U. S. DEPARTMENT OF AGRICULTURE.

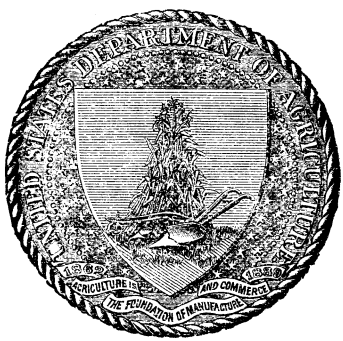
FARMERS' BULLETIN No. 29.

SOURING OF MILK

AND

OTHER CHANGES IN MILK PRODUCTS.

PREPARED IN THE OFFICE OF EXPERIMENT STATIONS.



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UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., June 15, 1895.

SIR: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on the fermentations of milk and its products and the means of preventing or controlling them. This bulletin is a revision of Farmers' Bulletin No. 9, on Milk Fermentations and their Relations to Dairying, which was originally prepared from a review by Prof. W. H. Conn of the investigations on the fermentations of milk. Considerable new matter has been added, especially on the practical bearing of these fermentations on the care and handling of milk and on butter and cheese making. The revision and additions have been made on the basis of a later article by Professor Conn, bringing the subject down to the present time. These matters are assuming more and more importance every year as they are better understood. As rapid progress is being made in dairy bacteriology, especially in its application, it is important that farmers and dairymen should be given the latest available information.

Respectfully,

E. W. ALLEN,
Acting Director.

Hon. J. STERLING MORTON,
Secretary of Agriculture.

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SOURING OF MILK AND OTHER CHANGES IN MILK PRODUCTS.

INTRODUCTION.

The souring of milk is due to the action of minute organisms known as bacteria. These bacteria are so minute that they can be seen only by the aid of a powerful microscope, but the result of the concerted action of myriads of them in souring milk is a familiar sight to every housewife. Besides the ordinary souring of milk, there are many other changes which may take place—as the ripening of cream, the ripening of cheese, butter becoming rancid, and many others less common. These changes are called fermentations, because they are similar to the fermenting of cider to vinegar, the fermentations produced by yeast in beer making, etc. The term includes many changes due to other microorganisms or ferments besides bacteria; and so here fermentation is used to cover all the changes which occur in milk, such as curdling, souring, and putrefaction, most of which are caused by bacteria. The great importance of these fermentations of milk is being realized. It is only by a proper control of them that good butter or cheese can be made. It is important that they should take place, but it is equally important that they should not be allowed to get the upper hand. To insure an understanding of these fermentations of milk some knowledge of the chemical composition of milk is necessary.

COMPOSITION OF MILK.

While the composition of milk obtained from different cows and produced under different conditions shows wide variations, a fair average composition may be given as follows: Water, 87 per cent; solids, 13 per cent. The solids include fat, 3.6; casein, 3.3; albumen, 0.7; milk sugar, 4.7; and ash, 0.7 per cent. The casein and albumen are the materials containing nitrogen, and are of special importance in cheese making. In general, the ash, sugar, and albumen are in solution, the casein in partial solution, and the fat in suspension, but not dissolved in the milk.

Milk fat consists of a mixture of several fats. As its composition begins to undergo changes almost immediately after the milk is drawn, its exact condition at any moment is very uncertain. It is distributed throughout the milk in the form of minute globules, varying in size. On

standing, or by treatment in a separator, the fat globules, being lighter than the rest of the milk, separate and form cream, the skim milk containing casein, sugar, and all other milk constituents. The whiteness of milk has usually been attributed to the presence of these globules of fat, but it is probably due largely to other ingredients of the milk, in part to the phosphate of lime which milk contains.

CAUSES OF FERMENTATION.

The organisms and substances concerned in the fermentation of milk may be divided into two distinct classes, namely, organized and unorganized ferments. The former include the minute living organisms (microorganisms), such as bacteria, yeasts, etc., which by their growth cause changes or fermentation.

The unorganized or chemical ferments, on the other hand, are substances devoid of life, which are capable of causing certain chemical changes in other substances without themselves being changed. Rennet and pepsin are familiar examples of unorganized ferments.

Bacteria proper, which have most to do with milk and cream, are found in immense numbers everywhere, and play an important part in nature. They are all extremely minute. In shape they show three chief varieties, which may be compared, respectively, to a lead pencil (*bacillus*), a ball (*coccus*), and a corkscrew (*spirillum*). With the highest powers of the microscope they appear as scarcely more than simple dots and lines. They are to be classed with plants rather than animals, in spite of the fact that many of them are endowed with motion.

The isolation and cultivation of a single kind of bacteria is a matter requiring the greatest care. Although imperfectly studied as yet, many different forms are known, which are distinguished by their habits of growth, the substances in which they thrive, and the changes which they produce in various substances as a result of their growth. Bacteria are cultivated in beef broth, gelatin, and other substances, which, when used for these purposes, are called *cultures*. What is known as a *pure culture* contains only one kind of bacteria.

Yeasts are also plants of a low order, which grow very rapidly in certain substances, and thus cause changes, which are commonly called fermentations. The most common kind of yeast is that used in making beer and raising bread. Yeasts have very little to do with dairy processes.

SOURCES OF BACTERIA IN MILK.

It has long since been ascertained beyond question that pure milk, drawn from a healthy cow, contains no bacteria, and that all bacterial contamination of the milk comes from external sources. While this fact has been redemonstrated by the most recent work, it has appeared that the statement must be for practical purposes quite considerably modified. In the first place, the difficulties which lie in the way of

obtaining milk from the cow without bacterial contamination are extremely great and sometimes seemingly insurmountable. Of the many attempts which have been made to obtain milk in this way which shall from the first be sterile, most have proved failures. Enough of them have met with success to demonstrate the general position; but so many of them have been unsuccessful as to show the extreme difficulty of obtaining sterile milk in this way. In spite of cleanly methods, of sterilized vessels, and of the greatest care to prevent dirt and dust from falling into the milk, the milk when first drawn from the cow has in the large majority of cases contained bacteria. The explanation of this fact has proved to be in the ease with which the milk is contaminated in the milk duct. The milk duct is, of course, open to the air, and it will contain at the close of the milking a considerable amount of milk adherent to its walls. Bacteria from the air have no difficulty in making their way into the duct, growing there, and becoming extremely numerous. The result is that by the time of the next milking the milk ducts contain bacteria in great numbers, and these will inevitably contaminate the milk. It has been suggested that the bacteria not only enter into the milk ducts between the milking, but that some of them actually make their way into the very depths of the milk gland itself, and there grow and multiply. Undoubtedly the milk gland of the healthy cow produces milk which is uncontaminated with bacteria, but the large caliber of the milk duct makes it possible for the bacteria to grow in the duct to considerable extent, so that it becomes a matter of extreme difficulty to obtain milk from the cow, even with the greatest precautions, which shall not be contaminated.

Of late the air has come to be regarded as a less important source of contamination than formerly. It is of course true that milk does receive some bacteria from the air during the milking. In an ill-ventilated stall, filled with dust from hay, bacteria will be floating in the air. When the milking occurs quantities of dirt and dust are brushed from the undersides of the cow's body and fill the air in the immediate vicinity with bacteria; but such contamination is to be charged to the hay or dirt on the cow rather than the air.

The milk vessels themselves are an important source of contamination, as are also the hands and clothing of the milker. The milker seldom makes a cleanly toilet before milking, and any dirt upon his hands or upon his clothing will have abundant chance to get into the milk vessels. The ordinary water in which the milk vessels are washed, and especially with which the milk is too frequently diluted, is also regarded as a very important source of bacteria contamination, particularly in connection with certain disease germs, like those of typhoid fever. But a more careful consideration of the work of the last few years shows that the great sources of bacteria contamination are from the cow itself, not, as we have seen, from internal, but from external sources.

Anyone who has noticed the uncleanly condition in which the cow is kept on the ordinary farm will readily appreciate this possibility.

The other sources of dirt are very great. The hairs of the cow are always covered with dirt and dust, and it is impossible for the milker to avoid a considerable amount of this dirt falling into his milk pail. Every one of these hairs which finds its way into the milk will furnish large quantities of bacteria for contamination. Milk drawn into a sterilized vessel was found to contain 520 bacteria per cubic centimeter, but when drawn into a flaring pail, with considerable disturbance of the udder and bedding, the number rose to 30,000 per cubic centimeter. When we examine the amount of solid material which finds its way into the milk we are amazed at the results. If ordinary milk is allowed to stand for a number of hours a sediment may be collected which is wholly extraneous matter, and must be regarded as dirt contamination. This dirt is largely composed of manure, and most of the rest can be traced directly to the cow.

We must, then, regard external conditions connected with the cow as the great and the most important source of bacteria that contaminate milk. We must also recognize that occasionally diseased udders are a source of milk contamination. In such cases there is probably active bacteria multiplication in the interior of the gland, and consequently abundant internal sources of milk contamination.

There is now also abundant evidence for the conclusion that the milk of tuberculous cattle, at least in certain stages of the disease, may be contaminated with the tuberculosis germ. This appears to be true at all events after the disease has attacked the milk glands, and possibly before. The great prevalence of tuberculosis among cattle makes this source of milk contamination one of considerable importance. There is also evidence that diphtheria may affect the cow, and that at least under some conditions the cow thus affected may serve as a source of diphtheria contamination to the milk.

It will be seen in general, then, that in dealing with healthy herds the greatest source of contamination is the bacteria in the milk duct and the dirt on the hairs of the cow. The next greatest source is the milk vessels and the milker himself. Lastly, and to a very slight extent, we must look upon air as a source of contamination, but if care be taken of the food and dirt on the cow little need be feared from the air itself.

There are other sources of milk contamination after the milking. Probably some of them are of considerable importance, although none of them for practical purposes have so much importance as those mentioned.

NUMBER OF BACTERIA IN MILK.

The work of the last few years has emphasized the fact that the number of bacteria present in milk is of very little significance. The widest possible variations in these numbers seem to be found under almost

identical conditions. While it is true that the general purity of the milk can be estimated by the number of bacteria that it contains, this is only true to a limited extent, and not infrequently the presence of large numbers of bacteria is possible even in very good quality of milk. At no time in the history of the milk can anything like uniformity in the numbers be given. Immediately after milking the number may vary from zero to over 10,000,000 in a single cubic inch of milk. The number depends upon various conditions of cleanliness. After the milk is drawn the bacteria begin to multiply rapidly, and the number present at any moment subsequently will depend simply upon the temperature at which the milk is kept and upon the species of bacteria present. Some species seem to multiply rapidly and to reach higher numbers than others. The favorable influence of warmth on the growth of bacteria makes more evident the value of keeping milk as cool as possible from the very outset, if we wish to avoid the troublesome growth of bacteria. For a day or two the bacteria increase with great rapidity, then their multiplication is checked, and finally they entirely cease to grow. This can not, of course, be due to a lack of food, for there is plenty of food in the milk at all times. It is rather to be attributed to the accumulation of the products of their action. Those growths which produce an acid will soon be checked by this, for bacteria can not grow in an acid medium. The amount of acid formed before the growth is checked will vary, however, for some species of bacteria are very sensitive to acid, while others will endure a larger amount without injury.

In regard to the milk supply of cities and towns, the number of bacteria varies very greatly. An important factor is the time between milking and delivery to customers. In large cities this often amounts to twenty-four or thirty-six hours. When this is the case it is necessary to keep the milk on ice, and by doing so the milk is kept fairly fresh. Judging from tests thus far made, city milk which contains not more than three or four million bacteria per cubic centimeter may be regarded as exceptionally good for European cities. No general average of American cities can be made, but the probability is that the milk supply delivered in our large cities, by the free use of ice, is in general superior to that of the milk supply of European cities. The milk of large cities contains more germs than that of small communities, but is probably no more harmful.

KINDS OF DAIRY BACTERIA.

Considerably over two hundred distinct types of ordinary milk bacteria have been described in literature up to the present time, and all of these will be found, in the descriptions given, to differ from each other. Most of them have been named or numbered by the persons who describe them. They have been found in various dairy products, in fresh milk, in old milk, in butter, cream, and cheese.

Some produce very pleasant flavors in the milk and cream; others produce decidedly unpleasant flavors; some of them are excessively troublesome to the milkman, but favorable to the butter maker; others are troublesome wherever they appear. In short, the effect of the different bacteria upon milk is extremely varied, so that the forms of fermentation are almost as numerous as kinds of bacteria themselves.

THE SOURING OF MILK.

When an acid, as acetic acid (the acid of vinegar), is added to milk the milk curdles, and we have the phenomenon of sour milk. Popularly it may be said that in the common souring of milk organisms in the milk act upon its constituents, notably the milk sugar, and produce from it acids, which give the milk a sour taste and curdle the casein, making the milk thick. Commonly, lactic acid is the principal acid formed, although smaller quantities of a number of other acids usually accompany it. Hence the normal souring of milk is spoken of as lactic fermentation. While the spontaneous souring of milk is an almost universal phenomenon, it is not always produced by the same or even very closely allied organisms. Occasionally the milk in a large number of dairies in one locality will be found to be soured by the same species of bacteria, while in other cases the spontaneous souring may be produced by different species in dairies at no great distance from each other. Sometimes, indeed, this spontaneous fermentation is absent. Certain herds of cattle have been noted whose milk does not sour, but will after a time undergo other types of fermentation. It is also a fact that not infrequently in the winter months milk is found not to undergo the souring spontaneously, but may be kept for a long time without curdling, and when it does show signs of fermentation the type is entirely different from that of normal milk souring.

It is probable that the decomposition of milk may take place in a number of different ways. While we are certain that the fermentation of milk, commonly known as souring, is caused by bacteria, we have yet much to learn regarding the details of the process.

SUPPOSED EFFECT OF THUNDERSTORMS ON THE SOURING OF MILK.

A consideration of the subject of the souring of milk would not be complete without reference to the effect of electricity. The popular belief that thunderstorms will sour milk is so widespread that it would seem as if there must be some foundation for it. It has been asserted by many that the ozone produced in the air by electricity causes the milk to become sour. In experiments in which electric sparks were discharged over the surface of the milk, however, little or no effect has been produced upon it. The conclusion is that electricity is not of itself capable of souring milk or even of materially hastening the process. Nor can the ozone developed during the thunderstorm be looked upon

as of any great importance. It seems probable that the connection between the thunderstorm and the souring of milk is one of a different character. Bacteria certainly grow most rapidly in the warm, sultry conditions which usually precede a thunderstorm, and it frequently happens that the thunderstorm and the souring occur together, not because the thunder has hastened the souring, but rather because the climatic conditions which have brought the storm have at the same time been such as to cause unusually rapid bacteria growth. This fact has been verified by many experiments which have shown that without the presence of lactic organisms there can be no spontaneous souring of milk. Milk deprived of bacteria will certainly keep well during thunderstorms. Dairymen find no difficulty in keeping milk if it is cooled immediately after being drawn from the cow and is kept cool. Milk submerged in cool water is not affected by thunderstorms. Dairymen find that during "dog-day" weather, even when there is no thunder, it is just as difficult to keep milk as it is during thunderstorms; and they also find that scrupulous cleanliness in regard to the milk vessels is the best possible remedy against souring during a thunderstorm. It is safe to conclude, therefore, that in all cases it is the bacteria which sour the milk, and if there seems to be a casual connection between the thunder and the souring it is an indirect one only; climatic conditions have hastened bacteria growth and have also brought on the thunderstorm. The same conditions would affect the milk in exactly the same way even though no thunderstorm were produced, and this effect, our dairymen tell us, is frequently observed during the warm, sultry autumn days.

OTHER FORMS OF FERMENTATION OF MILK.

Students have not recognized until within recent years that a great variety of fermentations may occur in milk. The reason for the tardiness of this discovery is easily seen. Under ordinary conditions milk always undergoes some sort of lactic fermentation (souring). Only under rare conditions is this absent. The production of lactic acid soon curdles the milk and immediately obscures all other forms of fermentation which have occurred during the process. The acid also stops the growth of all bacteria, so that no subsequent effect can be seen. Hence in normal milk clear evidence of fermentation of any other sort than souring is rarely noticed.

The later studies of this subject, however, have shown the great variety of form of organisms in milk, and the many different results of their action. Thus, while one class of organisms, as we have seen, curdles milk by the production of lactic acid, another class gives it an alkaline reaction, at the same time curdling it; others impart to it a deep blue, violet, yellow, green, or red color by the production of pigments in the milk; others give it a bitter or other unpleasant taste; another class produces alcohol from the milk sugar, which fact is taken advantage of

in the preparation of such beverages as koumiss and kefir, and still others cause putrefaction. Some of these forms of fermentation will be briefly noticed:

BUTYRIC ACID FERMENTATION.

The characteristic of this fermentation is the production of butyric acid. In the ordinary handling of the milk this class of organisms is of little importance, but it has been supposed that they have an important effect upon the keeping properties of butter. Rancid butter contains considerable quantities of butyric acid, and the development of the rancidity is simultaneous with the appearance of the butyric acid. When it became known that many species of bacteria produce butyric acid and that there are many bacteria in butter, it was a natural inference that the rancidity is produced by them. It is probable that the ordinary rancidity of butter is the result both of fermentation and chemical oxidation, although rancidity may occur when bacteria are entirely absent.

ALKALINE FERMENTATION OF MILK.

The fermentation of milk is not always accompanied by the production of an acid. Everyone who has had an extended experience with milk has seen instances of milk curdling without the usual acid taste, and it is a familiar fact that curdled milk is by no means constant in character. There is the greatest variety in the stiffness of the curd, the amount of the whey, the taste, odor, etc., and all these differences are due to varying numbers and species of bacteria other than the lactic acid class.

The milk may become coagulated into a soft, slimy mass, which usually possesses a bitter taste. The taste is never sour, and the milk, instead of having an acid reaction, is either alkaline or neutral. After a day or two the curd begins to dissolve into a somewhat clear liquid, and, if the action is allowed to continue long enough, may become completely dissolved into a semitransparent liquid having no resemblance to milk.

In the ordinary handling of milk the class of organisms included under this head of alkaline ferments is of little importance. They grow slowly, and the lactic-acid-forming species usually get the start of them, producing their own marked effect on the milk, so that the action of the alkaline species is entirely obscured. Moreover, the acid-forming species soon produce so much acid that the growth of all bacteria is checked. At the same time these species are of the greatest importance in dairy matters. In the first place, many of them form resisting germs which will endure high temperature and render the process of sterilizing milk by heat very difficult. They are always present in milk which has been standing for a short time, and sometimes their abundance is great enough to produce noticeable effects.

SLIMY FERMENTATION.

A slimy fermentation of milk is a somewhat common occurrence, and occasionally produces great trouble in dairies, since it destroys the milk for all ordinary uses. Slimy milk will furnish no cream. It can not be churned, and it is ruined for drinking purposes. Slimy fermentation, however, is made use of in the manufacture of Edam cheese.

There has been the greatest variety of theories as to the cause of slimy milk. Diseases of the mammary gland, variations in the food of the cow, and differences in conditions surrounding the dairy have all come in for a share in the explanation. But the slimy fermentation of milk has been found to be connected with a large variety of organisms. Some of them give to the milk only a slight sliminess, while others render it tenacious almost beyond belief. One, described by Conn, renders milk so slimy that it can be drawn into threads 10 feet long and so small as to be hardly visible. Some of the organisms render milk slimy in their early growth, others only after several days, and some do not render the fresh milk slimy at all, but first curdle it and then dissolve the curd into slimy solution.

BLUE MILK.

This fermentation, characterized by the deep blue color which has given it its name, occurs sometimes as an isolated trouble in individual dairies, and sometimes it has become so prevalent in certain localities as to be almost an epidemic. The explanation now given for blue milk is a double one. Ordinary milk contains some of the lactic acid organisms, and these, acting in connection with another species of bacteria, produce the brilliant blue color which characterizes this infection. When growing in ordinary milk the effect of this organism is very marked. For a few hours no change is noticed, but just about the time when the milk begins to become acid some intense blue patches make their appearance. The faster the acid forms the quicker the coagulation appears and the smaller are the blue patches, while if the acid is produced more slowly the blue patches are larger and of a better color.

Where the blue-milk organism comes from is unknown, nor have we any knowledge of the causes of the occasional epidemics of blue milk. There can be little doubt that the cause is always some unknown source of filth. In some cases the trouble has been traced to a single cow in a large dairy, and has been easily stopped by isolating the individual found to be the cause, or by carefully washing the cow's teats with a little weak acetic acid solution. Blue milk is always an infection due to outside contamination, and its remedy is always to be found in care and cleanliness. It does not occur in the carefully kept dairy.

Blue milk appears to be harmless. It has been fed to animals, which eat it readily and without harm. Within a few years blue cheese has been brought to the attention of scientists, and has been attributed to the same organism which produces the trouble in milk.

BITTER MILK.

Several organisms have been described which impart a bitter taste to milk. Recently two new forms have been isolated from bitter cheese and bitter cream. The bitter taste appears to be due to the production of a special bitter substance produced by the organisms. This substance has been isolated, but its nature is not definitely known. In one instance bitterness in milk was produced in a whole herd by feeding to the cattle turnips which had been washed in foul water. Whether it was due directly to the turnips or to the water in which they were washed was not ascertained, but the conditions were such as to point plainly to microorganisms as the direct cause.

SOAPY MILK.

A type of dairy trouble called soapy milk has been recently described. The milk frothed badly, failed to sour, and had a soapy taste. It was a troublesome infection, rendering the cream difficult to churn, and practically destroying its value. It was traced to bacteria on the straw used for bedding the cows. The trouble ceased after the straw was discarded. Another case of soapy milk was traced to the hay, on which the same bacteria were found as on the straw.

FERMENTATION OF MILK BY RENNET.

Rennet is a preparation usually made from the stomach of a calf, and has the power of coagulating the casein of milk in a very short time. This curdling of milk by rennet is the only form of fermentation of milk known which is produced by an unorganized ferment; i. e., one devoid of life.

When rennet is added to milk, a portion of the nitrogenous constituents of the milk is thrown down, and forms the curd which is made into cheese. Another portion, being soluble, goes into the whey and is lost to the cheese maker. The amount of protein thus lost may be still further increased through the action of bacteria, which have the power of making even curdled casein soluble; and this fact teaches the advisability of using rennet in a manner which will produce the coagulation as quickly as possible. The rapidity of the action will depend upon the relative amount of rennet and the temperature, and may be lessened by alkalies and increased by various salts.

The active principle of rennet is a chemical ferment which is distinct from other digestive ferments in the stomach juices. It is destroyed by a temperature of 158° F., and it acts best at about 95° F. It seems to be somewhat widely distributed in nature among animals and plants, and it is a common product of bacteria growth. Milk bacteria producing the rennet-like curdling are abundant, and their share in the ordinary fermentations of milk is not a small one, especially in cool weather. In the keeping property of butter they doubtless play a part, though they are not the sole cause of rancidity. In the ripening of

cream for churning their part is still greater, and in the ripening of cheese they are of the utmost importance. Undoubtedly we may trace many of the difficulties of the butter and cheese maker to bacteria of this class. A further knowledge of their action will be of great value to the dairy interest.

PRACTICAL BEARING OF THE SUBJECT UPON DAIRYING.

It is becoming more and more evident every year that the bearing of these fermentations upon dairying is of the utmost importance. The practical application of our knowledge of the fermentations of milk will concern each of the three chief dairy products—milk, butter, and cheese.

HANDLING OF MILK.

To those dealing with milk itself in any form the various fermentations are especially undesirable and are constant sources of trouble. Such persons want the milk pure and sweet, and any of the various forms of fermentation injure the milk for their purposes. Our study of milk fermentations has taught us that the cause of all these fermentations, even the common souring, lies in the contamination of the milk from without, and that the remedy lies in the exercise of extreme cleanliness. If there has been anything taught in regard to these matters it is the extreme necessity for cleanliness. Poor milk, poor butter, and poor cheese are, in a vast majority of cases, to be attributed to uncleanliness in the barn or dairy. The great source of bacterial contamination of the milk is *the cow herself.* This does not mean the bacteria from the mammary gland, but those connected with the exterior of the cow. It is true that there are other sources of importance. The food that the cow eats (indirectly), the cow stall itself, the water with which the cans are washed or with which the milk is adulterated, the hands of the milker as well as his clothes, are all occasionally the sources of bacteria contamination. But after all we must look upon the cow herself as the cause of the most trouble. From the cow the bacteria get into the milk during the milking, partly from the milk ducts, partly from the dirt that is attached to the cow, and in no small measure from her dung. We thus learn that the important point toward which to direct the cleanliness is the cow herself. The farmer never appears to feel that it is necessary for him to keep his cows as clean as he does his horse. But there is very much more real need for cleanliness in the case of the cow. Upon such cleanliness will depend his ability to obtain a pure, wholesome milk, while so sure as he allows his cow to become covered with dirt and manure so sure will he be liable to have trouble with the milk. So it is well to repeat that the last few years have taught us, above all things, that the great secret of obtaining a proper supply of milk is to have a *healthy cow and to keep that cow clean.*

Another fact of importance which has been emphasized is the value of cooling the milk as thoroughly as possible as soon as milked. When drawn from the cow, milk is at a high temperature, and, indeed, at just the temperature at which the majority of bacteria will grow the most rapidly. Under the influence of the atmospheric temperature, especially in the summer, the milk will become cool very slowly, but never becomes cooler than the air. The bacteria which have gotten into the milk will therefore have the very best opportunity for rapid multiplication and the milk will sour very rapidly. If, however, the milk is cooled to a low temperature immediately after it is drawn, the bacteria growth is checked at once and will not begin again with much rapidity until the milk has become warmed once more. This warming will take place slowly, and therefore the cooled milk will remain sweet many hours longer than that which is not cooled. A practical knowledge of this fact will be of great value to every person handling milk. Early cooling to as low a temperature as is practicable is the best remedy for too rapid souring of milk.

It is well to notice that certain abnormal odors and tastes in milk may be produced directly by the food eaten by the cow. If a cow eats garlic or turnip the flavor of the milk is directly affected. Various other foods may, in a similar manner, affect the taste of milk, but this class of taints may be readily distinguished from those due to bacteria growth. The odors and taints due to the direct influence of the food are at their maximum as soon as the milk is drawn, never increasing afterwards. But the taints due to bacteria growth do not appear at all in the fresh milk, beginning to be noticeable only after the bacteria have had a chance to grow. If, therefore, a dairyman has trouble in his milk, which appears immediately after the milking, he may look for the cause in something the cow has eaten. But if the trouble appears after a few hours, and then grows rapidly worse until it reaches a maximum, he may be assured that the cause is some form of fermentation, and that the remedy is to be sought, not in changing the food of the cow, but in greater care in the management of the dairy or barn.

Dairy inspection.—In this connection the desirability of an inspection of the dairies and herds furnishing milk for cities and towns may be mentioned. Our laws have furnished us with a milk inspection which protects our pocketbooks, but we are learning that the adulteration of milk by water is really of far less importance to the public in general than the contamination of the milk by improper types of microorganisms. We have learned, as already pointed out, that milk is occasionally contaminated with disease germs, such as tuberculosis, typhoid fever, diphtheria, scarlet fever, etc., but that such organisms come only from cases of disease, either diseased cattle, which directly contaminate the milk, or diseased persons, who indirectly are a source of such contamination. There is no need of milk becoming contaminated by any of these disease germs, with a possible exception of tuberculosis, if care

and scrutiny is used by the milk producer to prevent the milk from diseased cattle being distributed, and to prevent its being placed under conditions for secondary contamination from diseased persons.

With all these facts in mind, it becomes plain that the proper public precaution against the evils resulting from such contamination is to be found in some system of dairy inspection, by means of which the public may have a direct knowledge and direct control over the conditions of its milk supply. Already such a dairy inspection in one form or another has been attempted in several places. In some other places it is being demanded by State boards of health.

The chief advantage in such dairy inspection is to the milk producer. In Switzerland and in the United States the plans started with the dairymen. Of course the advantage is also largely to the public community, but the producer of the milk will in the end gain the greatest advantage in increased confidence which the public may have in his product. At the present time the public is rapidly becoming suspicious of the healthful qualities of our milk supply, and just so far as this suspicion can be allayed by the inauguration of a proper dairy inspection just so far will the milk industry be benefited.

BUTTER MAKING.

It is the custom of butter makers to allow their cream to "sour," or "ripen," for a number of hours before churning. This is accomplished by allowing it to stand in a warm place for twelve to twenty-four hours. As it is everywhere recognized to-day, the ripening of cream is simply a matter of bacteria growth, and whether the cream is ripened in a proper (normal) or in an improper (abnormal) manner depends upon the number and kinds of bacteria that chance to be in it at the beginning of the ripening.

Among the number of kinds of bacteria found in the cream there are a few species whose growth in the cream produces there a pleasant, desirable aroma and flavor. These species are seemingly fewer in number than the others, but it is to their presence that a good butter is due, and it is with little doubt largely the presence of these species in June cream and their absence in January cream that gives June butter a better flavor than winter butter. Now, the butter maker in ripening his cream will always produce in it a certain amount of acid from the lactic organisms, and even if he has no proper flavor-producing species present the butter that he obtains will be a moderately good product, provided he does not happen to have any of the mischievous species present. He knows well enough that during certain seasons in the year he can obtain a butter that has no very bad taste, and yet that does not have the desirable flavor. No method at his disposal will enable him at these times to give his butter the flavor he desires. Under such conditions his cream is affected with the neutral class of bacteria, while mischievous ones are absent as well as the desirable flavor-producing species.

By proper care in barns and dairies the mischievous species may be in general kept out of the cream. By the use of cleanly methods in the cow stall and dairy we may depend upon the milk and cream containing a small quantity of bacteria and only wholesome ones.

Conn has found that winter cream and June cream contain a distinct bacteria flora in the same creamery; that the species of bacteria in different creameries differ at identical dates; that the species furnished a creamery by different patrons differ, and that, in short, the bacterial flora of the creamery is undergoing constant change. It is, of course, largely a matter of luck whether the cream at a given creamery chances at a certain time to have the high flavor-producing species present.

To eliminate this factor of luck from the ripening of cream pure cultures have been prepared in laboratories of the bacteria that sour and give the desired flavor and aroma to cream, and these cultures have been used in practical experiments. When inoculated into the cream they sour it rapidly and produce at the same time a desirable aroma. The use of these organisms has extended from the laboratories where they started, in Denmark and in Germany, and at the present time they are used somewhat widely in European countries. In other cases forms of bacteria have been selected which impart a desirable flavor and aroma without materially aiding in souring the cream. In this case the lactic organisms commonly present in the cream are relied upon for giving it the desired acidity. An organism isolated by Conn, and named by him Bacillus No. 41, has given very promising results, and has been adopted in a number of creameries for ripening the cream. In the use of Bacillus No. 41 a large culture of the organism is added directly to the ordinary cream, and the ripening is carried on as usual. The result has been that the souring is delayed, and the ripening may be continued longer and thus the flavor be improved, and a noticeably better product is obtained. The peculiar effect of this organism appears to be to add to the butter a flavor which the butter maker describes as a "quick grass" flavor, such as he looks for in June butter. The aroma is not much affected. The pleasant flavor appears to be added to the butter in all conditions in which the experiments have thus far been made. It has been tried upon poor cream and upon good cream; upon fresh cream and stale cream; upon separated cream and upon gravity cream; in creameries of the very highest character and creameries of a very much lower grade, and the verdict in all the cases has been uniform. Wherever it has been added to the cream for ripening in the proper way there has been an improvement in the quality of the butter made in the individual creamery. The butter of a poor creamery has not, indeed, been brought up to the quality of gilt-edged butter, but it has been improved; and even the gilt-edged butter of our highest class creameries has been pronounced better after the use of this bacillus in the ripening of its cream. Indeed, up to the present time it has been chiefly the better creameries which have adopted its use.

There is very little doubt that the ripening of cream by pure cultures of bacteria is sure to become more popular, for they make it possible for the butter maker to obtain uniformity all the year round. Both the acid ferments and Bacillus No. 41 are now put up in such form that they can be readily distributed to the creameries of the country. Their use is rapidly growing, and in the opinion of some of our best butter makers it will not be long before it will become almost universal.

CHEESE MAKING.

If bacteria are desirable allies of the butter maker, they are absolute necessities to the cheese manufacturer. Without their agency in ripening cream, the butter, though it may taste flat, is still usable, but cheese is worthless without them. New cheese is not palatable; it tastes like fresh milk curd, and is not at all pleasant. The proper flavor of cheese appears only as a result of a ripening process which is allowed to continue for several weeks or months, the flavor slowly growing stronger all the while. This ripening is the result of the action of bacteria. It is customary to recognize the normal ripening and the abnormal ripening of cheese, although no very sharp line of distinction can be drawn between the two. The normal ripening of cheese is the one that produces a good marketable product, and the abnormal ripening an abnormal product.

Abnormal ripening.—Up to the present time we have very much better knowledge of the types of abnormally ripened cheese than of normally ripened cheese. In the last few years very many such cheeses have been studied. It is a well-known fact that such abnormally ripened cheeses make their appearance in almost all cheese factories. Sometimes as high as 50 per cent of the cheeses made in a factory are worthless, or comparatively worthless, from the results of abnormal ripening. Many investigators have been studying the various types of spoiled cheese for the purpose of discovering the cause of the trouble.

The most common type of abnormally ripened cheese is one in which there is a large accumulation of gas, chiefly carbonic acid, but sometimes ammonia or free nitrogen. This accumulation of gas causes the cheese to swell and produces large cavities. In another special form of a similar infection, known as "Nissler" cheese, the cheese is filled with innumerable small holes. This abnormal swelling has been found to be produced by certain species of bacteria or yeasts growing in the cheese, which develop a superabundance of gas. Some twenty-five species of microorganisms up to this time have been definitely proved to be the cause of such an abnormal swelling of cheese, including both bacteria and yeasts. It would appear, however, that much depends upon the conditions in the cheese and the numbers of the organisms present. It is certainly true that some of these species may be present in small quantity in the cheese and it will ripen normally, while if they are present in large quantities there will be an abnormal swelling of the

cheese. The sources of the organisms in this long list are of course variable. One important source is the organisms that come from cows suffering from udder inflammations. Other sources may be in special lots of hay, or they may come from sources that are entirely unknown. So varied appear to be the bacteria that no general directions can yet be given for avoiding them, and so little do we now know of the proper conditions that very little can be done to remedy the trouble.

Other types of abnormally ripened cheese that have been studied are red cheese, blue cheese, black cheese, bitter cheese, and poisonous cheese. In the last case the cheese becomes impregnated with a poisonous ptomaine (tyrotoxicon), produced by organisms as yet entirely unknown. In short, all the types of abnormally ripened cheese which are distinctly recognized in the cheese factory have been studied, and practically all of them at the present time have been traced to an origin in certain microorganisms.

Studies of the bacteria in normally ripened cheese have consisted in the examination of the bacteria in the cheese at intervals in the ripening from the first day until the time the cheese is fully ripened. It appears that the multiplication of bacteria in cheese is comparatively slow. In cream during its ripening the bacteria multiply with prodigious rapidity, increasing perhaps six hundredfold to a thousandfold within twenty-four hours. In cheese, however, while for some weeks the bacteria do increase in number, the increase is very slow. In one case an increase was found of about sixtyfold in eighty-five days; in another about 160-fold in twenty-eight days. After a time, moreover, this increase in bacteria comes to an end, and later the number of organisms present in a living, active condition becomes less and less, until finally, at the end of the ripening, the number is very much less than it was during the middle of the ripening period, sometimes coming down to nearly the original number. There are, however, great irregularities. At times the multiplication appears to be very much greater and more rapid than at others; sometimes the number present at a given stage of the ripening is ten times as great in one specimen as it is in another, even though the latter had the larger number to start with.

As for the species of bacteria present, this, too, undergoes constant change during the ripening. At the beginning the number of species may be considerable, depending, of course, upon the number in the original milk from which the cheese was made. But as the ripening continues the number decreases, and finally, at the end of the ripening, in many cases there has been left a single species or a very small number of species. Some species originally in the milk disappear at once and can have no share in the ripening process.

Whether the normal ripening and the flavor of properly ripened cheese is due to a single species in each kind of cheese, or to the combined action of several, or whether it may not be produced by a number of different species equally well, as in the case of the butter flavor, we

do not at present know. There is a growing belief that the flavor of different types of cheese is due to different species of bacteria, and that when we have mastered the problem we shall be able to produce any given type of cheese by simply inoculating the milk with the proper quantity of definite species of bacteria. But this belief is at present based upon general inferences, and not upon demonstrated facts. The fact that such definite types of abnormally ripened cheese can be produced by inoculating the milk with certain species of bacteria shows the great influence of bacteria. The fact that a given locality will produce a uniform product of cheese for a long time indicates that this locality has probably become impregnated with a certain species of microorganism. Moreover, it is known that when a new cheese factory is started precautions are frequently taken to carry some of the cheese from an old factory to the new one, and to rub over the shelves and vats and the other appurtenances in the factory with the old cheese, in order to infect it with the proper ripening organisms.

Many species of bacteria are known to produce desirable cheese flavors when growing in milk. In some cases the use of pure cultures has been adopted in cheese making, although not from the bacteriological standpoint. One method of making Edam cheese consists in inoculating the milk with a slimy whey, which has been found to contain a very nearly pure culture of a slimy organism. These facts indicate that the cheese ripening is the result of distinct specific germs, but what they are or how large a variety we do not at present know.

The sources of cheese bacteria are more variable than the sources of bacteria in ripening the cream. Of course we have in the first place many organisms in the milk which is brought to the cheese factory, but in addition to this the cheese is inoculated with organisms from several other sources. The cheese vats and the various apparatus used in the cheese factory are a prolific source of organisms. The water that is used in the manufacture of cheese is an important source. More important than any of these is the rennet which is used to curdle the casein. Recent studies of rennet have shown that the number of bacteria in it is very great, especially in certain forms of rennet. The rennet added to the milk in considerable quantities is thus a direct inoculation of the milk with a large number of bacteria. It has long been recognized that it makes considerable difference in the character of the cheese whether one or another kind of rennet is used for curdling, and after we have recognized that the various types of ripening are due to different kinds of bacteria, we see at once that the addition of rennet to the milk is to be regarded as an inoculation of the cheese which will result in a vast modification of its ripening. This agency of the bacteria rennet in the ripening of cheese is only just beginning to be recognized, and is a subject upon which much work needs to be done.

We have, in short, at the present time an insufficient knowledge of the ripening of cheese to enable us to control the process. We can to a certain extent avoid some types of abnormal ripening by the following simple method: If cheese ripens abnormally it will probably be due to the milk from one patron being impregnated with an unfavorable species of bacteria. By use of a simple apparatus samples of milk of each patron may be set by themselves and allowed to ferment spontaneously. After two days an examination of the samples, a study of the odor, the taste, and the amount of gas produced enables the cheese maker to judge somewhat accurately whether the milk is safe to put in his cheeses. If there is a superabundance of gas, or if very vile odors are produced, the milk of the patron in question should be excluded from the cheeses. Of course it takes a day or two to apply this test, but this is a matter of no very great importance in the cheese factory, because the farm that is furnishing an improper species of bacteria one day will probably continue to do so for the season. A method of preventing the abnormal swelling of cheese has been suggested by Freudenreich; i. e., the salting of the milk. When the trouble appears in a cheese factory all the subsequent cheeses may be treated as follows: After the milk has curdled, about two-thirds of the whey is removed and salt is added to the rest to the extent of 3 per cent. The cheese is then made as usual, although a smaller quantity of salt must be put into it in the end. This use of salt has been found in some cases to be quite efficient in preventing the abnormal swelling. Another method of remedying the abnormal swelling, also based upon bacteriological knowledge, has sometimes been found to be useful. When the cheese begins to show signs of this abnormal production of gas it is at once cooled to a very low temperature, either by putting it into a cold cellar or, if the cheese is a large one, by the use of ice. This lowering of the temperature at once stops the fermentation which is going on, and if the cheese is kept at this temperature for some time the milk sugar will gradually undergo such changes that when subsequently the temperature is increased the fermentation will not recommence. Beyond these facts, however, little of practical importance to the cheese maker has as yet resulted from bacteriological study.

In guiding the milk producer to the best method of furnishing pure milk, in aiding the butter maker in obtaining a uniform and desirable flavor, and in helping the cheese maker to avoid some of his difficulties dairy bacteriology has already done much. In the immediate future we can see further practical results. To the dairy interest the bacteriologist holds out the hope of uniformity. The time will come when the butter maker may always make good butter and the cheese maker may be able in all cases to obtain exactly the kind of ripening that he desires.

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No. 18. Forage Plants for the South. Pp. 30.
No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
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