casein and albumin	7.25
Sugar	3.15
Ash	1.05

Sow's milk is also rich in mineral matter. When skim-milk is enriched by some product, such as shorts and a little boiled flax-seed meal, the mixture can be put together so as to have about the same composition as sow's milk.

78. **Sheep's Milk** is rich in fat and casein as well as in ash. It is one of the most concentrated milks given by domestic animals.

COMPOSITION OF SHEEP'S MILK.

	Per cent.
Water	82.25
Fat	5.30
Casein	6.10
Albumin	1.00
Milk sugar	4.35
Ash	1.00

If a lamb is to be raised on milk it demands the best milk that can be given. Goat's milk resembles sheep's milk but is not so rich in fat or casein. The object in giving the composition of these milks is to supply the necessary information so that one may know how to substitute one animal's milk for another.

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CHAPTER XI.

Preserving Milk.

The various methods employed to preserve milk all follow one or more of these main lines :

1. Application of cold.
2. Application of heat.
3. Use of chemicals.
4. Condensing.

79. Use of High and Low Temperatures.—When fresh milk or cream is cooled to 50° F. or lower, it will remain sweet for a longer time than when kept at a higher temperature. Fermentation cannot readily take place at a low temperature.

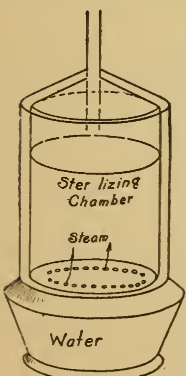

Fig. 20.

When the milk is heated to 200° to 212° F. for twenty minutes, and then sealed at this temperature, it has undergone the process known as sterilizing. When milk is properly sterilized and then placed in a cool room, it will keep a long time. A cheap and serviceable form of sterilizer is shown in Fig. 20. When the temperature registers higher than 159° or 161° F., the albumin coagulates and forms a coat on the surface, commonly known as the "scum." The object of the sterilizing is to destroy all organisms in the milk. The milk is sealed at the temperature at which it is sterilized so as to protect it from the air and to keep out new colonies of organisms. All of the organisms in sterilized milk may be destroyed, but the products which these organisms have produced are still in the milk. Sterilizing milk may, for example, kill the tyrotoxicon organisms, but it does not remove the tyrotoxicon products; again, sterilizing the milk from tuberculous cows may kill the tuberculous organisms, but it cannot destroy the ptomaines produced by them. Sterilizing milk greatly improves its sanitary condition.

Sterilized unwholesome milk cannot, however, be placed on an equal footing with unsterilized wholesome milk.

The preparation of sterilized milk is becoming quite a profitable and prominent feature of dairying. Many dairy farms have means of sterilizing the fresh milk and putting it in sealed quart and pint cans. The milk is then sold at a higher price to hospitals and for the use of children and invalids.

80. Pasteurizing.—The pasteurizing of milk is accomplished at a lower temperature; the process being to heat the milk for a longer time, at a lower temperature, 157° to 160° F., so as not to coagulate the albumin but at the same time to destroy the vitality of the organisms which may be present in the milk. In order to pasteurize milk for family use, clean pint or quart fruit cans, or bottles are first heated gradually in the oven so as to free them from organisms. A pail or pan, provided with a false bottom, is filled with cold water so that the water will come up to the neck of the cans when they are set in the water. Fresh milk is then put into the glass cans or bottles, so as to completely fill them. The cans are then placed into the water, and the whole is placed on the stove and slowly heated until the temperature of the water is 160°. The covers are then put on the cans, or the stoppers in the bottles. Cork stoppers should never be used. The pail is removed to the back of the stove and the lid put on. After twenty minutes the bottles are removed, cooled as rapidly as possible, and then placed on ice. The cooling restores the flavor to a great extent, so that the milk does not have the cooked taste which is so objectionable to many.

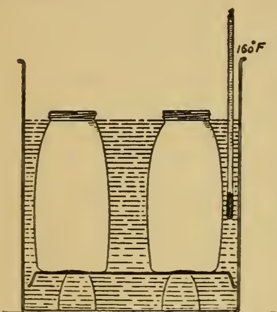

Fig. 21.

In the pasteurizing of milk, use is made of the application of both heat and cold. Simply heating the milk to 160° and then allowing it to cool, unprotected from the air, does but little good, and may do much harm, because the milk in cooling down, cools slowly, and it is then in a condition to be readily "re-seeded" and to allow rapid development of fresh organisms from the air and of those that have escaped the pasteurizing process.

For the pasteurizing of milk on a large scale there are many forms of apparatus in use, a description of which is not within the province of this work.

81. Use of Chemicals.—Various chemical substances are advertised to preserve milk, cream, and butter.

These preservatives are composed invariably of either borax, boric acid, saltpeter, or salicylic acid. Medical authorities seriously object to the use of preservatives in milk or in other foods. These chemicals, when used in excess, interfere with the process of digestion and cause diarrhoea. Inasmuch as preservatives are used most liberally in summer and warm weather, at the time when bowel disorders are most prevalent, their extensive use might be the source of much trouble. These chemicals are used to destroy the bacteria in milk and they are equally capable of destroying those organisms, in the stomach, which carry on the work of digestion. Inasmuch as many objections are urged against their use, it is safer not to employ them and to preserve milk by means of some other method which is free from objections.

82. Condensed Milk.—Preserving milk by condensing it, is one of the best methods when the milk is to be kept for a long time. When any material is deprived of its water, fermentation cannot readily take place. Condensed milk is made by removing half or more of the water. Various methods are employed for condensing milk, as boiling in vacuum pans under diminished pressure, or allowing the milk to flow over heated metallic aprons.

COMPOSITION OF CONDENSED MILK.[1]

	Condensed milk. Per cent.	Diluted three parts water. Per cent.
Water	50.40	87.60
Fat	14.00	3.50
Milk sugar	18.00	4.50
Casein	12.80	3.20
Albumin	2.00	0.50
Ash	2.80	0.70

One gallon of milk has been condensed to one quart, hence when the milk is used it is to be diluted with three quarts of water, when it will have the composition of the original milk and as given in the table. Condensed milk is extensively used in sea voyages. It is much to be preferred to poor milk.

Of the various methods employed to preserve milk, those which make use of high and low temperatures, as sterilizing and pasteurizing, are the best and most economical; condensing is more satisfactory when the milk is to be kept for a long time. Chemicals should not be used for preserving milk.

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CHAPTER XII.

The Composition of Skim-Milk, Buttermilk and Whey.

Skim-milk, buttermilk and whey are quite frequently spoken of as the by-products of milk. They are all valuable for feeding purposes.

83. Skim-Milk.—When the cream is separated from milk, the chief ingredient which has been removed is the fat. The 800 pounds or so of skim-milk obtained from 1000 pounds of milk contain nearly all of the casein, albumin and ash, as well as the milk sugar originally present in the milk. The skim-milk is, pound for pound, more concentrated in these food constituents than the original milk. A hundred pounds of skim-milk is produced from 118 or 120 pounds of whole milk and contain nearly all of the casein, albumin and milk sugar formerly present in the 118 or 120 pounds of milk.

84. The Composition of Skim-Milk.—The most important constituents of skim-milk are the casein and albumin, which are so essential for the production of muscle and a solid frame-work in young and growing animals. The milk sugar is a valuable heat- and energy-producing nutrient.

In 100 pounds of skim-milk there are about three and five-tenths pounds of casein and albumin. When we take into consideration the small per cent. of dry matter in both whole milk and skim-milk, this is a relatively large amount of muscle-forming material. After removing the water from 100 pounds of skim-milk, there will be left about 9.75 pounds of solid matter, of which three and five-tenths pounds are casein and albumin, 5.25 pounds are milk sugar, a little over 0.75 pound is ash, while the remainder consists of fat and traces of other constitents.

85. Skim-Milk and Whey Make Other Foods More Valuable.—In assigning a feeding value to skim-milk, it must be remembered that when it is properly used, skim-milk, as well as whey, is very valuable also in making other foods more palatable and digestible.

Neither skim-milk, buttermilk, nor whey are, when fed alone, complete or balanced foods; they are the most valuable when combined with grains or milled products, as shorts, bran, corn, oil meal, etc. When properly combined, the weak points in the food value and digestibility of the grains are reinforced by the strong points of the skim-milk, while the weak points of the skim-milk are strengthened by the strong points of the grains.

86. Comparative Value of Sweet and Sour Milk Products.—When souring takes place, some of the milk sugar is converted into lactic acid. It is very questionable whether the acid which is formed is as valuble for food as the original milk sugar. The ferments, which cause the souring of the milk, may be associated with other ferments which produce products that cause serious bowel troubles.

Experiments have shown that for young pigs 500 pounds of whey are worth as much for feeding as 100 pounds of mixed corn and shorts, which at twenty-eight cents per bushel for the corn would make the whey worth ten cents per hundred pounds.

When skim-milk is only about half soured, it frequently causes more trouble than when it is fully soured, and in the curdled state. When fully soured the acid may kill off some of the bad ferments. The skim-milk should, when possible, be fed sweet; when partially soured it is frequently very troublesome. The old skim-milk or whey, which is left over in the barrel from one day, should never be carried over to another day, because a little old sour skim-milk will act as a starter and will soon sour and spoil a fresh lot of skim-milk or whey when put into the barrel. In fact the scouring of calves, when fed on stale skim-milk, is caused by ferments which are present only in the milk after it has been contaminated by ferments such as the tyrotoxicon organism which feeds upon stale and decomposing milk and other foul matter. To prevent scouring and allied diseases, the utmost cleanliness and care should be exercised in the handling and feeding of skim-milk, buttermilk and whey, so as to prevent the organisms, which cause the bowel troubles, from gaining access.

Occasionally skim-milk is over-fed; this causes a great deal of trouble. The chief benefit from the feeding of skim-milk comes from using it moderately.

When skim-milk has a little boiled or scalded ground flax-seed added to it the mixture has nearly the same composition as sow's milk. Flax-seed contains protein and fat, the two ingredients which are present in sow's milk in liberal amounts.

When buttermilk has not been over-diluted with wash water from the churn, it has about the same composition and feeding value as skim-milk.

Sour whey, skim-milk, or buttermilk will act upon tin, zinc and iron, dissolving some of the metal. This is due to the action of lactic acid. The tin, zinc, and iron compounds are all poisonous when taken in sufficiently large doses. Hence it is not advisable to store sour whey or milk in zinc, tin or iron for any great length of time. When spilled on iron, as the springs and bolts of wagons, whey weakens the iron and in time causes it to become brittle and easily broken.

When whey and skim-milk are spilled on floors and near beams, they will cause more rapid rotting than if water were spilled, because the casein and albumin will ferment and start fermentation and rotting of the wood. The whey barrel should never be placed near a large beam or directly over a sill.

87. Separator Skim-Milk.—Skim-milks differ in composition mainly in the amount of fat present. Skim-milk from the separator differs in no material way from ordinary skim-milk, except in the more thorough removal of the fat, by the gravity process. Separator skim-milk sours very readily, because in cooling down from the temperature of separation it remains at 70° to 90° F. for a number of hours, which, with a little old skim-milk in the vat as a starter, are the most favorable conditions for souring.

88. Composition of Whey.—One hundred pounds of whey contain about seven pounds of dry matter, of which five pounds are milk sugar. Whey contains from eight-tenths to one per cent of protein, mainly in the form of albumin. The albumin in the milk is not recovered in cheese-making, but finds its way into the whey. It is the albumin in the whey which gives it its chief feeding value. There is not as much ash in whey as in milk or skim-milk, because a part of the ash is combined with the casein and is recovered in the cheese. In addition to the milk sugar and albumin, whey also contains about 0.65 per cent. ash and a small variable amount of fat. The most essential difference in composition between skim-milk and whey is the casein which is present in the skim-milk, but not in the whey.

The composition of each of the by-products of milk is given in the following table:

COMPOSITION OF ONE HUNDRED POUNDS OF

	Cow's milk.	Skim-milk.	Butter milk.	Whey.
Water, lbs	87.50	90.25	90.50	93.00
Fat	3.50	0.20	0.20	0.35
Casein and albumin.	3.25	3.60	3.30	0.80
Sugar	5.00	5.15	5.30	5.20
Ash	0.75	0.80	0.70	0.65

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CHAPTER XIII.

Other Methods Employed in Milk Testing, and the Adulteration of Dairy Products.

89. Other Methods Employed in Milk-Testing.—There are a number of other simple methods which are occasionally employed for testing milk. Many of these methods are reliable, but they require more skill and time than the Babcock test, and hence they are not so generally used.

90. Beimling Method.—This test is quite similar to the Babcock test; a centrifugal is used. The test-bottles are smaller, and two acids instead of one are made use of. Wood alcohol is required; this is quite apt to be impure and cause too high results. With the Beimling method care must be taken to obtain pure wood alcohol.

91. The Lactochrite is a method which has been in use in Germany and Denmark for some time. The separation of the fat is made by means of acetic and sulphuric acids, combined with centrifugal action. In its workings it is quite like the Babcock test. The centrifugal used is in form like the "Alpha" separator. The method is patented and the apparatus expensive. The method gives reliable results.

92. Gerber's Butyrometer.—In this method the fat is separated by centrifugal action, aided by sulphuric acid and wood alcohol. This method is a combination of the more important features of the Babcock and the Beimling methods. It gives accurate results and is quite extensively used in Europe.

93. Short's Method.—In this test an alkali solution is first added to the milk, which changes the fat into soap.

The soap is then converted into insoluble fatty acids by adding sulphuric acid. The fatty acids are then measured in a graduated tube. In this method test-bottles, similar to those used in the Babcock test, are employed. The test-bottles frequently break and muchmore time is required than for the Babcock test.

94. **Cochrane's Method.**—The fat is separated by a mixture of sulphuric and acetic acids and ether is then used to raise the fat into a graduated tube, where it is measured. The Cochrane fat bottles are made with two tubes, one for measuring the fat and the other for adding the reagents.

All of the above methods are patented, while the Babcock method is not.

95. **In Failyer and Willard's Method** an acid is first added to the milk, and then gasoline to collect the fat. The gasoline is removed by a current of air. The fat is then brought up into a graduated neck and measured.

96. **The Lactoscope and Ferser's Pioscope** were methods once in use. They are optical methods and depend upon the opacity of the milk serum. They are totally unreliable and the results are very inaccurate. Neither method should ever be used. None of these short methods are sufficiently accurate for scientific work, or as final evidence in court in case of adulteration, except in the hands of skilled operators.

In the chemical laboratory, the chemist makes use of what is known as the gravimetric method, where the fat in the milk is carefully separated and weighed on a delicate balance.

ADULTERATION OF DAIRY PRODUCTS.

97. **Butter.**—Artificial butter is found on the market in the well-known forms of oleomargarin and butterin. These products are made mainly from beef drippings. The fats are first put through filter presses, remove a portion of the harder fats, which are used for candles and soap-making. The softer fats which pass through the press are introduced into large churns, together with sweet milk, and then churned, salted, and colored so as to resemble butter. In trade there is a slight difference between oleomargarin and butterin; oleomargarin is the harder and has the higher melting-point. Oleomargarin is used to supply Southern trade, while butterin is sold in Northern markets.

The distinguishing difference between butter and these products is the presence or absence of the characteristic fat, butyrin found in butter, to the extent of nearly seven per cent.

98. **Cheese** is adulterated (1) by removing the fat from the milk and making skim-milk cheese; (2) by removing the fats from the milk and substituting other and cheaper fats, thus producing what is called filled cheese. Filled cheese is made by first passing the milk through a separator to remove the fat, and then, while the milk is still in the vat and warm, addingl ard or cottolene to the milk and thoroughly mixing it before the rennet is added.

99. **A Simple Method for Testing the Purity of Butter-Fats.**—Take a piece of butter or material about the size of a peanut, put it in a glass or porcelain dish, add

a little water, and a piece of potash about the size of the fat. Place the dish in warm water for an hour or so on the back of a stove until it makes soap. When cool carefully add about 10 cc. sulphuric acid to liberate the butyric acid, which is like the concentrated odor of stale butter. Genuine butter will give an intense odor of butyric acid, which cannot be mistaken. Oleomargarin will give scarcely any reaction for butyric acid.

In order to detect the presence of foreign fats in cheese, the chemist first extracts the fat from the cheese and then determines the amount of butyric acid present. If the skimming has been done very thoroughly and foreign fats added, the foreign fats can be detected by first sampling the cheese in the same way as in testing for the per cent. of fat in cheese by the Babcock test.

The pieces of cheese are put into a small bottle, gasoline is added, one-half teacupful is sufficient, the bottle corked and thoroughly shaken. The bottle is then allowed to stand for a few minutes, and the gasoline, which has dissolved the fat, is poured off into a teacup. The dish is placed in the open air and the gasoline evaporated, leaving the fat deposited in the cup. Do not let the gasoline evaporate in a room where there is a fire or a light. The fat is then tested for butyric acid in the same way as the butter-fat. If the skimming has been only partially done the test will not show decisive results.

The injury which results from the sale of oleomargarin and filled cheese is due to its being a dishonest competitor more than to its unwholesomeness. People buy these materials, intending to purchase pure butter or cheese. As to the digestibility of oleomargarin, there have been but few experiments made, and these few experiments have shown it to be less digestible than butter, so that the claim that it is equally as digestible as butter is simply a statement that is not based on any number of exact experiments.

When the butter or cheese is submitted to chemical analysis, the fat is first separated, and then the amount of butyric acid products determined. Five grams of pure butter-fat will require from twenty-three to twenty-six cc. of a tenth normal alkali solution to neutralize the volatile butyric acid products.

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CHAPTER XIV.

Effect of Food upon the Quality of Dairy Products.

The nature and quality of the food consumed has, in many cases, a marked effect upon the quality as well as upon the quantity of milk produced by different cows. The quality of the milk is capable of being influenced to a greater extent than is the proximate composition; that is, the quality of the milk fats, as hard or soft, can be influenced more than the per cent. of fat.

The fat which is present in the milk is not produced entirely from the fat in the food. Neither does the fat in the food find its way, directly and unchanged, into the milk. The fats, as well as the other food compounds first undergo digestion. They are then reconstructed within the body before passing into the milk. The fat in the milk may be produced from either the fats, non-nitrogenous compounds, or proteids of the food. Although the fat and other compounds of the food do not pass directly into the milk, but first undergo reconstruction within the body, nevertheless the nature of the fat, etc., produced in the milk is greatly influenced by the nature of the building materials, originally present in the food.

100. Production of Hard Butters.—Cotton-seed meal, the product obtained by removing the oil from cotton seed, when fed in large amounts produces a butter with a very high melting-point, in some cases 10° higher than ordinary butter. Chemical analysis shows that such a butter is rich in stearin and palmitin. The fats in the cotton-seed meal have not been taken directly into the milk. The fat and protein of the cotton-seed meal have been first broken down in the digestive tract and then the large amounts of digested hard fat products have influenced the production of stearin and palmitin in the milk. In case cotton-seed meal is fed, the milk, when put through the separator, must be warmed 5° to 10° higher than ordinary milk, otherwise the separator will clog. In fact, the milk must be handled in a different way throughout, because of the higher melting-point of the fat.

101. Production of Soft Butter.—Linseed oil, the product obtained by removing the oil from flaxseed, when fed in large amounts, has a tendency to produce a soft butter. The fat and protein of the linseed meal have, in a general way, the opposite effect, from the cotton-seed meal, upon the quality of the fat in the milk. As in the case of the cotton-seed meal, the fat and protein of the food do not pass directly into the milk, but simply the digested products of the linseed meal favor the production of a softer butter.

102. Effects of Balanced Rations upon the Quality of the Milk Fat.—The feeding of balanced rations has a marked effect upon the quality of the butter produced. The main object of feeding a balanced ration is to furnish the body with just the right amount and kind of food, so that there will be enough protein and other nutrients for the support of the body and the production of milk. An unbalanced ration produces an abnormal butter, as the following example will show: When cows are fed only hay and potatoes, the quantity of milk produced is greatly lessened, while the butter is very much like tallow. The hay and potatoes are deficient in protein. When grain is fed along with the hay and potatoes, making a balanced ration, the butter is of unusually good quality.

103. Peculiarities of Different Foods upon the Nature of the Milk Fats.—As a general rule the coarse fodders, as hay, corn stalks, and straw, which are deficient in protein, have a tendency to produce hard and tallow-like butter.

Corn meal, when fed in large amounts, has a tendency to produce a mediumly firm butter. Gluten meal, a product of corn, produces a softer butter than corn meal.

Oats, when fed in large amounts, produce a firm butter of good quality, but which is sometimes a little crumbly. When oats and corn are fed together, as is usually the case, the butter is of very good quality because the tendency of the oats to produce a crumbly butter is neutralized by the opposite tendency of the corn. Bran and shorts both produce good normal butter of neither too hard nor of too soft a quality.

104. Ensilage and Its Effects upon the Milk.—The effect of ensilage upon the quality of milk has been quite extensively studied. When fed with coarse fodders it has a tendency to produce a softer butter, improving the quality, because the ensilage is fed, when the coarse fodders have the tendency to produce over-hard butter.

The ensilage odor imparted to the milk is due more to the odors gaining access to the milk through the air during and after milking. It frequently happens that the stables, through imperfect ventilation, are thoroughly saturated with the ensilage products. As soon as the milk is drawn it becomes saturated. When cows which are fed on ensilage are milked in a place free from the ensilage odors, there is scarcely a trace of the ensilage taste in the milk.

105. Effects of some Green Fodders and Weeds upon the Quality of Milk. — Some green fodders have a marked effect upon the taste of milk. Rye fodder, for example, if fed when it begins to head out, produces a fish-like taste in the milk. This is due to the fodder at that state containing compounds like trimethylamine which produce the peculiar taste in milk. Rye fodder, however, is a valuable fodder if cut and cured at the right time; it does not then produce this taste in the milk.

Many weeds are also responsible for bad-tasting milk. Wild mustard contains two bitter principles which impart flavor. Wild garlic also produces a foul-tasting milk. The volatile sulphur oil present in turnips, as is well-known, passes directly into the milk. All members of the rape family, containing the volatile oil of rape, impart a characteristic taste to milk.

106. The Desirable Flavors of Butter and Cheese. — The flavor produced in good butter and cheese is supposed to be due largely to the working of bacteria. The bacteria produce definite chemical compounds, and it is these compounds which impart the flavor to butter and cheese—both the desirable and the undesirable ones. It is now the aim of the bacteriologist and the chemist to study the products produced by each class of organisms, and the conditions which are favorable or unfavorable for their development, so as to control the workings of the desirable ones, and prevent the action of the undesirable ones.

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CHAPTER XV.

The Composition of Fodders and the Calculation of Rations.

107. Importance.—Before a cow can produce milk she must be supplied with food (1) for the production of heat, and (2) for furnishing materials to renew the worn-out tissues of her body. After the body has been supplied with food for these two purposes, whatever food is left over is used for either producing milk or flesh. With a dairy cow this surplus food goes for the production of milk. There is a great difference in the way in which cows make use of their food. Some cows require a smaller amount of food for supplying the needs of their bodies than others. A cow that requires a large amount of food for the support of her body and produces a small return in milk yield is an unprofitable cow.

Inasmuch as the milk is produced from the food which is in excess of that required for the support of the body, it naturally follows that the production of milk depends very largely upon the kind and quantity of food consumed. Some combinations of food are favorable for milk production, while other combinations are very unfavorable. The combining of foods so as to supply the right amount and kind of food is spoken of as "rational feeding." The feeding of farm animals and dairy stock, is in itself a separate subject of study. In this work only the brief outline of the subject of the rational feeding of dairy stock, will be given. Our knowledge regarding the feeding of rations is based upon the results of extended investigations in chemistry and physiology.

108. Heat-Producing and Tissue-Renewing Foods.—The foods which produce heat are those which contain the most fat and starch-like materials. The foods which are the most valuable for renewing the worn-out tissues of the bodies are those which contain a group of compounds known as protein. Clover, peas, oats, oil-meal, bran, shorts, and wheat all contain a good supply of protein and are valuable for renewing worn-out tissues of the body and stimulating milk production. Corn fodder, silage, potatoes, and roots, are food-stuffs which are rich in starch or heat-producing materials. Hence a mixing or blending of these two classes of foods, the heat-producing and the tissue-renewing and milk-stimulating ones, produces the best results. The combining of these two classes of foods forms what is known as a balanced ration, and the composition of the foods is the basis for their combination.

EXPLANATION OF TERMS USED.

109. Water in Food-stuffs.—In all foods, even those which have been thoroughly sun- and air-dried, there is an appreciable amount of water. Substances like meal and flour, which appear perfectly dry, are not free from water. In the tables of analyses the figures for water represent the amount which is present in a hundred pounds of the material. The last traces of water are removed by drying the substance in an oven at a temperature of 212° F., when all of the water in the material is converted into steam and escapes.

110. **The Dry Substance** is what is left after all of the water has been removed from any material. Frequently the results of analyses are given on the basis of the dry substance, or water-free material, as it is called. In this work all of the results are given on the basis of the original material, or the material as it is ordinarily used as food, unless otherwise stated.

111. **The Ash.**—The ash is what is left after the substance is burned. It is sometimes called the mineral or inorganic part. The ash is important, inasmuch as it furnishes the main portion of the necessary materials for bone-growth. Too much ash, especially when it is rich in silica (sand), or in strong alkalies, is objectionable. The ashes of all grains are usually the richest in phosphates, and hence the most valuable for bone-growth. In nearly all mature agricultural plants there is less than ten per cent. ash. There is generally a sufficient amount of ash in all food products for bone-growth.

112. **Organic Matter.**—The organic matter is that portion of a fodder which is converted into volatile products when the dry matter is burned; the organic matter is found by subtracting the ash from the dry matter.

113. **The Non-Nitrogenous and Nitrogenous Organic Compounds.**—From the feeder's point of view the organic matter of food-stuffs may be divided into two large classes of compounds: (1) The non-nitrogenous, and (2) the nitrogenous compounds. The division is made

according to the presence or absence of the element, nitrogen. Starch, sugar, fat, and cellulose contain no nitrogen, and are non-nitrogenous compounds. Albumin, casein, and fibrin contain nitrogen, and hence are nitrogenous compounds.

114. **Non-Nitrogenous Compounds.**—The non-nitrogenous compounds include the fiber (cellulose and lignin), starches, sugars, fats, pectose substances, organic acids, volatile or essential oils, and other compounds. The non-nitrogenous compounds do not all possess the same food value. The non-nitrogenous compounds make up by far the larger portion of the dry matter of a fodder. There is from four to ten times more of the non-nitrogenous compounds in any ordinary food than nitrogenous compounds. There is usually a sufficient amount of non-nitrogenous materials in all foods, but the nitrogenous compounds are liable to be too deficient.

115. **Ether Extract.**—The compounds which are soluble in ether are called the ether extract. In the grains and milled products the ether extract is nearly pure fat; in hay, grass, and other coarse fodders the ether extract is from fifty to seventy-five per cent. pure fat. All fats contain about one-half more carbon than does starch or sugar; hence when the fats are digested and undergo oxidation within the body, they produce over twice as much heat as starch or sugar. The fat in the food has much to do with producing heat in the body, and but little to do directly with furnishing fat for the production of milk. In fact, any good cow will give much more fat in her milk for a given period than there is fat

in her food. A certain amount of fat in a food is essential; too large a quantity, when not associated with a sufficient amount of protein, is objectionable.

116. Crude Fiber.—The fiber includes the cellulose and lignin, which constitute the framework of the plant. The fiber is not entirely indigestible. An ordinary amount of fiber, when associated with sufficient amounts of the right kinds of other digestible materials is unobjectionable. The fiber and ash of the food, as ordinarily used, ought not to exceed forty to fifty-five per cent. of the total nutrients, because they represent too much inert material in a fodder.

117. Nitrogen-Free Extract.—The nitrogen-free extract includes the sugars, starch, pectose substances and all non-nitrogenous compounds which are soluble in dilute acid and alkali solutions. The term means easily soluble bodies, free from nitrogen. The nitrogen-free extract includes all of the non-nitrogenous compounds except the fat and fiber. The term nitrogen-free extract is a very indefinite one, and is employed because no better classification has as yet come into general use. In the potato the nitrogen-free extract consists mainly of starch ; in the sugar beet it consists of sugar ; in straw it consists largely of pentosans, and in fruit it consists mainly of pectose substances.

118. The Nitrogenous Compounds.—The characteristic building material of these compounds is the element nitrogen. The nitrogenous compounds are by far the most expensive and the most important materials found in food-stuffs. Unfortunately the terms employed to designate these bodies are somewhat confused. By many the terms nitrogenous compounds, proteids, and albuminoids are used synonymously; each term, however, has a separate and distinct meaning. The total nitrogenous compounds is the term employed to designate all of the organic nitrogenous compounds of a food-stuff. The term protein represents only a single class of the nitrogenous bodies. All nitrogenous compounds are not proteids, but all proteids are nitrogenous compounds. The albuminoids are another distinct class of the nitrogenous compounds, while albumins and albuminates are subclasses of the proteids. In the tables of analyses the term crude protein is used. Crude protein includes the protein and other bodies, as amines and alkaloids, which are not proteids. In the grains and milled products the crude protein is ninety-five per cent. or more true protein, while in potatoes and root crops about half of the crude protein is true protein.

119. Importance of Protein.—For food purposes, protein is the largest and most important class of the nitrogenous compounds. The proteids are the materials out of which the muscles are formed; the proteids enter into the composition of the tissues of the nervous system, the ligaments, bones, hoofs, hair, and all of the vital fluids. The protein compounds are the nutrients which are so important for tissue-renewing purposes. A certain amount of protein in the food is absolutely necessary, and this protein must be supplied before growth or the production of milk can take place.

120. Digestible Nutrients.—In all fodders and grains there is a certain amount of each of the food nutrients which is indigestible and cannot be counted upon for food purposes. The amounts of the various indigestible nutrients in fodders have been determined by a number of our American experiment stations. In the tables of analyses the composition of 100 pounds of fodder as ordinarily used is first given, and then, in the same line, under digestible nutrients, the pounds of each digestible nutrient in 100 pounds of the fodder, are given. The digestible nutrients represent the amount which can ordinarily be counted upon for actual food purposes.

121. Nutritive Ratio.—The term nutritive ratio is frequently made use of in connection with rational feeding. The nutritive ratio is the ratio which exists between the digestible protein and the digestible non-nitrogenous compounds. A nutritive ratio of 1 to 6.7 means one part of digestible protein to every six and seven-tenths parts of digestible non-nitrogenous compounds. A wide ration means a large amount of non-nitrogenous compounds, and a narrow ration a comparatively small amount.

122. Heat Units.—When the food is digested it produces heat, which is transformed into muscular energy. The heat which is produced can be measured by the work which it is capable of doing. The heat produced is measured in calories. A calorie is the amount of heat required to raise a kilogram of water from 0° to 1° in the Centigrade scale, or approximately 2.2 pounds of water, 1.8° on the Fahrenheit scale. One pound of digestible fat yields 4225 calories. One pound of digestible starch and nitrogen-free extract compounds yields 1860 calories. One pound of digestible protein yields the same amount of heat as one pound of starch; *viz.*, 1860. The amount of heat produced by fodders can be calculated by the use of these factors:

One pound digestible fat produces... 4225 calories.
One pound digestible starch, protein
and other nutrients produces...... 1860 calories.

123. Standard Ration.—An ordinary cow of 1000 pounds weight, should receive about twenty-five pounds of organic matter per day. This organic matter should contain from 2.25 to 2.5 pounds of digestible protein and produce about 30,000 heat units.

124. How to Calculate a Ration.—In order to calculate a ration it is first necessary to consider the composition of the foods which are to be used. In case that you are using coarse fodders, which are poor in protein, it will be necessary to use some grain or milled product which is more concentrated in protein. Suppose that you have clover hay, corn fodder, and bran, and you desire to make a ration containing these three articles of food. Ten pounds of clover hay, and five pounds each of corn fodder and bran will contain in all about 1.40 pounds of digestible protein. This is not a sufficient amount of protein. Ten pounds each of clover hay, corn fodder and bran will contain about 2.10 pounds of digestible protein, which is not far from the required amount, but more protein could be added with advantage to the ration, so the clover hay is increased to twelve pounds. In the table of the average composition of American feeding stuffs the per cent. of digestible nutrients is given :

	Crude protein. Per cent.	Ether extract. Per cent.	Non-nitrogenous. Per cent.
Clover..........	6.5	1.6	34.9
Corn fodder.....	1.8	1.2	32.0
Bran............	12.6	2.9	44.1

These figures represent the amounts of digestible nutrients in 100 pounds of food-stuff. The amount in one pound would then be 0.01 part of these amounts. The digestible crude protein in twelve pounds of clover hay is $0.065 \times 12 = 0.78$ pound ; ether extract, $0.016 \times 12 = 0.192$ pound ; non-nitrogenous, $0.349 \times 12 = 4.19$. Ten pounds of corn fodder contain : Protein, $10 \times 0.018 = 0.18$ pound; ether extract, $10 \times 0.012 = 0.12$ pound ; non-nitrogenous, $0.32 \times 10 = 3.2$ pounds. Ten pounds of bran contain: Protein, $0.126 \times 10 = 1.26$ pounds; ether extract, $0.029 \times 10 = 0.29$ pound ; non-nitrogenous compounds, $0.441 \times 10 = 4.41$ pounds. Tabulating the results gives :

DIGESTIBLE NUTRIENTS.

	Crude protein.	Ether extract.	Fiber and nitrogen-free extract.
Clover, 12 pounds........	0.78	0.19	4.19
Corn fodder, 10 pounds...	0.18	0.12	3.20
Bran, 10 pounds..........	1.26	0.29	4.41
Total	2.22	0.60	11.80

Heat units : $(11.80 + 2.22) \times 18.60 = 26077$

$4225 \times 0.6 = 2535$

Total $= 28612$

Nutritive ratio: $0.6 \times 2.25 = 1.35$. $\frac{11.80 + 1.35}{2.22} = 5.9$

The nutritive ratio is 1 to 5.9.

In calculating the nutritive ratio, the ether extract is first multiplied by 2.25 because the fats are so much more concentrated than the other non-nitrogenous compounds.

This ration contains 2.22 pounds of digestible crude protein and will produce about 28,600 heat units. This is not too far from the standard. The ration could to advantage have about five pounds of roots of some kind added to it.

125. Roots or Silage Desirable in a Ration.—A good ration should also contain a small amount of some succulent food, as silage, roots, or potatoes. In feeding roots they should be freed as much as possible from dirt. Five or ten pounds per day of roots is as much as should be fed. These foods are valuable on account of favorably effecting the digestion of the ration.

126. Bulky and Concentrated Rations.—A ration should not be too bulky, neither should it be too concentrated. The digestive organs are capable of taking care of from twenty-five to thirty-two pounds of dry matter, and from fifty to ninety pounds of water per day. When bulky foods are fed in excess the organs of digestion are overworked. A cow, if fed entirely on hay, as timothy or prairie hay, would have to consume sixty to seventy pounds of hay in order to obtain the 2.25 pounds of digestible protein. This is over twice the digestive capacity of the cow. In the same way a food may be too concentrated. A ration of five pounds of bran, four pounds of linseed meal, and some fatty material would supply all of the necessary digestible protein and heat units, but such a mixture would be an objectionable ration because it is too concentrated and the digestive tract will not have enough bulky food.

127. Requirements of Different Animals.—In the feeding of rations it is to be remembered that the variations in the requirements of different animals must be considered. A ration which is well suited for a small cow may have to be increased for a larger cow. If a cow consumes all of her ration, and then appears anxious for more, she should not necessarily be restricted to the ration. The standard ration is to be considered as a guide rather than an inflexible rule. Ordinarily, a daily ration of ten pounds of mixed grain, twenty pounds of hay and coarse fodder, together with a few roots, will make a good, balanced ration.

Many of our most successful dairymen, who lay no claim or stress upon the rational feeding of their stock, have learned from experience how to combine the food in just about the right way to form a balanced ration.

128. Comparative Cost and Composition of Fodders and Grain.—The dairyman should consider the relative cost of fodders and grains, as well as their composition. The market value of dairy fodders is frequently quite different from the actual food values of those fodders. In order to compare, in a general way, the cost and food value of fodder articles, first calculate the number of pounds of fodder or grain that can be purchased for one dollar; for example, which is the cheaper food, corn at 20 cents per bushel or oats at 12 cents per bushel? A dollar will buy 280 pounds of corn and 265.6 pounds of oats. In the 280 pounds of corn there are 25.8 pounds of digestible protein and 440,335 heat units. In the 265.6 pounds of oats there are 24.5 pounds of protein and 342,626 heat units. The amount of protein in these two foods is nearly the same, but the dollar's worth of corn will procure over 100,000 more heat units than the dollar's worth of oats. In order to calculate the amount of digestible protein and heat units that can be obtained for one dollar, multiply the number of pounds of the material purchased for one dollar by the per cent. of digestible matter, as given in the tables.

In purchasing fodders the preference should first be given to the protein. When there is but a slight difference in the amount of digestible protein in two foods, purchase the one containing the larger number of heat units. In some cases a dollar's worth of mixed food will furnish more nutrients or a better balanced ration than if just one of the foods were purchased. In order to compare the food value of grains and fodders at different prices, a table has been prepared (see Appendix, p. 144) which gives the number of digestible pounds of the separate nutrients and the heat units in a dollar's worth of the material, when the prices are as stated in the table. When the prices are different from those given in the table, the amount of each nutrient which may be procured for one dollar can be calculated from the composition of the material in the way explained.

REFERENCES TO CHAPTER XV.

[NOTE.—The literature on this subject is so extensive that only a few typical references are given. For references to special topics, as the characteristic value of any food for milk production, the student is referred to the card catalogue index issued by the United States Department of Agriculture, Office of Experiment Stations. In calculating rations, it is best to use the figures given for the average composition of American feeding stuffs, except in those cases where extended special investigations have been made of the fodders of a State by an Experiment Station.]

1. Manual of Cattle Feeding. Armsby.

2. Landwirtschaftliche Fütterungslehre. Emil Wolff.

3. Feeding Farm Animals. Allen: Office of Experiment Stations, United States Department of Agriculture, Farmer's Bulletin No. 22.

4. A Compilation of Analyses of American Feeding Stuffs. Jenkins and Winton: Office of Experiment Stations, United States Department of Agriculture, Bulletin No. 38.

5. One hundred American Rations for Dairy Cows. Woll: Wisconsin Experiment Station, Bulletin No. 38.

Average Composition of American Feeding Stuffs.

Feeding Stuffs.	Total parts in 100 parts of the fodder.						Digestible nutrients in 100 parts of the fodder.		
	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract (fat).	Crude protein.	Carbohydrates	Ether extract (fat).
Green Fodders and Silage.									
Pasture grass	80.0	2.0	3.5	4.0	9.7	0.8	2.6	10.6	0.5
Green fodder corn (maize)	79.3	1.2	1.8	5.0	12.2	0.5	1.3	11.8	0.4
Alfalfa (lucern)	71.8	2.7	4.8	7.4	12.3	1.0	3.6	11.4	0.4
Green clover	70.8	2.1	4.4	8.1	13.5	1.1	2.9	14.1	0.7
Alsike clover, in bloom	74.8	2.0	3.9	7.4	11.0	0.9	2.7	13.1	0.6
Rye fodder	76.6	1.8	2.6	11.6	6 8	0.6	2.1	14.1	0.4
Oat fodder	62.2	2.5	3.4	11.2	19.3	1.4	2.7	22.7	1.0
Sorghum	79.4	1.1	1.3	6.1	11.6	0.5	0.8	12.7	0.4
Red top, in bloom	64.8	2.3	3.3	9.4	19.1	1.2	2.3	20.5	0.7
Timothy	61.6	2.1	3.1	11.8	20.2	1.2	2.2	23.0	0.7
Blue grass	65.1	2.8	4.1	9.1	17.6	1.3	2.9	19.2	0.8
Corn silage	79.1	1.4	1.7	6.0	11.1	0.8	1.2	11.8	0.6
Clover silage	72.0	2.6	4.2	8.4	11.6	1.2	2.2	10.0	0.5
Sorghum silage	76.1	1.1	0.8	6.4	15.3	0.3	0.4	14.0	0.2
Hay and Dry Coarse fodders.									
Fodder corn (maize), field cured	42.2	2.7	4.5	14.3	34.7	1.6	1.8	32.0	1.2
Corn stalks (stover), field cured	40.1	3.4	3.8	19.7	31.9	1.1	2.0	34.1	0.6

AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS.—*Continued.*

Feeding Stuffs.	Total parts in 100 parts of the fodder.						Digestible nutrients in 100 parts of the fodder.		
	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract (fat).	Crude protein.	Carbohydrates	Ether extract (fat).
Hay from red clover	15.3	6.2	12.3	24.8	38.1	3.3	6.5	34.9	1.6
Hay from mammoth clover	21.2	6.1	10.7	24.5	33.6	3.9	5.7	32.0	1.9
Hay from alfalfa (lucern)	8.4	7.4	14.3	25.0	42.7	2.2	7.6	37.8	1.3
Hay from alsike clover	9.7	8.3	12.8	25.6	40.7	2.9	6.8	36.8	1.4
Oat hay	8.9	6.2	7.6	29.3	45.1	2.9	4.3	46.4	1.5
Hay from mixed meadow grasses	16.0	4.6	6.4	29.9	41.0	2.1	3.6	42.7	1.0
Hay from Hungarian grass	7.7	6.0	7.5	27.7	49.0	2.1	4.5	46.4	1.0
Timothy hay	13.2	4.4	5.9	29.0	45.0	2.5	3.0	43.9	1.2
Oat straw	9.2	5.1	4.0	37.0	42.4	2.3	1.6	41.4	0.7
Barley straw	14.2	5.7	3.5	36.0	39.0	1.5	0.9	41.3	0.6
Wheat straw	9.6	4.2	3.4	38.1	43.4	1.3	0.8	37.9	0.5
Rye straw	7.1	3.2	3.0	38.9	46.6	1.2	0.8	42.7	0.4
Buckwheat straw	9.9	5.5	5.2	43.0	35.1	1.3	2.3	37.7	0.6
Roots and Tubers.									
Potatoes	78.9	1.0	2.1	0.6	17.3	0.1	1.4	16.1	0.1
Sweet potatoes	71.1	1.0	1.5	1.3	24.7	0.4	0.9	22.2	0.3
Red beets	88.5	1.0	1.5	0.9	8.0	0.1	0.9	7.6	0.1
Sugar beets	86.5	0.9	1.1	0.9	9.8	0.1	1.1	9.3	0.1

AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS.—*Concluded.*

Feeding stuffs.	Total parts in 100 parts of the fodder.						Digestible nutrients in 100 parts of the fodder.		
	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract (fat).	Crude protein.	Carbohydrates	Ether extract (fat).
Mangel-wurzels	90.9	1.1	1.4	0.9	5.5	0.2	1.1	4.8	0.2
Rutabagas	88.6	1.2	1.2	1.3	7.5	0.2	0.9	7.1	0.2
Turnips	90.5	0.8	1.1	1.2	6.2	0.2	0.6	5.5	0.2
Carrots	88.6	1.0	1.1	1.3	7.6	0.4	1.0	7.1	0.3
Grains and Mill Products.									
Corn (maize)	10.9	1.5	10.5	2.1	69.6	5.4	7.1	62.7	4.2
Corn and cob meal	15.1	1.5	8.5	6.6	64.8	3.5	6.5	56.3	2.9
Corn cob	10.7	1.4	2.4	30.1	54.9	0.5	1.6	43.9	0.3
Corn bran	10.9	1.7	9.4	4.8	67.3	5.9	6.2	50.9	3.4
Oats	11.0	3.0	11.8	9.5	59.7	5.0	9.1	44.7	4.1
Barley	10.9	2.4	12.4	2.7	69.8	1.8	9.5	66.1	1.2
Barley screenings	12.2	3.6	12.3	7.3	61.8	2.8	9.3	57.3	1.8
Wheat	10.5	1.8	11.9	1.8	71.9	2.1	9.2	64.9	1.4
Wheat bran—roller process	12.0	5.6	16.1	8.4	53.7	4.2	12.6	44.1	2.9
Wheat bran—old process	12.0	4.9	13.0	8.1	58.2	3.8	10.1	47.5	2.6
Wheat shorts	11.8	4.6	14.9	7.4	56.8	4.5	11.6	45.4	3.2
Wheat middlings	12.1	3.4	15.7	4.7	60.2	4.0	12.2	47.2	2.9

Average Composition of Minnesota Feeding Stuffs.

Feeding stuffs.	Total parts in 100 parts of the fodder.						Digestible nutrients in 100 parts of the fodder.		
	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract. (Fat)	Crude protein.	Carbohydrates.	Ether extract. (Fat.)
Grains.									
Barley	11.78	3.32	11.20	5.12	65.88	2.70	9.1	59.0	1.8
Corn	11.00	1.50	10.25	2.25	71.72	3.88	9.2	68.5	3.1
Millet seed	12.50	3.82	10.61	8.07	61.11	3.89	9.0	54.1	2.9
Oats	9.00	3.62	10.70	6.75	65.05	4.88	9.2	51.0	3.9
Peas	9.84	3.40	22.00	5.73	58.00	1.03	19.4	59.6	0.5
Rye	11.00	2.10	12.75	2.10	70.04	2.01	10.5	59.3	1.5
Wheat	11.00	1.92	13.75	2.25	69.03	2.05	11.0	58.6	1.5
"Goose" wheat	10.85	1.81	16.41	2.50	66.60	1.77	13.1	56.8	1.4
Flaxseed	7.00	3.75	27.00	7.00	20.00	35.00	....	....	...
Milled Products.									
Corn meal	12.00	1.50	10.00	1.00	71.70	3.80	9.00	67.4	2.8
Corn cobs	10.75	1.20	1.43	32.15	54.03	0.44	0.20	52.0	0.2
Cotton-seed meal	8.14	7.95	44.38	5.61	22.71	11.20	32.00	20.2	10.0
Gluten meal	10.00	0.75	28.20	1.35	52.10	7.60	24.50	47.0	6.7
Germ meal	7.00	1.25	14.00	4.25	67.30	6.47	12.30	52.4	6.1

AVERAGE COMPOSITION OF MINNESOTA FEEDING STUFFS—(*Continued*).

Feeding stuffs.	Total parts in 100 parts of the fodder.						Digestible nutrients in 100 parts of the fodder.		
	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract. (Fat.)	Crude protein.	Carbohydrates.	Ether extract. (Fat.)
Linseed meal (O. P.)	10.00	5.50	31.00	8.50	36.80	8.20	27.60	33.5	7.3
Oat feed	10.00	4.20	15.00	7.50	57.10	6.20	11.10	40.1	3.7
Wheat bran	10.50	6.01	15.65	10.85	52.04	4.95	12.50	42.1	3.6
Wheat shorts	10.50	3.25	13.25	5.52	64.47	3.01	10.00	55.9	2.3
Wheat germ	10.50	2.75	16.25	2.25	64.75	3.50	13.80	59.8	2.4
Wheat flour	10.50	0.50	11.25	....	77.20	0.55	10.60	73.3	0.4
Wheat flour, "Red Dog"	10.00	2.25	15.75	1.60	67.65	2.75	13.50	61.3	2.0
Wheat screenings	10.00	2.20	13.80	3.60	67.65	2.75	....	...	..
Cockle bran	11.00	3.30	10.60	9.20	63.50	2.50	....	...	..
Green Crops and Silage.									
Pasture, blue grass	85.00	1.75	3.00	3.25	6.30	0.70	1.9	6.9	0.9
Green clover	86.00	1.48	3.36	1.87	6.54	0.75	2.3	6.2	0.5
Ensilage, corn	74.00	1.40	1.95	6.28	14.72	0.80	1.2	15.0	0.6
Rape, whole plant	86.00	1.06	2.09	1.71	8.89	0.25	1.5	8.1	0.2
Rape, leaves	88.00	1.00	2.04	1.08	7.50	0.38	1.5	6.8	0.2
Sugar beets	85.00	0.85	1.75	0.50	11.80	0.10	1.5	12.3	1.0

AVERAGE COMPOSITION OF MINNESOTA FEEDING STUFFS—(*Continued*).

Feeding stuffs.	Total parts in 100 parts of the fodder.						Digestable nutrients in 100 parts of the fodder.		
	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract. (Fat.)	Crude protein.	Carbohydrates.	Ether extract. (Fat.)
Mangles	86.00	1.25	1.95	1.10	9.45	0.25	1.5	9.0	1.0
Potatoes	75.45	1.00	2.50	0.33	20.64	0.08	2.1	20.24	..
Field Cured Crops.									
Clover hay, red	12.25	6.78	12.67	24.05	41.08	24.05	7.6	40.0	1.5
Timothy hay	12.32	5.11	12.37	27.13	36.29	27.13	7.4	37.8	1.4
Blue grass hay	14.00	6.92	8.45	29.20	37.52	29.20	4.6	40.0	2.2
Millet hay	12.00	8.95	6.52	31.00	41.03	31.00	3.9	48.5	1.0
Mixed prairie hay	15.90	6.70	6.02	27.40	41.58	27.40	3.4	41.5	1.2
Upland prairie hay	12.50	6.25	5.91	26.32	46.22	26.32	3.5	41.8	1.4
Oat hay	15.00	6.87	8.75	28.12	38.01	28.12	5.7	41.3	1.3
Corn fodder[1]	15.00	4.25	6.46	21.25	50.11	21.25	3.9	51.2	2.2
Wheat straw	7.41	9.22	3.25	38.27	40.88	38.27	1.0	38.0	0.4
Oat straw	8.36	9.00	4.06	41.11	38.07	41.11	1.5	43.4	0.5
Barley straw	10.40	9.11	3.45	40.66	35.43	40.66	1.0	40.6	0.4
Clover straw	13.50	7.80	8.63	35.40	33.10	35.40	..	...	...

[1] Corn fodder, if not properly cured and stored, may contain thirty-five per cent. or more of water, and proportionally less nutrients.

Table Giving the Number of Pounds of Digestible Nutrients and Heat Units that Can be Obtained for One Dollar When Grains and Milled Products are at Different Prices.

	Price.	Dry matter.	Digestible pounds of Proteids.	Fat.	Carbohydrates.	Heat units.
Corn, per bushel	$ 0.20	224	25.8	8.7	191.8	440335
Corn, per bushel	0.25	179	20.6	6.9	153.4	352854
Barley, per bushel	0.35	97	12.5	2.5	80.9	184123
Oats, per bushel	0.12	175	24.5	10.4	136.0	342626
Oats, per bushel	0.15	140	19.6	8.3	108.8	274032
Oats, per bushel	0.18	116	16.4	6.9	90.7	226949
Oil meal, per ton	14.00	102	39.4	10.4	47.9	206416
Oil meal, per ton	15.00	95	36.8	9.7	44.7	192634
Oil meal, per ton	16.00	89	34.5	9.1	41.9	180611
Cotton-seed meal, per ton	14.00	93	45.0	14.0	29.0	199173
Cotton-seed meal, per ton	16.00	81	40.0	12.5	25.2	174084
Rye, per bushel	0.45	88	13.0	2.0	72.0	166550
Timothy hay, per ton	8.00	127	9.0	3.0	108.0	230295
Prairie hay, per ton	6.00	163	11.0	4.0	138.0	294040
Clover hay, per ton	10.00	105	15.0	3.0	82.0	193095
Millet hay, per ton	8.00	138	10.0	3.0	121.0	256236
Wheat shorts, per ton	10.00	134	20.0	4.6	111.8	264583
Wheat shorts, per ton	8.00	168	25.0	5.8	140.0	330728
Wheat shorts, per ton	6.00	223	33.3	7.7	186.3	440673
Wheat bran, per ton	10.00	120	25.0	7.2	84.2	333532
Wheat bran, per ton	8.00	150	31.3	9.0	105.3	291910
Wheat bran, per ton	6.00	200	41.7	12.0	140.3	389220
Potatoes, per bushel	0.15	95	8.4	...	79.2	162936

TABLE FOR CORRECTING THE LACTOMETER NUMBER OF MILK ACCORDING TO TEMPERATURE.

Lactometer number.	Degrees of Thermometer (Fahrenheit).																
	45.	46.	47.	48.	49.	50.	51.	52.	53.	54.	55.	56.	57.	58.	59.	60.	61.	62.
25....	23.8	23.9	24.0	24.0	24.1	24.1	24.2	24.3	24.4	24.5	24.6	24.6	24.7	24.8	24.9	25.0	25.1	25.2
26....	24.8	24.9	24.9	25.0	25.1	25.1	25.2	25.2	25.3	25.4	25.5	25.6	25.7	25.8	25.9	26.0	26.1	26.2
27....	25.8	25.9	25.9	26.0	26.1	26.1	26.2	26.2	26.3	26.4	26.5	26.6	26.7	26.8	26.9	27.0	27.1	27.3
28....	26.7	26.8	26.8	26.9	27.0	27.0	27.1	27.2	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28.0	28.1	28.3
29....	27.7	27.8	27.8	27.9	28.0	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1	29.3
30....	28.6	28.7	28.7	28.8	28.9	29.0	29.1	29.1	29.2	29.3	29.4	29.6	29.7	29.8	29.9	30.0	30.1	30.3
31....	29.5	29.6	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5	30.6	30.8	30.9	31.0	31.2	31.3
32....	30.4	30.5	30.5	30.6	30.7	30.9	31.0	31.1	31.2	31.3	31.4	31.5	31.6	31.7	31.9	32.0	32.2	32.3
33....	31.3	31.3	31.4	31.5	31.6	31.8	31.9	32.0	32.1	32.3	32.4	32.5	32.6	32.7	32.9	33.0	33.2	33.3
34....	32.2	32.3	32.3	32.4	32.5	32.7	32.9	33.0	33.1	33.2	33.3	33.5	33.6	33.7	33.9	34.0	34.2	34.3
35....	33.0	33.1	33.2	33.4	33.5	33.6	33.8	33.9	34.0	34.2	34.3	34.5	34.6	34.7	34.9	35.0	35.2	35.3

Table for Correcting the Lactometer Number of Milk according to Temperature.

Lactometer number.	Degrees of Thermometer (Fahrenheit).																
	63.	64.	65.	66.	67.	68.	69.	70.	71.	72.	73.	74.	75.	76.	77.	79.	81.	86.
25....	25.3	25.4	25.5	25.6	25.7	25.9	26.0	26.1	26.2	26.4	26.5	26.6	26.8	27.0	27.1	27.2	27.5	28.3
26....	26.3	26.5	26.6	26.7	26.8	27.0	27.1	27.2	27.3	27.4	27.5	27.7	27.8	28.0	28.2	28.4	28.8	29.5
27....	27.4	27.5	27.6	27.7	27.8	28.0	28.1	28.1	28.3	28.4	28.6	28.7	28.9	29.1	29.3	29.5	29.9	30.6
28....	28.4	28.5	28.6	28.7	28.8	29.0	29.1	29.2	29.4	29.5	29.7	29.8	29.9	30.1	30.4	30.6	31.0	31.7
29....	29.4	29.5	29.6	29.8	29.9	30.1	30.2	30.3	30.4	30.5	30.7	30.9	31.0	31.2	31.5	31.7	32.1	32.8
30....	30.4	30.5	30.7	30.8	30.9	31.1	31.2	31.3	31.5	31.6	31.8	31.9	32.1	31.3	32.5	32.7	33.2	33.9
31....	31.4	31.5	31.7	31.8	32.0	32.2	32.2	32.4	32.5	32.6	32.8	33.0	33.1	33.3	33.6	33.8	34.2	35.1
32....	32.5	32.6	32.7	32.9	33.0	33.2	33.3	34.4	33.6	33.7	33.9	34.0	34.2	34.4	34.7	34.9	35.3	36.2
33....	33.5	33.6	33.8	33.9	34.0	34.2	34.3	34.5	34.6	34.7	34.9	35.1	35.2	35.5	35.8	36.0	36.4	37.3
34....	34.5	34.6	34.8	34.9	35.0	35.2	35.3	35.5	35.6	35.8	36.0	36.1	36.3	36.5	36.8	37.1	37.5	38.4
35....	35.5	35.6	35.8	35.9	36.1	36.2	36.4	36.5	36.7	36.8	37.0	37.2	37.3	37.5	37.8	38.1	38.5	39.5

[NOTE.—In order to make the corrections for temperature in the lactometer reading, first find the lactometer number, and then the degree of the thermometer. The number found where these two lines intersect will be the corrected reading for the standard temperature of 60°; as, lactometer reading 30, temperature 75, corrected reading for 60°, 32.1 or specific gravity at 60° = 1.0321].

APPENDIX.

Review Questions for Classroom Use.

1. What are the milk solids, and how are they obtained? 2. State the average composition of milk; which constituent is the most variable? 3. What is the size, form, and appearance of the fat globules? 4. Why do they retain this shape? 5. How does the size of the globules vary with the period of lactation and individuality of the cow? 6. What is the milk serum and what can be said about its constancy of composition? 7. Why is it necessary to take into consideration the quantity of milk as well as its composition in calculating the amount of fat produced? 8. How can the total pounds of each constituent of the milk, given by a cow in one day, be determined, when the composition is known? 9. What is the difference in composition between the first milk and the strippings? 10. What is gained by testing milk? 11. How is the ash in milk determined? 12. How does milk vary in composition? 13. What is the difference between butter and milk fats? 14. What is the albumin in milk? 15. Define solids not fat. 16. How should a sample of milk be taken? 17. How is the milk measured with the pipette? 18. Describe the various pieces of apparatus used in testing milk with the Babcock test. 19. Explain the best method employed to read the fat. 20. How can the machine be speeded? 21. How is the acid to be handled and what is to be avoided? 22. What is the result when the acid is either too strong or too dilute? 23. How can the test-bottles be tested? 24. What are the agents which cause the milk fats to separate in the Babcock milk test? Explain the question in detail. 25. Name the four separate fats of which milk fat is composed. 26. What can you say about the reliability of the Babcock test? 27. How about its use for testing skim-milk? 28. Which of the milk fats impart the hard qualities to butter? Which one the soft quality? 29. Which fat is characteristic of butter, and how does butter differ in composition from oleomargarine, etc.? 30. What compound is common to all fats? 31. What is saponification? 32. What is the difference in composition between butter and oleomargarin, etc.? 33. How does milk sugar differ from common sugar? 34. What is produced out of milk sugar when milk sours? 35. How is it produced? 36. What are the conditions favorable for its production? 37. How is the acid in milk determined? 38. Why is not all of the milk sugar made into

lactic acid? 39. Explain the working of the starter. 40. Why is care necessary in the selection of a starter? 41. What is the object of the alkali test for lactic acid? 42. Explain the working of the lactometer. 43. To what extent is it reliable? 44. Explain how it can be used jointly with the Babcock test to tell the character of the milk 45. What effect has the temperature upon the working of the lactometer? 46. How can the test and lactometer be used in determining the solids in milk? 47. Be prepared to give opinions of milk, as fat 2.80, sp. gr. 1.026, watered or skimmed. 48. Draw the three positions of the lactometer: skim-milk, watered milk, whole milk. 49. What can you say regarding the composition of cream? 50. How does the composition of skim-milk vary according to the methods of creaming employed? 51. How is the amount of fat in cream determined? 52· With separator work, what per cent. of fat ought to be returned in the butter? 53. What changes occur to the fat globules while churning? 54. Why is it necessary to churn different creams at different temperatures? 55. How does the ripeness of the cream effect the churning? 56. State the necessary conditions for creaming milk by the cold, deep-setting process. 57. How does the amount of total fat lost in the skim-milk compare with the amount lost in the buttermilk? 58. How does a can of milk set in water at 60° compare as to rapidity and thoroughness of creaming with a can set in water at 44°? 59. How does the amount of water and foreign matter effect the keeping qualities of butter? 60. State the average composition of butter. 61. Show how a difference in the temperature of the washing, working and churning of butter effects the per cent. of water retained in the butter. 62. State briefly what becomes of the various constituents in milk when butter is made. 63. What are the nitrogenous compounds of milk? 64. How does casein and albumin differ in regard to the action of heat? 65. What is rennet, and what two principles does it impart to the milk? 66. Explain the hot iron test and what it is used for. 67. Explain the rennet test and what it is used for. 68. Explain the action of the "starter." 69. How much of the solid matter of the milk is recovered in the cheese? 70. State briefly where the constituents in the milk go in the process of of cheese-making. 71. State how the amount of milk required to make a pound of cheese varies with the composition of the milk. 72. How can skim-milk cheese be told from whole milk cheese? 73. Explain the comparative losses of fat when cheese is made from milk poor in fat, and from milk rich in fat. 74. Give the composition of cheese. 75. What conditions determine the amount of water in cheese? 76. What causes the changes in the curd while in the vat? What is this change similar to? 77. How would you determine the amount of fat in cheese? 78. Give the conditions in cheese-making for the production of a quick-curing and early-market cheese. 79. Give the conditions for making a long-keeping cheese. 80. What is the ripening of cheese? 81. What are the two most important conditions for ripening cheese? 82. How is the amount of moisture in the curing room determined? 83. Explain the construction and workings of the hygrometer. 84. What can you say about the justice for the paying for milk in cheese factories by the Babcock test? 85. How does the amount of cheese produced from a pound of fat compare with different milks? 86. How could you compare the *gross* proceeds for butter-making and cheese-making on the basis of the test? Be prepared to work an example. Don't learn the figures; they will be given you. 87. How are the dividends for either a cheese factory or a creamery to be made out on the basis of the test? Be prepared to work an example. 88. How can you determine the amount of butter that can be made from a certain amount of butter fat on the basis of your own work? 89. What is the composite sample and how is it made use of? 90. What may be used for preserving the milk in the composite samples? 91. How can the test be made when the number of cows in the herd is small? 92. How are the skim-milk test-bottles different in structure from the ordinary test-bottles? 93. What is the ash of milk? 94. What is the value of ash as a food? 95. What is the lime in the milk combined with? 96. What two compounds are found in milk ash in the largest amounts? 97. What is colostrum milk? 98. Why is it called colostrum? 99. What effect has colostrum upon the value of butter or cheese? 100. What is tyrotoxicon? 101. How does the tyrotoxicon get into milk? 102. What is urea and what does an abnormal amount of it in milk signify? 103. What is the (yellow) color of milk due to? 104. What relation does this color bear to the fat content? 105. What are the butter colors composed of? 106. Why is not the use of butter colors adulterating butter? 107. What is lacto-fibrin? 108. What effect has it, as far as kuown, upon the creaming of milk? 109. What are the best proofs of the presence of fibrin in milk? 110. What effect has partial freezing upon the composition of the unfrozen milk? 111. What is the nature of the gases in fresh pure milk? 112. When milk gets old, how does the nature of the dissolved gases change? 113. Give the tests for a good dairy salt. 114. How may an impure salt effect the taste of butter? 115. To what extent is milk subject to change in chemical composition during transportation? 116. What results have been obtained on this question? 117. What is the aeration of milk? 118. When and how should milk be aerated? 119. What effect has aeration upon the quality of cheese produced? 120. How would you determine when it is advisable to mix the milk of fresh cows with the milk of cows well along in their milking period? 121. What is the result of mixing under such conditions when the milk is creamed by gravity process? 122. What effects has delay and cooling upon the gravity creaming process? 123. Why is a delay not advisable? 124. When milk is creamed by gravity processes it is advisable to add very much hot or cold water to the milk? 125. Give three reasons why this is not advisable. 126. What effects have different diseases upon the chemical composition of milk? 127. With only such appliances as found at home, how would you distinguish an unwholesome milk from one that would probably be all right? 128. What four factors mainly influence the sanitary condition of milk? 129. How and why may milk be the cause of the spreading of contagious diseases? 130. State the main difference in composition between mare's milk and cow's milk. 131. Between cow's milk and sow's milk. 132. Between cow's milk and the milk from sheep and goats. 133. Name the four methods employed for preserving milk. 134. Explain the difference between sterilizing and pasteurizing of milk. 135. What effect has the cooling in the pasteurizing process? 136. Why is the use of chemicals objectionable for preserving milk? 137. State how you would pasteurize milk for family use on the small scale. 138. Why is milk sterilized or pasteurized? 139. Why is pasteurized poor milk not as good as unpasteurized good milk? 140. What is condensed milk and how is it made? 141. How about the feeding value of both sweet and sour whey? 142. How does skim-milk differ in composition from whey? 143. How does separator skim-milk differ from deep-setting skim-milk? 144. What can you say about the composition of butter-milk? 145. Why is it objectionable to store old whey in iron, tin, or zinc vats? 146. Why should the old whey or skim-milk never be carried over to the next day in hot weather? 147. What additional feeding value does whey, skim-milk and butter-milk possess in addition to the nutrients which they contain? 148. Why not locate the whey barrel over a large beam or sill? 149. Why is it that skim-milk, whey or buttermilk alone are not complete foods? 150. Why is it preferable to feed skim-milk fully soured rather than partially soured? 151. Why does separator skim-milk, as usually handled, sour so quickly? 152. What can you say regarding the working of the lactocrite and the reliability of the results? 153. In what respects is the

Babcock method superior to other methods, as Short's, Cochrane's, etc.? 154. What can you say regarding the lactoscope, and the pioscope? 155. What is the gravimetric method for fat determination? 156. How is butter adulterated? 157. In what ways may cheese be adulterated? 158. How would you detect a sample of oleomargarin? 159. How could you detect a sample of filled cheese when the skimming has been done by a separator? 160. Why is this test not reliable when the milk has been only partially skimmed? 161. What is the main objection to the use of oleomargarin, etc.? 162. State the average amount of dry matter, digestible protein, and heat units which an ordinary dairy ration should contain? 163. What is the function of the protein of the food? 164. Of the fats and carbohydrates? 165. What is a balanced ration? 166. How would you proceed to calculate a ration? Be prepared to work an example. 167. Why is a bulky ration objectionable? 168. Why is a ration, of very small bulk, yet containing all the nutrients, objectionable? 169. What is gained by feeding a balanced ration? 170. Does the nature of the food influence the percentage composition of milk or does it influence the quality more? 171. What is the fat in milk prodcued from? 172. Explain the effects upon the quality of the butter, of the following foods when fed in large amounts: Cottonseed meal, linseed meal, corn meal, gluten meal, ground oats, coarse rough fodders, ensilage, bran, shorts. 173. What is the effect of an unbalanced ration, as hay and potatoes, upon the quality of butter? 174. Effect of a balanced ration? 175. The odor of ensilage in milk is mainly due to what? 176. What effect has rye pasture (when headed out) upon the taste of milk? Why? 177. Explain the effects of wild mustard, garlic, turnips, and rape upon the taste of milk? 178. How is the flavor produced? 179. What is formed?

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