UTILIZATION OF BY-PRODUCTS OF THE DAIRY.

By HENRY E. ALVORD, C. E.,
Chief of the Dairy Division, Bureau of Animal Industry.

INTRODUCTION.

In making butter or cheese, a raw material (milk) is transformed into a commercial product. The process may therefore be regarded as manufacturing, even if done on a farm where the milk is produced. When milk or cream from a number of farms is brought together at one place to be made into butter or cheese, under either the cooperative or the proprietary system, the establishment is considered a factory, and the industry is properly classed among manufactures. This classification has been adopted by the United States Census, where the butter and cheese made on farms appear as farm products in one volume and the same articles made at creameries and cheese factories are included among the products of manufactures in another volume.

Regarding all butter and cheese making as a species of manufacture, the same principles should apply as to other manufactures. The cost of the work is of great importance, and should be carefully studied with a view to exercising every possible economy. The selling price of the finished product depends upon the market conditions rather than upon cost of production. Any saving which can be made in producing the raw material, or converting it into merchandise, ought primarily to benefit the milk producer, especially if the manufacturing is done under one of the advantageous forms of cooperative dairying.

Experience shows that in most lines of manufacture there are waste products, and upon the careful management of these often depends the difference between profit and loss in the business. The manufacture of butter and cheese may be included in this statement. All cow owners, therefore, who make milk into butter or cheese, as well as owners and managers of creameries and factories, are concerned in studying economy of production, and should be interested in the important subject of the proper utilization of the waste products of the dairy.

QUANTITY OF PRINCIPAL BY-PRODUCTS.

Butter and cheese making result in three well-known residues, which constitute the waste, or by-products, of dairying, namely, skim milk, buttermilk, and whey. For every pound of butter made there are 15 to 20 pounds of skim milk and about 3 pounds of buttermilk, and for every pound of cheese nearly 9 pounds of whey. The
aggregate of these by-products is therefore enormous. The butter and cheese annually produced in the United States leave as residues at least 24,000,000,000 pounds of skim milk, 4,000,000,000 pounds of buttermilk, and 2,500,000,000 pounds of whey. This is about equal to 75,000,000 barrels of skim milk and buttermilk combined and 7,000,000 barrels of whey. It is easier to deal with these quantities by the barrel than by the pound, although the latter would be more accurate. Some people are able to make skim milk and buttermilk worth $1 a barrel, or more, while others find difficulty in getting from it a value of 30 cents. This difference amounts to over $50,000,000, or an average of $4 for every butter and cheese making cow per year. The item is one of consequence, and the way in which these materials can be made to yield the most value is well worthy of careful consideration.

SKIM MILK.

Skimmed milk, or skim milk, should be first considered. It is by far the greatest in quantity of the by-products of dairying, the most valuable and the most susceptible of varied and profitable uses. Skim milk is that portion of milk, or “whole milk,” which remains after removal or separation of the cream. The process of removal is generally known, as skimming, although changes in method have been such as to largely substitute the term “separating.” The object of skimming or separating is to get all the fat out of the milk. The more completely this is done, the better the skimming. Theoretically, skim milk contains no butter fat. Practically, however, it is impossible, by any method in vogue, to remove all of the fat, and therefore skim milk always contains more or less. The quantity depends upon the method of skimming and the skill with which it is done.

METHODS OF SEPARATING THE CREAM.

There are two distinct methods of getting cream from milk, with modifications of both. The older plan is to let the milk rest undisturbed, or “set;” the fatty portion, which is lighter, naturally separates from the watery and heavier part of the fluid, “rises” and forms cream at the surface; this is known as the gravity method. The modern way is to employ mechanical devices which exert centrifugal force and throw the heavier parts of the milk outward from the center of revolution, thus separating the cream; this is the centrifugal method, commonly called the separator plan. The success of the gravity method depends upon the conditions of time and temperature. The milk may be set in vessels shallow or deep. The higher the temperature to which the milk is subjected, the shallower should be the vessels or the body of milk and the longer the time required for creaming. Deep vessels and low temperature, usually secured by setting in cold water, hasten creaming and effect more complete separation of the fat. Mechanical creaming is the most effective, and can be done in the
least time; its completeness depends upon the efficiency of the machine and the skill of its operator.

**Percentage of Fat in Skim Milk.**

There is consequently material variation in the portion, or percentage, of butter fat which skim milk contains, and this is about the only difference of consequence which is found in different lots of skim milk. Centrifugal separators are operated in ordinary practice so as to leave less than 0.1 of 1 per cent of fat in the skim milk; sometimes as little as 0.01 of 1 per cent. A number of trials with machines of eight different styles in this country gave an average result of 0.13 of 1 per cent of fat. A similar set of 171 trials in Germany, with separators of nine different patterns, gave an average of 0.243 of 1 per cent. “At the present time it is considered that where more than 0.1 of 1 per cent of fat is left in skimmed milk a centrifugal machine is not doing perfect work” (Wing). As the separator system is very rapidly extending, 0.1 of 1 per cent of fat may be adopted as the standard maximum fat content of skim milk. Skim milk from separators is the best skimmed; it is superfluous to call it “separator skim milk,” because it is simply skim milk in the best sense, that is, the most completely skimmed. The deep-setting gravity method of creaming, when well managed, leaves from 0.2 to 0.4 of 1 per cent of fat in the skim milk; careless treatment may increase this to 1 per cent, but no such loss is consistent with good dairying, and half of 1 per cent should be the maximum allowed. The old-style shallow-set method of creaming usually results in a comparatively high percentage of fat in the skim milk. This method may be so skilfully managed as to leave not more than 0.3 of 1 per cent of fat, but 0.5 of 1 per cent and more is not uncommon. No dairyman can afford to lose as much as half of 1 per cent in his skim milk, and it is absurd to call any article by this name which contains 1 per cent of fat or more. Such milk is not skimmed, or is but partly skimmed. It certainly is not “skim milk.”

**Composition of Skim Milk.**

A fair standard for the composition of skim milk is 90.5 per cent of water and 9.5 per cent of solids, including the fat. The State of Massachusetts prescribes a legal standard of 9.3 per cent total solids for skim milk. The solids other than fat are casein and albumen, ranging from 3 to 3.5 per cent; milk sugar, from 4.7 to 5 per cent, and ash, from 0.7 to 0.8 per cent. The solids of skim milk sometimes rise to 10 per cent, but it should always be remembered, in using this article, that in 100 pounds only 9 to 10 pounds can be relied upon as being food material; the rest is water.

**The Best Use of Skim Milk.**

The best use to which skim milk can be applied is as human food, in its natural, uncooked state. The value of the article as a desirable
and useful portion of an everyday diet for most people is not at all appreciated. This use of skim milk ought to be very largely increased.

In the course of dietary studies made at the Maine State College during the year 1895 special attention was given to milk, for the reasons stated in the following from the report of Director W. H. Jordan:

(1) Milk has a widespread use as an article of diet, and in all civilized countries is an important item of food supply.

(2) Milk is a very valuable food. It contains a mixture of the three classes of nutrients in forms that are readily digested and assimilated.

(3) Milk is a low-cost animal food in proportion to its value as based upon chemical analysis. It is shown that when milk is purchased at $2 per hundred pounds the cost of a pound of edible solids is 15.7 cents, while the cost of a pound of edible solids in beef at $10.50 per hundred pounds is 34.3 cents. This is a comparison of the retail cost of milk (fresh and not skimmed) with the cost of hind-quarter beef when purchased by the carcass. Beef bought as steak at retail prices would have a much higher comparative cost.

(4) Notwithstanding the high quality and general distribution of milk as a food, it seems by many to be regarded as a luxury in the purchase of which economy must be exercised. This attitude toward this particular food may in part be explained by the somewhat prevalent notion that a free supply of milk in the dietary is not economical, because it is supposed that as much of other foods is eaten as would be the case if the milk were not taken. This belief runs contrary to certain generally accepted facts which relate to the physiological use of foods, and it only remains for experimental data to prove or disprove its correctness. Again, milk is not given full credit by people at large for its true nutritive value. Surprise is generally occasioned by the statement that a quart of milk has approximately the food value of a pound of steak. It is important to demonstrate, for reasons of economy, whether, as is the custom with many, it is wise to purchase the least possible quantity of milk and exercise little care in buying meats.

Trials were accordingly made by which a large number of young men, students at college, were furnished milk as a part of their daily diet, the quantity being varied during successive trial periods. The milk was much relished by a large majority of the students, and at the time the quantity was greatest there was no indication of any effects injurious to health. When after a fixed, although liberal, allowance in one period, milk was supplied to be used ad libitum in the next, the quantity thus voluntarily consumed increased 55 per cent, the increase amounting to about 1 pound of milk per day to each person. It was conclusively shown that such free use of milk diminished the consumption of other foods. In the springtime the additional milk replaced other animal foods, while in the fall it replaced vegetable foods, this by a process of selection entirely natural and almost involuntary. The daily cost of food per man was 8 cents less during the period when milk was furnished in unlimited quantity than when the supply was limited. Following are the main results of these trials, as summarized in the report mentioned:

(1) The cost of the animal foods bought for the commons of the Maine State College during two hundred and nine days was 69 per cent of the total food cost, varying in the different periods from 63.7 to 73.1 per cent. This shows very clearly
the direction in which economy can most effectively be exercised in purchasing a food supply.

(2) The freer use of milk did not, as is supposed by some to be the case, increase the gross weight of food eaten. The extra amount of food consumed replaced other animal foods to a nearly corresponding extent in the first trial and caused a proportionate diminution in the consumption of vegetable foods in the second study.

(4) In both trials the increased consumption of milk had the effect of materially narrowing the nutritive ratio of the dietary, a result which, in view of the recognized tendency of Americans to consume an undue proportion of fats and carbohydrates, appears to be generally desirable.

(5) The dietaries in which milk was more abundantly supplied were somewhat less costly than the others and at the same time were fully as acceptable.

(6) These results indicate that milk should not be regarded as a luxury, but as an economical article of diet which families of moderate income may freely purchase as a probable means of improving the character of the dietary and of cheapening the cost of their supply of animal foods.

In the Maine experiments referred to above, fresh whole milk was used, having a fat content of 3.6 per cent. It can not be doubted, however, that the same general results would have been obtained had skim milk been used instead. To some this would have been less acceptable, but while the total quantity consumed might have been less, the daily cost would also have been still further decreased, and the "balance" of the daily ration would have been still more improved. The use of skim milk instead of whole milk as food, in its natural state, is simply a matter of taste and habit. It must not be forgotten that a quart of skim milk contains more protein than a quart of whole milk, and the former is better and cheaper than the latter as a substitute for meats and other animal foods.

A report upon dietary studies made at the University of Tennessee in 1897, contains the following:

What is needed is to use foods better adapted to the needs of the body; in other words, food which contains more protein. Such are * * * and milk, which is of itself an economical and well-balanced food, and skim milk, which has all the protein and half the fuel value of whole milk, and is, in most localities, the most economical source of animal protein. * * * The nutrients in milk are equal in physiological value to those of meats, and are far less expensive.

SUGGESTIONS AS TO TRADE IN SKIM MILK.

An eminent contributor to the Journal of the British Dairy Farmers' Association lately wrote: "The question of how to dispose of more separated (skimmed) milk to the public without reducing the price of pure (whole) milk, is, to my mind, the most important dairy problem of the day." Earnest effort should be made to accomplish this object. Health and police officials having in charge the regulations for milk supply of cities and large towns should study the problem as one in which producers and consumers are alike interested. The advantages to be gained by an increased use of skim milk will repay the trouble.
incident to devising local methods for preventing fraud in connection with the sale of this article. One way which has proved efficient in some places, is to allow skim milk to be sold only from vehicles, stores, and cans in which no other milk or cream is kept, carried, or offered for sale, all to be plainly marked "skim milk," with, perhaps, the maximum price at which it may be sold. Such restrictions, however, seem to be unnecessary. In the factory towns of New England, skim milk from near-by creameries is sold in large quantities among the families of mill operatives at 4 cents and 3 cents a quart, and sometimes for 2 cents, to the great satisfaction of all concerned. The most common retail price for skim milk is half the price of whole milk at the same place. It furnishes a supply of cheap and wholesome food to those needing it, and has been found to interfere little, if at all, with the regular trade in whole milk. Skim milk is so bulky, compared with its value, less than one-tenth part being useful as food, that transporting it for any distance is very expensive. This difficulty has been partly overcome, in a few instances, by evaporating a portion of the water or partly condensing the milk. A product results which has decided commercial and domestic advantages. There is evidently room for more "plain condensed skim milk" or "partly condensed skim milk" to be advantageously sold in many local markets.

SKIM MILK IN COOKING.

Besides the use of skim milk as human food in its raw state, there are many ways in which it can be advantageously used in cooking. As a substitute for water in preparing various dishes, as well as for others mainly made of milk, there is no waste, but a distinct gain in food value. This is especially true in making bread. Milk adds to the weight and nutritive value of the loaf. Substituted for water, enough flour may be saved to more than pay for the milk, and yet produce a loaf of equal weight and greater food value. As an encouragement to this use of skim milk, the premium list for the annual exhibition of the British Dairy Farmers' Association at London includes prizes for four or five classes of bread made with skim milk instead of water. Two comparisons of the chemical composition of bread made in these two ways are given in the following table, taken from recent reports of the exhibitions referred to:

Comparisons of water bread and skim-milk bread.

<table>
<thead>
<tr>
<th>Kind of bread</th>
<th>Water</th>
<th>Fat</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water bread</td>
<td>39.96</td>
<td>0.12</td>
<td>7.31</td>
<td>53.92</td>
<td>0.29</td>
</tr>
<tr>
<td>Water bread</td>
<td>37.29</td>
<td>0.18</td>
<td>9.69</td>
<td>51.73</td>
<td>1.20</td>
</tr>
<tr>
<td>Skim-milk bread</td>
<td>38.64</td>
<td>0.51</td>
<td>9.19</td>
<td>51.38</td>
<td>0.28</td>
</tr>
<tr>
<td>Skim-milk bread</td>
<td>30.44</td>
<td>0.80</td>
<td>10.24</td>
<td>56.32</td>
<td>2.20</td>
</tr>
</tbody>
</table>
These figures show the milk bread to be richer in fatty matter and markedly superior in the albuminoid or flesh-forming constituents, "due undoubtedly to the casein of milk becoming incorporated with the fibrin of the flour." "It is clear from these comparisons that the milk bread is more nutritious than ordinary water bread." One of the reports further states: "All these breads certainly looked appetizing, and they were most undeniably nutritious. In white bread, especially, the use of milk instead of water gives a loaf an excellent appearance and taste, and the milk not only renders it more valuable as food, but easier of digestion."

Bakers have long known the value of skim milk in bread making, and yet it is not as generally used in this way as it should be. This is partly owing to the unfortunate restrictions in some large cities, which make it difficult for bakers to get the skim milk wanted. One baker gives these reasons for using skim milk largely instead of water: "(1) It makes a loaf which is more moist and will remain moist longer; (2) it makes a closer loaf; (3) it improves the eating quality of the bread; (4) the sugar in the milk caramels in baking and browns the crust." He advises adding the milk when making the dough and not in the sponge.

The general opinion seems to be that the more thoroughly milk is skimmed the better it is suited to the needs of bakers and confectioners. The sale of skim milk to this class of consumers is capable of being very largely increased. (See note, p. 528.)

Used in this way, skim milk may be made to net the producers from 50 cents to $1.50 per hundred pounds, which is better than any other known market, except consumption in the families of the producers themselves.

**SKIM MILK AS FEED FOR DOMESTIC ANIMALS.**

Next to human food, the most profitable use to which skim milk can be applied is in feeding domestic animals of various kinds. Reports and bulletins of the agricultural experiment stations of Europe as well as America contain numerous results comparing skim milk with other articles for stock feeding and showing its successful use, especially with young and growing animals. In numerous cases figures are given which indicate the value which can be obtained from skim milk thus used, but it is safer to accept these values as relative rather than absolute.

The important facts which seem to be proved by these experiments are as follows: (1) Skim milk gives the best returns when fed to very young animals, constituting the greater part of their food; (2) it is next best for animals making rapid growth but which need food other than milk and mainly of a more carbonaceous character; (3) except for the very young, skim milk gives much better results when used in combination with other materials, generally grain, than when fed
alone; (4) no class of live stock gives a better return for skim milk fed to it than poultry of various kinds. The nutritive ratio of skim milk ranges from 1:1.7 to 1:2; it is therefore a highly nitrogenous food and too "narrow" or concentrated to be used alone save in exceptional cases. Hence, the advice is given to feed it usually in combination with some carbonaceous material, like corn meal, to "broaden" the ratio and ration.

**Skim milk for chickens.**—The New York Experiment Station reports growing chickens successfully upon a diet which was mainly skim milk, although they had the run of fields. It was estimated that while allowing 25 cents per 100 pounds for the milk and some other food in proportion, the cost of producing a pound of live weight was less than 6 cents up to the time the birds weighed about 3 pounds. The milk was fed sweet in this case, but it has been found equally satisfactory to use it when loppered and quite thick, and in the latter form there seems to be less waste. Several careful feeders believe skim milk to be worth fully 50 cents per 100 pounds when judiciously fed to turkeys and poultry.

**Skim milk for hogs.**—The greatest number of experiments recorded are in connection with the use of skim milk in feeding swine. Director Henry, of Wisconsin, has written as follows on this subject:

Skim milk has a higher value with stockmen than merely serving as a substitute for grain. All of the constituents of milk are digestible, and this by-product of the creamery is rich in muscle and bone building constituents. The writer conducted experiments in which milk and other foods were fed to pigs for the purpose of ascertaining the effect of these feeds on the muscle and bone of hogs. It was found by actually testing the strength of the bones that milk made the strongest bones of any food that was fed. When we consider the use of this food for bone and muscle building, also remembering its easy digestion and how, by adding variety, it makes other food articles more palatable and probably assists in their digestion, we must hold skim milk as occupying a high place in the list of feed stuffs available on most farms.

From the numerous results reported in pig feeding these items may be taken: Ten pounds of skim milk produce as much gain with young pigs as 15 pounds with maturing swine. With young pigs, 1 or 2 ounces of corn meal (or its grain equivalent) to 1 quart of milk seems enough. The proportion of the grain must be gradually increased until in finishing off pork, with animals weighing 200 pounds or more, the meal may become two-thirds the weight of the milk.

Authorities differ much as to the relative merits of having the skim milk sweet or sour, but the weight of evidence seems to favor sour milk for swine. Yet, the milk must not be too sour; the sugar of milk certainly has food value, and in very sour milk this has been largely replaced by lactic acid. Too much lactic acid is believed to be injurious. In different trials 100 pounds of skim milk has shown a feeding value equivalent to 20 to 28 pounds of corn meal; its money value may be thus easily computed, with the market price of corn meal as
a base. But several experimenters, upon a basis of "4-cent pork," report returns of 20 to 30 cents per hundred pounds of skim milk. Danish experiments give 6 pounds of separated milk as the equivalent of 1 pound of barley or rye, 4 pounds of potatoes, and 8 pounds of mangel beets, when fed to swine. All agree that for economical feeding, while the skim milk may be acid, it must be sound and not putrid; skim milk from neglected, unclean, creamery tanks is often miserable stuff, hardly worth hauling away, and sometimes actually dangerous to feed. The following table of comparative values, taken from the Wisconsin Report of 1895, may be useful for reference:

Comparison of values of corn and milk.

<table>
<thead>
<tr>
<th>Value of corn.</th>
<th>Value of 100 pounds of skim milk.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per ton.</td>
<td>Per bushel.</td>
</tr>
<tr>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>12</td>
<td>33.6</td>
</tr>
<tr>
<td>14</td>
<td>93.2</td>
</tr>
<tr>
<td>16</td>
<td>44.8</td>
</tr>
<tr>
<td>18</td>
<td>50</td>
</tr>
<tr>
<td>20</td>
<td>56</td>
</tr>
</tbody>
</table>

As the result of ten years continued experiments, the Massachusetts Experiment Station advises the following proportions for combining skim milk and corn meal in feeding pigs:

Animals 20 to 70 pounds weight: 2 ounces meal to 1 quart milk; nutritive ratio 1:2.8 to 1:3.

Animals 70 to 130 pounds weight: 4 ounces meal to 1 quart milk; nutritive ratio 1:3.6 to 1.4.

Animals 130 to 200 pounds weight: 6 ounces meal to 1 quart milk; nutritive ratio 1:4.5 to 1.5.

This station reports that it has never been able to get as much as 50 cents per hundred pounds for skim milk fed to pigs.

Skim milk for calves.—Calves appear to be next in favor as profitable consumers of skim milk, and some authorities conclude, after reviewing the records, that calves make greater gains than pigs from a given quantity of skim milk. There has been much prejudice on the part of some against using well-skimmed milk, such as comes from farm separators and separator creameries, especially for veal calves. But there is abundant evidence that good results follow proper care and judicious feeding. The use of whole milk for calves, except for a week or so, is simply wasteful. "One cent's worth of oil meal will do calves as much good as a pound of butter (or butter fat in milk). Besides this, skim milk from a separator, when run through immediately after milking and fed while new and warm and sweet, is better for calves than milk which is old and partly sour, even though the latter contains a quarter of the fat originally in it" (Goodrich).
The Ontario Experiment Station of Canada reports that after twenty years of careful work it is evident that whole-milk calves cost too much, adding: "Skimmed milk and linseed meal are a good substitute for whole milk in feeding calves. A young beast fed on a skim-milk ration, with adjuncts, may be made to weigh almost as much when one year old as one of similar breeding fed on whole milk with adjuncts of a similar character."

The Iowa Experiment Station, which has given particular attention to calf feeding, considers oil meal as too nitrogenous, making the ration too "narrow" except for very young calves. Oatmeal and corn meal are found better to "balance" the skim milk after the first four weeks. The mixture producing the greatest gain at the least cost was found to be nine parts corn meal to one part flax meal, and 1 pound of this mixture was used to 18 or 20 pounds of skim milk to each calf per day, the meal being later increased to 2 pounds a day. Grade Shorthorn calves thus fed made gain at a cost of from 1 to 2 cents a pound, the skim milk being rated at 15 cents per hundredweight. Started on such a ration, the milk was gradually withdrawn after the first one hundred days, and these calves reached an average weight of 760 pounds when one year old, a gain of 660 pounds in three hundred and sixty-five days.

The Minnesota Station, in a trial with younger calves, found that a whole-milk ration cost nearly 10 cents per day and produced no more gain than in some of the calves on skim milk. The latter made an average gain of 1½ pounds per day, at a daily cost of 3½ cents; the feeding period was twenty-four weeks.

At the Massachusetts Station, with veal selling at 4½ cents live weight, the skim milk on which it was raised was made to yield 37 cents per 100 pounds.

Calves for veal may be started on whole milk, gradually shifted to skim milk, and finally finished off with whole milk for a week or ten days, to give them a smooth appearance and improve their sale. In a number of careful trials reported, calves gained 1 pound in weight from 10 to 16 pounds of skim milk.

Calves for beef stock can be profitably raised on a diet largely skim milk, but should be taught to eat hay and grain as soon as possible. Heifers for dairy purposes should grow in a thrifty way, but should not get fat; for these skim milk is the best food of all until they are a year old, wheat bran and middlings being added as soon as they will eat them.

In feeding milk to calves, especially young ones, overfeeding must be guarded against, and the milk can be used to the best advantage when fresh from the separator, and warm, as already described. If skim milk from a creamery is used, great care must be exercised to prevent injury from old or tainted milk. Calves are much sooner
made sick with bad milk than are pigs. If the milk is clean and pure, acidity does not hurt, but dirty and putrid milk is death to calves.

_Skim milk for lambs._—There are few records of carefully conducted experiments in feeding skim milk to lambs. But one at the North Carolina Experiment Station showed the milk thus used to be absolutely lost, and even injurious to some extent, and a similar report from Germany is equally unfavorable, milk being the least satisfactory of a number of food materials compared.

_Skim milk for colts._—The Iowa Experiment Station reports an experiment in feeding colts in which milk was one of the important items, and concludes: “The results of utilizing separator milk for feeding colts may be regarded as highly satisfactory.” Ten pounds of skim milk were found to be the equivalent of 1 pound of grain. This accords with the results in several private trials known to the writer. In Prussia suckling colts are fed some skim milk and also buttermilk.

_Skim milk for horses._—The Cooperative Dairy Association of Hamburg is reported as feeding large quantities of skim milk to its working horses with satisfactory results.

_Skim milk for cows._—A seemingly unnatural use for skim milk, but one which has been reported as satisfactorily practiced in a number of places, is as food for milch cows. Some German accounts are given of mixing skim milk with water, a very little at first and gradually increased until the cows are taught to drink the milk alone. Others describe using milk and meal or bran of some kind to make a paste, and claims are made that in this form 10 pounds of skim milk replace 1 pound of wheat or rye bran, having the same food value with cows. The method of feeding skim milk back to the cows producing it, which has been most practiced and advocated in Europe, originated in Sweden. The milk is heated to 155° or 160° F. for half an hour, then cooled to 100°, and rennet is added. While the milk is thickening an equal weight of chaff or finely cut straw is mixed in, and after being well stirred it is allowed to stand two or three hours in a large tub or tank. The separated whey is then drawn off and poured over the mixture, that as much as possible may be absorbed. The whole mass is then left to ferment from forty to forty-eight hours, according to the weather, when it is regarded as prepared for feeding. Cows are given as much of this “skim-milk feed” as will equal a gallon of milk per day. It is claimed that as thus prepared a gallon of skim milk amply replaces 4 pounds of concentrated grain food. Reports from Sweden, Norway, and Denmark are favorable to this method of utilizing creamery skim milk, and some who have tried it in this country make like reports, while others give a contrary opinion.
CHEESE MADE OF SKIM MILK.

Skim milk may be made into cheese. If the latter is of the "white-oak" variety known in some parts of the United States, it is not easily sold, and the rate of value obtained for the milk is very low. Yet skim cheese has a really high food value, and may be used to advantage in cooking. In Europe both hard and soft cheeses, and several varieties of these, are made from skim milk, and so skillfully ripened or cured as to be readily sold and acceptable to consumers. The conversion of skim milk into cheese of better quality deserves more attention in America. Skim cheese should always enter the market, however, plainly marked and fully identified, as is required by law in several States.

Cottage cheese.—This product, also called pot cheese or smear-case, is a form into which skim milk is easily converted. It is nutritious and a favorite not only as made and used at home, but for sale in the markets of cities and towns. Prices vary so much locally that no reliable figures can be given, but some persons report that they have realized fully $1 per hundredweight for milk thus used, and it is certain that good returns can usually be obtained in this way, and the sale of this kind of cheese might be greatly increased.

Filled cheese.—The article now known by law in this country as "filled cheese" and in Europe as "margarine cheese" has skim milk for its chief component. To the skim milk is added some cheap form of fat, usually of animal origin, but sometimes vegetable, to replace the original fat of milk. The product resulting is, while not too old, a good counterfeit of whole-milk cheese. Laws have become necessary to prevent fraud in selling it and to check the disastrous effects upon the reputation of genuine United States cheese at home and abroad, caused by the substitution on a large scale of this cheap imitation.

FERTILIZER FROM SKIM MILK.

In the various ways described, skim milk can be used, either in its natural state or manufactured, as food for man and beast, and can thus be made to yield a value to the producer ranging from 15 or 20 cents to $1, or even more, per 100 pounds. As in all such cases, the profit will depend largely upon the skill of the feeder or the person who finds the market for the milk or its product. But if use in one or more of these ways is impossible and no sale can be made for other purposes, it must always be remembered that skim milk possesses a positive value as a fertilizer. Its composition is such that when compared with carefully saved animal manures or commercial fertilizers it is regarded as worth from $2 to $2.80 per ton, or 10 to 14 cents per 100 pounds—this, if used in a compost pile and properly managed. It remains for the experiment stations to determine whether skim milk has not a still higher value as a manure, if applied directly to growing crops.
But there are other ways of utilizing skim milk in quantities greater or less, besides its use as a food for animals or plants. The casein and the sugar in skim milk, which are its principal solid constituents, can both be separated and put into commercial form. In separating the curd or casein, whey remains, which contains the sugar and ash and such small quantity of fat as there may be, and this whey will be mentioned later. Casein, when separated and dried, forms a hard, horny, and elastic mass, which can be used in different ways. And (according to Fleischmann) when combined with the oxides and salts of the metals of the calcium group, casein forms a cement-like compound, insoluble in water.

**Paper dressed with casein.**—The principal use for dried casein in this country is for sizing or dressing in the manufacture of paper. For this purpose it takes the place of several kinds of glue, but, as the latter are all cheap, it follows that skim milk can not be worth much to be converted into this commercial form, although the quantity which may be thus used in connection with paper making is almost unlimited. Already there are several establishments connected with creameries or located in the creamery districts of New York and New England engaged in making large quantities of dried casein, the product being contracted for by paper makers.

**Manufacture of dried casein.**—For various reasons it is expedient to make casein in a place by itself and specially prepared, but the building and equipment are not necessarily expensive. The milk preferred is that from separators, containing the least possible portion of fat. It is placed in large tanks arranged for heating and raised to a temperature of 130° F.; 6,000 or 8,000 pounds may be thus handled at once. A special formula of acid is then applied, the best acid or mixture of acids to use and the quantity being secrets of the process. The milk at once coagulates and the curd is precipitated. The whey is then drawn off and the curd broken up to facilitate separation. At this stage the curd is rather stringy and tenacious. It is shoveled out to a draining table with high sides and covered with coarse cloth, where it is further drained and the whey and remaining acid are washed out by running streams of cold water over and through the curd. It is then allowed to drain and dry for two hours, or, instead, it is passed through a hand press and is pressed dry. The curd then becomes more flaky. It is then run through a cheese-curd mill, ground fine, and spread thinly on drying trays which have cloth bottoms. These trays are placed in tiers in a drying oven or flue, heated with steam pipes, and having an upward air draft much like large fruit evaporators. At a temperature of 120° F. it usually requires about twenty-four hours to dry, and the curd is stirred occasionally. It has then reached its commercial form. It is in small, yellowish-
white, irregular lumps, similar to coarse gum arabic. Some skill is needed to prevent too much discoloration. If an undue portion of milk sugar remains in the curd and the heat is too great, the sugar caramelizes and makes the dried curd so dark in color as to be unsalable. When it is quite dry it is put up in 2-bushel meal sacks of 70 pounds weight each and is ready for shipment. For the skim milk to be used for this purpose manufacturers pay from 10 to 15 cents per 100 pounds in different places. From a hundredweight of milk about 3\frac{1}{4} pounds of merchantable dried casein can be made. The selling price to the paper makers is 4 to 7 cents per pound, but of course much depends upon the distance it has to go to be used and the cost of transportation. It is evident that milk thus used does not yield to the producers its value as a feeding material for any class of growing live stock, and in some cases not even its value as a farm fertilizer.

*Use of whey from casein as hog feed.*—The whey, which is a waste product, is too strongly acid when drawn off for any feeding purpose. But it has been found that by treating with alkali and mixing it with more or less buttermilk it can be utilized for feeding swine.

*Fertilizer from casein.*—A few years ago a firm in Pennsylvania desiccated casein in a similar way and offered it as a source of nitrogen to fertilizer manufacturers, but the price obtained did not satisfy those concerned, and that method of utilizing skim milk ceased.

*Casein as a substitute for celluloid.*—There is at least one establishment in this country which converts the casein of skim milk into a form so hard as to be a good substitute for ivory, bone, and celluloid. Billiard balls, backs for brushes, combs, checks, and buttons are among the articles made. The material is sometimes called lactite. It is nearly white, with a yellowish shade, but may be variously colored, and when made black it is a fair imitation of hard rubber. The process of manufacture is similar to that already described for dried casein, but greater care has to be taken to prevent discoloration. The chemical treatment is more complex, and powerful pressure is required to give the final solidity and desired shapes.

**SKIM MILK USED IN WHITENASH AND IN MANUFACTURES.**

For many years the use of skim milk in whitewash has been known to prevent the coating from peeling off, and at one time the Department of Agriculture gave out a simple recipe for making a skim-milk paint. It is mixed with hydraulic cement, or "water lime," so as to make a thin paint, and laid on with a broad, flat brush. One pound of cement to a gallon of milk is the usual mixture. Not more than a gallon or two should be mixed at once for one workman, and it has to be kept gently stirred and used immediately. If stirred too much, it will harden. This makes an excellent, durable, and inexpensive covering for any structure of wood or stone. If nothing but cement
and milk are used, the color will be a light, yellowish brown, but other coloring matter may be added in the form of dry pigment. Another mixture for similar use is sour-milk curd, linseed oil, chalk, and water. Emulsions of olive oil and skim milk are used in wool manufacture as a dressing for the wool.

The following extract indicates other uses for skim milk:

Lactarine or casein gum is almost pure casein specially prepared, which, when dissolved in ammonia, is used for fixing and thickening colors in calico printing. Casein lime or casein cement is made out of skim-milk cheese poor in fat. It is very useful, and is much (?) used in carpentry. The cheese is cut into small morsels, quickly dried, and ground into a fine powder, which is mixed with 20 per cent of burnt chalk. If it be desired to keep it for some time, it must be put into closed vessels and mixed intimately with not more than 1 per cent of camphor. Casein lime comes in fair quantities from Switzerland. (Fleischmann.)

BUTTERMILK AND ITS USES.

Next to skim milk in importance among the waste products of the dairy is buttermilk. The two are much alike in chemical composition, their main difference being physical. Besides this, while skim milk is in most cases sweet when used, buttermilk is uniformly sour, although varying much in the degree of acidity. The total solids of buttermilk average 9.5 per cent; the casein and albumen are rather less in buttermilk than in skim milk, and the fat should be, while the sugar is a little more and the ash about the same. The percentage of fat is the most likely to vary of any of the constituents, this depending upon skill in churning. But with modern methods of well-ripened cream and exhaustive churning at low temperature there is likely to be as little fat in the buttermilk as in well-skimmed milk. The usual nutritive ratio is therefore 1 to 2 or less.

BUTTERMILK AS FOOD.

The best use for buttermilk, also, is as human food, in its natural state and in cooking. Sales are large in many places and might be much increased by proper management. A good article, the real residuum of butter making, taken from the churn and delivered while reasonably fresh, often sells at a higher price than skim milk; it sometimes retails for as much as whole milk. But a great deal of surplus milk in cities and towns, after being "much traveled" and becoming quite sour, is churned for the purpose of changing its appearance and consistency and sold for buttermilk. Such an article, although likely to contain a higher percentage of fat (the same as the milk thus manipulated), is not to be compared with the genuine buttermilk, fresh from the churn of a country dairy or creamery.

LIVE STOCK FED ON BUTTERMILK.

If fed to live stock, buttermilk seems to be best adapted to calves and pigs. For calves it must not be allowed to get too sour nor too old; the animals receiving it should not be very young, and the
change from sweet milk to buttermilk should be made gradually and carefully. As food for swine, some experimenters report better results from buttermilk than skim milk, and some the contrary. At the Vermont Agricultural Experiment Station "the pigs fed buttermilk grew faster and shrunk less in dressing than the pigs fed skim milk. At 13 cents per 100 pounds, the financial returns were considerably in favor of buttermilk; rating both at 15 cents, the two gave about the same profit." In other places the opinion is expressed that buttermilk has about four-fifths the value of skim milk. This is about the relative value of the two articles in the opinion of experienced and observing feeders.

SOURCES, COMPOSITION, AND USES OF WHEY.

Whey is the by-product of dairying remaining to be considered, with its uses. When cheese is made from milk, whether the milk be skimmed or not, the only waste product is whey. And, as already stated, whey results from separating the casein from skim milk for use in the arts.

From every hundred pounds of milk converted into cheese about 90 pounds of whey is obtained, and this includes a large part of the solids of the milk—from one-third to almost one-half of them. Whey itself, a watery, semitransparent liquid in appearance, is composed of about 93 per cent of water and 7 per cent solids. The latter include the greater part of the albumen of milk, which has not been coagulated by the rennet, nearly all the sugar of milk, some of the ash, and small fractions of casein and fat. Stated in figures, average whey contains 0.35 of 1 per cent of fat, 1 per cent of albumen and casein, 5 per cent of sugar, and 0.65 of 1 per cent of ash. The fat may be increased by carelessness on the part of the cheese maker; but if the latter be expert, there will be no serious escape of fat in the whey, however rich the milk. The whey from good cheese making is therefore very uniform in composition and quality, but the solids rise and fall with those of the milk it comes from; the better the milk the better the whey. The albumen is valuable as a food, but the sugar is so largely in excess that whey is a carbonaceous material, with a broad nutritive ratio of about 1 to 6.

Under the most approved processes of cheese making the whey is sweet when drawn off from the curd, or only very slightly acid. Having such a large content of sugar and ample lactic ferment for an active "starter," whey sours very rapidly. Therefore, if the sugar is to be utilized, whether for feeding or manufacture, the whey should be used as soon as possible after coming from the cheese vat or draining sink.

VALUE OF WHEY AS FEED FOR HOGS.

Numerous recorded trials show whey to have considerable value as a food for swine, when judiciously mixed with other material. The
Wisconsin Experiment Station reports that 760 pounds of whey effected a saving of 100 pounds of corn meal and shorts, mixed in equal parts, the latter being worth $12 per ton; the whey was worth 8 cents per 100 pounds. At $15 per ton for the grain, whey was worth 10 cents per hundredweight. Whey was fed in varying quantity, from 2 to 10 pounds to 1 pound of grain. Feeding pigs on whey alone was not successful. In Danish experiments it required 1,200 pounds of whey (from skim milk) to equal 100 pounds of meal. And several trials at home and abroad indicate that whey has just about the same feeding value for hogs as half the same weight of skim milk.

A Canadian experiment is reported where sweet whey and sour whey were compared in feeding to hogs, the trials lasting from six to eight weeks. The results were practically alike, the slight difference existing being in favor of the sour whey. The latter was allowed to get into the condition usual when left in a cheese-factory tank to be hauled away by patrons. Its feeding value was computed at 8 cents per 100 pounds. This result is surprising, as it does not agree with the opinion of many practical feeders or the theory of students. "A little old, sour whey will quickly sour a large lot of new, fresh whey, especially in hot weather. It acts in the same way as the starter in cream, and when the whey sours not only is there a loss of milk sugar, but there is also a loss of albumen. Sour whey will act on bright tin or zinc and even on iron, if allowed to remain in contact with it for any length of time, and will form lactates of tin and zinc, which are poisonous compounds if taken in sufficiently large doses. The lactate of iron is not so much so." (Snyder.) The same writer further states: "A number of comparative trials have shown sweet whey to be more valuable than sour whey for feeding. When sweet, the good effects are secured of the digestive ferments of the rennet that is left in the whey."

WHEY FOR CALVES AND COWS.

Some foreign trials with calves show whey to have had about half the value of skim milk, which is rather more than the general estimate. Sweet whey has also been fed to milch cows, in foreign experiments and satisfactory results obtained where 10 to 20 pounds were given to each animal, in addition to other food.

MANUFACTURE OF SUGAR OF MILK FROM WHEY.

Sugar of milk is made from whey, and generally from the whey of cheese factories. It may be made from whey separated from the skim milk of creameries; but this industry can not accompany that of making dried casein, already mentioned, because the sugar in the whey there separated has been destroyed by the strong acid used in the process.

History and extent of milk-sugar making.—This component of milk was discovered late in the seventeenth century, and during the first
half of the nineteenth century practical methods were invented for separating the sugar from the milk in a white and crystalline form. For many years Switzerland controlled the milk-sugar industry and supplied the markets of the world, although small quantities were made elsewhere. Germany just about supplied her home demand with a product quite inferior to the Swiss. The United States became in time the chief customer of Switzerland for this article, finally taking about three-fourths of the $60,000 worth annually exported from that country. Between 1880 and 1890 the manufacture of sugar of milk began in the United States, and became fairly established in two or three places before the year last named. The article was then mainly used by druggists, and the price ranged from 30 to 35 cents per pound. The tariff act of 1890 placed an import duty of 8 cents a pound on this sugar, which was reduced to 5 cents in 1894, and still stands at that rate. Increased supply has very much reduced the price, which is now 10 to 17 cents per pound for different grades. The duty is relatively higher than at first, and importations have practically ceased. European production has decreased also, because of the relative scarcity and high cost of fuel and the very great improvement in machinery and methods of manufacture in this country.

Milk-sugar making in the United States.—There are now in the States of New York, Ohio, and Illinois four or five factories of considerable size making sugar of milk. Two of these are in operation the entire year, the others only during the active cheese-making season of their localities. All use whey from neighboring cheese factories, for which they pay from 4 to 6 cents, and sometimes 7 cents per 100 pounds, usually delivered at the sugar factory.

The methods differ in these establishments from crude, open, boiling, or evaporating pans, in cheap sheds, to expensive vacuum boilers, powerful filter presses, condensers, centrifugal driers, pebble mills, and other elaborate machinery, in substantial brick buildings. In the simple method there is but one acid and chemical treatment, which, with boiling, is depended upon to remove most of the casein and fat; the purified whey is then treated much as maple sap would be to make sugar. The resulting product is, of course, of comparatively low grade.

In the finely equipped modern factory the chemical and mechanical processes are much more complete, and the sugar is so entirely free from fat, casein, and mineral matter that it will stand the test of complete combustion. These factories each consume from 10,000 to 60,000 pounds of whey per day. From this is recovered 2½ to 3 per cent of its weight in refined sugar, the higher the grade the less the product in quantity. It seems strange that milk in which the chemist finds 5 per cent or more of sugar will not yield more than half this quantity in commercial form under the highly perfected processes of
manufacture, where losses and wastes seem to be almost impossible. Two or three of the factories have branches where whey is reduced to a crude sugar, which is refined at the central plant.

The finished product is prepared for market in different grades and forms. The purest of all, prepared for a special drug trade, is in large, clear crystals, formed on sticks or in "cobs," as they are called, resembling rock candy on a string. This has a wholesale price of 17 cents per pound. Granulated sugar in boxes or barrels comes next, and is worth 15 or 16 cents. Powdered sugar, pure white, and as fine as the finest flour, is the standard product. This is usually packed in barrels of 225 pounds each, and sells at $10\frac{1}{2}$ to 12 cents. A less refined grade is quoted at 9 and 10 cents. Milk sugar in all forms has a very delicate, sweet taste, but is not as sweet as cane sugar or beet sugar. It is mainly used in the preparation of drugs and medicines and various special foods for infants and invalids.

The production of milk sugar a few years ago increased so rapidly in this country that home markets soon became supplied and exports began in the year 1895. There is now a growing demand for the American product in England and Germany. The lowest, or 10-cent, grade, now sent abroad, is an article superior in quality to the best which this country formerly bought in Europe at more than three times this price. One factory in Illinois has a capacity for turning out 16 to 18 barrels per day. This is not only more than is made by all other factories in the United States, but probably more than all made elsewhere in the world. German milk sugar has greatly improved in quality, but the American product now undersells all foreign competitors.

Use of waste at milk-sugar factories.—Waste products accompany the manufacture of sugar of milk. In the large factories these are found in a solid or nearly solid form in the tank precipitates or filter press cakes, and although they have a high fertilizer value, they are usually burned under the boilers. In the simple factories, the albumen, casein, and fat of the whey are largely removed from the boiling vats in the form of a white scum, which is taken off with hand skimmers; there is also more or less curdy precipitate from the vats and pans. Acids and mineral matter have been added in the purifying process. These wastes, well mixed, have been fed while warm to pigs of different ages and with marked success. The mixture seems to be a complete food for swine. The practice has been to buy weaned pigs six, eight, or ten weeks old and feed them absolutely nothing else till ready to butcher. The pigs are kept in open yards, with rough sheds attached, grouped according to ages. They not only grow but fatten, and are ready to kill at six or seven months old. The pork thus made is hard, white, and satisfactory to consumers. The pigs maintain good health. Successive lots of swine have been fed and reared as described in the same yards for four or five years.
without disease or any apparent sickness. This milk-sugar factory waste has not been analyzed, but it evidently contains all needed elements, and is undoubtedly highly nitrogenous, forming quite a “narrow” ration.

WHEY BUTTER AND WHEY CHEESE.

If the whey from a cheese factory appears to have enough fat in it to justify the labor, the fat is collected or separated and made into a low grade of butter, used for “dressing” cheese while in the curing room. This is whey butter or cheese grease. A whey cheese is also made, known as Mysost, in the northern European countries and in Scandinavian settlements in America. It consists chiefly of milk sugar, but contains also the albumen, fat, and ash of whey. It is molded in brick form, has the color of chocolate, is about as hard as ordinary cheese, slightly granular, and has a peculiar, sweetish taste. Ziger cheese is another European product from the whey of rennet cheese making, well known in Switzerland and Germany. Mysost is dry, less than 25 per cent water, strong in sugar and fat, and low in protein; Ziger, on the contrary, is very soft, being two-thirds water, and is strong in protein, while low in sugar and fat.

WHEY FOR INVALIDS.

Finally, ordinary whey has been considerably used for invalids and convalescents, especially in cases of lung and chlorotic diseases, mainly as an aid to digestion. An article known as “wheyn” has been patented, which is a purified and sterilized whey, free from albumen and fat, and constitutes a nourishing and mildly stimulating beverage.

NOTE.—Since the foregoing matter was put in type a new skim-milk product has taken commercial form, under the name of “faracurd.” Skim milk is so separated that the whey carries practically all the sugar and ash, while the albumen, coagulated, and the casein are preserved together, and with these is mixed a very small quantity of fine wheat flour. The only purpose of the latter is to act as a divisor and keep the casein from hardening in mass. Faracurd is preferably in the form of a thick paste, but may be dried and powdered. It is used by bakers and confectioners, being found an excellent substitute for eggs in many bakery products. Provided this article meets present expectation, it will give a new outlet for large quantities of skim milk; and since the product can be sold for less than half the price of its practical equivalent in eggs, it will thus yield at the rate of more than 50 cents per hundredweight for the milk consumed.