OUTLINES OF DAIRY BACTERIOLOGY

RUSSELL

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DAIRY BACTERIOLOGY

A CONCISE MANUAL FOR THE USE OF STUDENTS IN DAIRYING

BY

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PREFACE TO FIFTH EDITION.

Knowledge in dairying, like all other technical industries, has grown mainly out of experience. Many facts have been learned by observation, but the *why* of each is frequently shrouded in mystery.

Modern dairying is attempting to build its more accurate knowledge upon a broader and surer foundation, and in doing this is seeking to ascertain the cause of well-established processes. In this, bacteriology is playing an important rôle. Indeed, it may be safely predicted that future progress in dairying will, to a large extent, depend upon bacteriological research. As Fleischmann, the eminent German dairy scientist, says: "The gradual abolition of uncertainty surrounding dairy manufacture is the present important duty which lies before us, and its solution can only be effected by bacteriology."

It is therefore natural that the subject of Dairy Bacteriology has come to occupy an important place in the curriculum of almost every Dairy School. An exposition of its principles is now recognized as an integral part of dairy science, for modern dairy practice is rapidly adopting the methods that have been developed as the result of bacteriological study. The rapid development of the subject has necessitated a frequent revision of this work, and it is gratifying to the writer that the attempt which has been made to keep these Outlines abreast of bacteriological advance has been appreciated by students of dairying.

While the text is prepared more especially for the practical dairy operator who wishes to understand the principles and reasons underlying his art, numerous references to original investigations have been added to aid the dairy investigator who wishes to work up the subject more thoroughly.

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UNIVERSITY OF WISCONSIN,
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CHAPTER I.

STRUCTURE OF THE BACTERIA AND CONDITIONS GOVERNING THEIR DEVELOPMENT AND DISTRIBUTION.

Before one can gain any intelligent conception of the manner in which bacteria affect dairying, it is first necessary to know something of the life history of these organisms in general, how they live, move and react toward their environment.

Nature of Bacteria. Toadstools, smuts, rusts and mildews are known to even the casual observer, because they are of evident size. Their plant-like nature can be more readily understood from their general structure and habits of life. The bacteria, however, are so small, that under ordinary conditions, they only become evident to our unaided senses by the by-products of their activity.

When Leeuwenhoek (pronounced Lave-en-hake) in 1675 first discovered these tiny, rapidly-moving organisms he thought they were animals. Indeed, under a microscope, many of them bear a close resemblance to those minute worms found in vinegar that are known as "vinegar-eels." The idea that they belonged to the animal kingdom continued to hold ground until after the middle of the present century; but with the improvement in microscopes, a more thorough study of these tiny structures was made possible, and their vegetable nature demonstrated. The bacteria as a class are separated from the fungi mainly by their method of growth; from the lower algae by the absence of chlorophyll, the green coloring matter of vegetable organisms.

Structure of bacteria. So far as structure is concerned the bacteria stand on the lowest plane of vegetable life. The single individual is composed of but a single cell, the structure of which does not differ essentially from that of many of the higher types of plant life. It is composed of a protoplasmic body which is surrounded by a thin membrane that separates it from neighboring cells that are alike in form and size.

Form and size. When a plant is composed of a single cell but little difference in form is to be expected. While there are intermediate stages that grade insensibly into each other, the bacteria may be grouped into three main

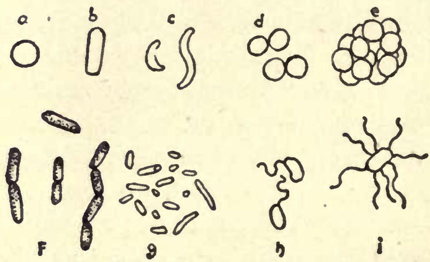

FIG. 1. Different forms of bacteria. *a*, *b*, *c*, represent different types as to form: *a*, coccus, *b*, bacillus, *c*, spirillum; *d*, diplococcus or twin coccus; *e*, staphylococcus or cluster coccus; *f* and *g*, different forms of bacilli, *g* shows internal endospores within cell; *h* and *i*, bacilli with motile organs (cilia).

types, so far as form is concerned. These are spherical, elongated, and spiral, and to these different types are given the names, respectively, *coccus*, *bacillus* and *spirillum* (plural, *cocci*, *bacilli*, *spirilla*) (fig. 1). A ball, a short rod, and a corkscrew serve as convenient models to illustrate these different forms.

In size, the bacteria are the smallest organisms that are known to exist. Relatively there is considerable difference in size between the different species, yet in absolute amount, this is so slight as to require the highest powers of the microscope to detect it. As an average diameter, one thirty-thousandth of an inch may be taken. It is difficult to comprehend such minute measurements, but if a hundred individual germs could be placed side by side, their total thickness would not equal that of a single sheet of paper upon which this page is printed.

Manner of Growth. As the cell increases in size as a result of growth, it elongates in one direction, and finally a new cell wall is formed, dividing the so-called mother-cell into two, equal-sized daughter-cells. This process of cell division, known as *fission*, is continued until growth ceases and is especially characteristic of bacteria.

Cell Arrangement. If fission goes on in the same plane continually, it results in the formation of a cell-row. A coccus forming such a chain of cells is called *strepto-coccus* (chain-coccus). If only two cells cohere, it is called a *diplo-coccus* (twin-coccus). If the second cell division plane is formed at right angles to the first, a *cell surface* or *tetrad* is formed. If growth takes place in three dimensions of space, a *cell mass* or *sarcina* is produced. Frequently, these cell aggregates cohere so tenaciously that this arrangement is of value in distinguishing different species.

Spores. Some bacteria possess the property of forming *spores* within the mother cell (called *endospores*, fig. 1g) that are analogous in function to the seeds of higher plants and spores of fungi. By means of these structures which are endowed with greater powers of resistance than the vegetating cell, the organism is able to protect itself from the effect of an unfavorable environment. Many of the bacilli form endospores but the cocci do not. It is these spore forms that resist the action of heat in pasteurizing milk.

Movement. Many bacteria are unable to move from place to place. They have, however, a vibrating movement known as the *Brownian* motion that is purely physical. Many other kinds are endowed with powers of locomotion. Motion is produced by means of fine thread-like processes of protoplasm known as *cilia* (sing. *cilium*) that are developed on the outer surface of the cell. By means of the rapid vibration of these organs, the cell is propelled through the medium. Nearly all cocci are immotile, while the bacilli may or may not be. These cilia are so delicate that it requires special treatment to demonstrate their presence.

Classification. In classifying or arranging the different members of any group of living objects, certain similarities and dissimilarities must be considered. These are usually those that pertain to the structure and form, as such are regarded as most constant. With the bacteria these differences are so slight that they alone do not suffice to distinguish distinctly one species from another. As far as these characters can be used, they are taken, but in addition, many characteristics of a physiological nature are added. The way that the organism grows in different kinds of cultures, the by-products produced in different media, and effect on the animal body when injected into the same are also used as data in distinguishing one species from another.

Conditions favoring bacterial growth. The bacteria, in common with all other living organisms are affected by external conditions, either favorably or unfavorably. Certain conditions must prevail before development can occur. Thus, the organism must be supplied with an adequate and suitable food supply and with moisture. The temperature must also range between certain limits, and finally, the oxygen requirements of the organism must be considered.

Food supply. Most bacteria are capable of living on dead, inert, organic matter, such as meats, milk and vegetable material, in which case, they are known as *saprophytes.* In contradistinction to this class is a smaller group known as *parasites*, which derive their nourishment from the living tissues of animals or plants. The first group comprise by far the larger number of known organisms which are concerned for the most part in the decomposition of organic matter. The parasitic group includes those which are the cause of various communicable diseases. Between these two groups there is no sharp line of division, and in some cases, certain species possess the faculty of growing either as parasites or saprophytes, in which case they are known as *facultative* parasites or saprophytes.

The great majority of bacteria of interest in dairying belong to the saprophytic class; only those species capable of infecting milk through the development of disease in the animal are parasites in the strict sense of the term. Most disease-producing species, as diphtheria or typhoid fever, while parasitic in man lead a saprophytic method of life so far as their relation to milk is concerned.

Bacteria require for their growth, nitrogen, hydrogen, carbon, oxygen, together with a limited amount of mineral matter. The nitrogen and carbon are most available in the form of organic compounds, such as albuminous material. Carbon in the form of carbohydrates, as sugar or starch, is most readily attacked by bacteria.

Inasmuch as the bacteria are plant-cells, they must imbibe their food from material in solution. They are capable of living on solid substances, but in such cases, the food elements must be rendered soluble, before they can be appropriated. If nutritive liquids are too highly concentrated, as in the case of syrups and condensed milk, bacteria cannot grow therein, although all the necessary ingredients may be present. Generally, bacteria prefer a neutral or slightly alkaline medium, rather than one of acid reaction; but there are numerous exceptions to this general rule, especially among the bacteria found in milk.

Temperature. Growth of bacteria can only occur within certain temperature limits, the extremes of which are designated as the *minimum* and *maximum.* Below and above these respective limits, life may be retained in the cell for a time, but actual cell-multiplication is stopped. Somewhere between these two cardinal temperature points, and generally nearer the maximum limit is the most favorable temperature for growth, known as the *optimum.* The temperature zone of most dairy bacteria in which growth occurs ranges from 40°–45° F. to somewhat above blood-heat, 105°–110° F., the optimum being from 80°–95° F. Many parasitic species, because of their adaptation to the bodies of warm-blooded animals, generally have a narrower range, and a higher optimum, usually approximating the blood heat (98°–99° F). The broader growth limits of bacteria in comparison with other kinds of life explain why these organisms are so widely distributed in nature.

Air supply. No living organism can thrive without oxygen and most species require atmospheric oxygen; but there exist certain bacteria (and yeasts as well), which possess the peculiar property of not being able to utilize elemental oxygen. These secure the necessary element for respiratory purposes from oxygen in combination, and on account of their ability to thrive in an atmosphere devoid of free oxygen are called *anaerobic*, while those requiring air are called *aerobic*. Some species grow strictly under one condition or the other, and hence are *obligate* aerobes or anaerobes; others known as *facultative* or optional forms possess the ability of growing under either condition. The majority of milk bacteria are either obligate or facultative aerobes.

Rate of Growth. Growth takes place very slowly at or near the minimum temperatures, but as the temperature is increased the rate of growth becomes more rapid, until at the optimum point, a single bacterial cell, in an active vegetative condition may divide into two cells in twenty minutes. If the temperature is raised to the maximum the rate of development is very rapidly lessened, until finally cell-multiplication ceases altogether. Even under optimum conditions this initially rapid rate of development cannot be maintained indefinitely, for growth is soon limited by the accumulation of by-products of cell activity. Thus, the sour milk germ grows rapidly at ordinary temperatures until the accumulation of lactic acid checks its own growth. If this is removed by neutralizing it with chalk, the lactic bacteria renew their growth.

Detrimental effect of external conditions. Enviromental influences of a detrimental character are constantly at work on bacteria, tending to repress their development or destroy them. These act much more readily on the vegetating cell than on the more resistant spore. A thorough knowledge of the effect of these antagonistic forces is essential, for it is often by their means that undesirable bacteria may be killed out.

Effect of cold. While it is true that chilling largely prevents fermentative action, and actual freezing stops all growth processes, still it does not follow that exposure to low temperatures will effectually destroy the vitality of bacteria, even in the vegetative condition. Numerous non-spore-bearing species remain alive in ice for a prolonged period, and recent experiments with liquid air show that even a temperature of –310° F. for hours does not effectually kill all exposed cells.

Effect of heat. High temperatures, on the other hand, will destroy any form of life, whether in the vegetative or latent stage. The temperature at which the vitality of the cell is lost is known as the *thermal death point.* This limit is not only dependent upon the nature of the organism, but varies with the time of exposure and the condition in which the heat is applied. In a moist atmosphere the penetrating power of heat is great; consequently cell-death occurs at a lower temperature than in a dry atmosphere. An increase in time of exposure lowers the temperature point at which death occurs.

For vegetating forms the thermal death point of most bacteria ranges from 130°–140° F. where the exposure is made for ten minutes which is the standard arbitrarily selected. In the spore stage resistance is greatly increased, some forms being able to withstand steam at 210°–212° F. from one to three hours. If dry heat is employed, 260°–300° F. for an hour is necessary to kill spores. Where steam is confined under pressure, a temperature of 230°–240° F. for 15–20 minutes suffices to kill all spores.

Drying. Spore-bearing bacteria like anthrax withstand drying with impunity; even tuberculous material, although not possessing spores retains its infectious properties for many months. Most of the dairy bacteria do not produce spores, and yet in a dry condition, they retain their vitality unimpaired for considerable periods, if they are not subjected to other detrimental influences.

Light. Bright sunlight exerts on many species a powerful disinfecting action, a few hours being sufficient to destroy all cells that are reached by the sun's rays. Even diffused light has a similar effect, although naturally less marked. The active rays in this disinfecting action are those of the chemical or violet end of the spectrum, and not the heat or red rays.

Influence of chemical substances. A great many chemical substances exert a more or less powerful toxic action of various kinds of life. Many of these are of great service in destroying or holding bacterial growth in check. Those that are toxic and result in the death of the cell are known as *disinfectants;* those that merely inhibit, or retard growth are known as *antiseptics*. All disinfectants must of necessity be antiseptic in their action, but not all antiseptics are disinfectants even when used in strong doses. Disinfectants have no place in dairy work, except to destroy disease bacteria, or preserve milk for analytical purposes. Corrosive sublimate or potassium bichromate are most frequently used for these purposes. The so-called chemical preservatives used to "keep" milk depend for their effect on the inhibition of bacterial growth. With a substance so violently toxic as formaldehyde (known as formalin, freezene) antiseptic doses are likely to be exceeded. In this country most states prohibit the use of these substances in milk. Their only function in the dairy should be to check fermentative or putrefactive processes and so keep the air free from taints.

Products of growth. All bacteria in their development form certain more or less characteristic by-products. With most dairy bacteria, these products are formed from the decomposition of the medium in which the bacteria may happen to live. Such changes are known, collectively, as fermentations, and are characterised by the production of a large amount of by-products, as a result of the development of a relatively small amount of cell-life. The souring of milk, the formation of butyric acid, the making of vinegar from cider, are all examples of fermentative changes.

With many bacteria, especially those that affect proteid matter, foul-smelling gases are formed. These are known as putrefactive changes. All organic matter, under the action of various organisms, sooner or later undergoes decay, and in different stages of these processes, acids, alkalies, gases and numerous other products are formed. Many of these changes in organic matter occur only when such material is brought in direct contact with the living bacterial cell.

In other instances, soluble, non-vital ferments known as *enzyms* are produced by the living cell, which are able to act on organic matter, in a medium free from live cells, or under conditions where the activity of the cell is wholly suspended. These enzyms are not confined to bacteria but are found throughout the animal and plant world, especially in those processes that are concerned in digestion. Among the better known of these non-vital ferments are rennet, the milk-curdling enzym; diastase or ptyalin of the saliva, the starch-converting enzym; pepsin and trypsin, the digestive ferments of the animal body.

Enzyms of these types are frequently found among the bacteria and yeasts and it is by virtue of this characteristic that these organisms are able to break down such enormous quantities of organic matter. Most of these enzyms react toward heat, cold and chemical poisons in a manner quite similar to the living cells. In one respect they are readily differentiated, and that is, that practically all of them are capable of producing their characteristic chemical transformations under anaesthetic conditions, as in a saturated ether or chloroform atmosphere.

Distribution of bacteria. As bacteria possess greater powers of resistance than most other forms of life, they are to be found more widely distributed than any other type. At the surface of the earth, where conditions permit of their growth, they are found everywhere, except in the healthy tissues of animals and plants. In the superficial soil layers, they exist in myriads, as here they have abundance of nourishment. At the depth of several feet however, they diminish rapidly in numbers, and in the deeper soil layers, from six to ten feet or more, they are not present, because of the unsuitable growth conditions.

The bacteria are found in the the air because of their development in the soil below. They are unable to grow even in a moist atmosphere, but are so readily dislodged by wind currents that over land areas the lower strata of the air always contain them. They are more numerous in summer than in winter; city air contains larger numbers than country air. Wherever dried fecal matter is present, as in barns, the air contains many forms.

Water contains generally enough organic matter in solution, so that certain types of bacterial life find favorable growth conditions. Water in contact with the soil surface takes up many impurities, and is of necessity rich in microbes. As the rain water percolates into the soil, it loses its germ content, so that the normal ground water, like the deeper soil layers, contains practically no bacterial life. Springs therefore are relatively deficient in germ life, except as they become infected with soil organisms, as the water issues from the soil. Water may serve to disseminate certain infectious diseases as typhoid fever and cholera among human beings, and a number of animal maladies.

While the inner tissues of healthy animals are free from bacteria, the natural passages as the respiratory and digestive tracts, being in more direct contact with the exterior, become more readily infected. This is particularly true with reference to the intestinal tract, for in the undigested residue, bacterial activity is at a maximum. The result is that fecal matter contains enormous numbers of organisms so that the possibility of pollution of any food medium such as milk with such material is sure to introduce elements that seriously affect the quality of the product.

CHAPTER II.

METHODS OF STUDYING BACTERIA.

Necessity of bacterial masses for study. The bacteria are so extremely small that it is impossible to study individual germs separately without the aid of first-class microscopes. For this reason, but little advance was made in the knowledge of these lower forms of plant life, until the introduction of culture methods, whereby a single organism could be cultivated and the progeny of this cell increased to such an extent in a short course of time, that they would be visible to the unaided eye.

This is done by growing the bacteria in masses on various kinds of food media that are prepared for the purpose, but inasmuch as bacteria are so universally distributed, it becomes an impossibility to cultivate any special form, unless the medium in which they are grown is first freed from all pre-existing forms of germ life. So accomplish this, it is necessary to subject the nutrient medium to some method of sterilization, such as heat or filtration, whereby all life is completely destroyed or eliminated. Such material after it has been rendered germ-free is kept in sterilized glass tubes and flasks, and is protected from infection by cotton stoppers.

Culture media. For culture media, many different substances are employed. In fact, bacteria will grow on almost any organic substance whether it is solid or fluid, provided the other essential conditions of growth are furnished. The food substances that are used for culture purposes are divided into two classes; solids and liquids.

Solid media may be either permanently solid like potatoes, or they may retain their solid properties only at certain temperatures like gelatin or agar. The latter two are of utmost importance in bacteriological research, for their use, which was introduced by Koch, permits the separation of the different forms that may happen to be in any mixture. Gelatin is used advantageously because the majority of bacteria present wider differences due to growth upon this medium than upon any other. It remains solid at ordinary temperatures, becoming liquid at about 70° F. Agar, a gelatinous product derived from a Japanese seaweed, has a much higher melting point, and can be successfully used, especially with those organisms whose optimum growth point is above the melting point of gelatin.

Besides these solid media, different liquid substances are extensively used, such as beef broth, milk, and infusions of various vegetable and animal tissues. Skim-milk is of especial value in studying the milk bacteria and may be used in its natural condition, or a few drops of litmus solution may be added in order to detect any change in its chemical reaction due to the bacteria.

Methods of isolation. Suppose for instance one wishes to isolate the different varieties of bacteria found in milk. The method of procedure is as follows: Sterile gelatin in glass tubes is melted and cooled down so as to be barely warm. To this gelatin which is germ-free a drop of milk is added. The gelatin is then gently shaken so as to thoroughly distribute the milk particles, and poured out into a sterile flat glass dish and quickly covered. This is allowed to stand on a cool surface until the gelatin hardens. After the culture plate has been left for twenty-four to thirty-six hours at the proper temperature, tiny spots will begin to appear on the surface, or in the depth of the culture medium. These patches are called *colonies* and are composed of an almost infinite number of individual germs, the result of the continued growth of a single organism

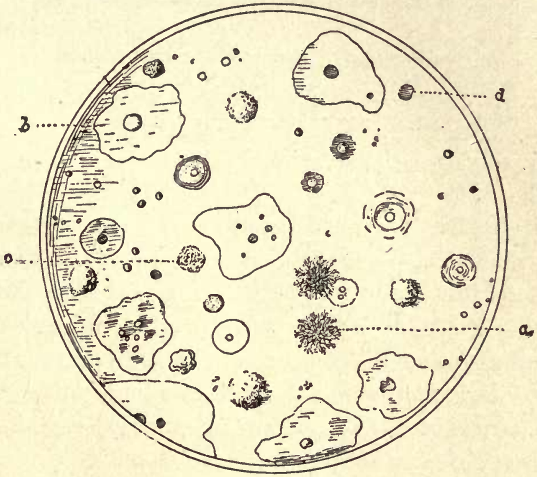

FIG. 2. A gelatin plate culture showing appearance of different organisms in a sample of milk. Each mass represents a bacterial growth (colony) derived from a single cell. Different forms react differently toward the gelatin, some liquefying the same, others growing in a restricted mass. *a*, represents a colony of the ordinary bread mold; *b*, a liquefying bacterium; *c*, and *d*, solid forms.

that was in the drop of milk which was firmly held in place when the gelatin solidified. The number of these colonies represents approximately the number of germs that were present in the milk drop. If the plate is not too thickly sown with these germs, the colonies will continue to grow and increase in size, and as they do, minute differences will begin to appear. These differences may be in the color, the contour and the texture of the colony, or the manner in which it acts toward gelatin. In order to make sure that the seeding in not too copious so as to interfere with continued study, an *attenuation* is usually made. This consists in taking a drop of the infected gel-

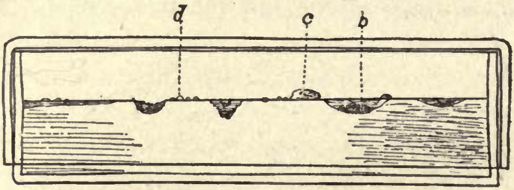

FIG. 3. Profile view of gelatin plate culture; *b*, a liquefying form that dissolves the gelatin; *c* and *d*, surface colonies that do not liquefy the gelatin.

atin in the first tube, and transferring it to another tube of sterile media. Usually this operation is repeated again so that these culture plates are made with different amounts of seed with the expectation that in at least one plate the seeding will not be so thick as to prevent further study. For transferring the culture a loop made of platinum wire is used. By passing this through a gas flame, it can be sufficiently sterilized.

To further study the peculiarities of different germs, the separate colonies are transferred to other sterile tubes of culture material and thus *pure cultures* of the various germs are secured. These cultures then serve as a basis for continued study and must be planted and grown upon all the different kinds of media that are obtainable. In this way the slight variations in the growth of different forms are detected and the peculiar characteristics are determined, so that the student is able to recognize this form when he meets it again.

These culture methods are of essential importance in bacteriology, as it is the only way in which it is possible to secure a quantity of germs of the same kind.

The microscope in bacterial investigation. In order to verify the purity of the cultures, the microscope is in constant demand throughout all the different stages of the

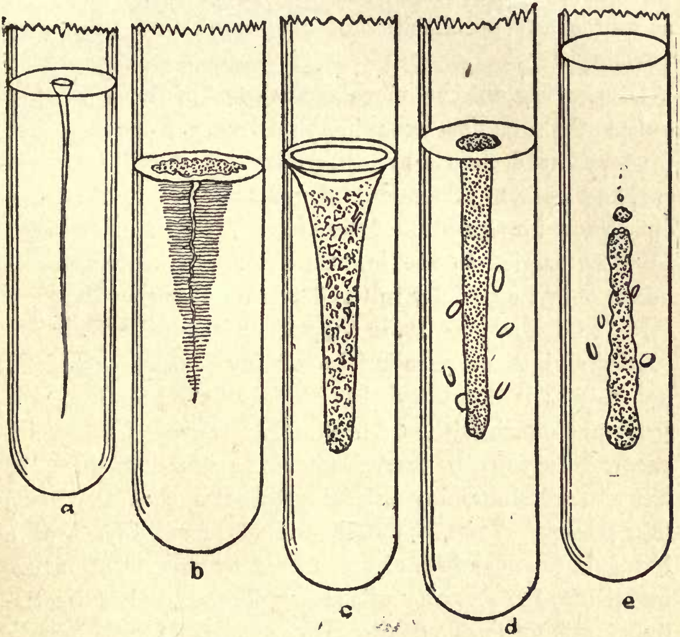

FIG. 4. Pure cultures of different kinds of bacteria in gelatin tubes. *a*, growth slight in this medium; *b*, growth copious at and near surface. Fine parallel filaments growing out into medium liquefying at surface; *c*, a rapid liquefying form; *d*, a gas-producing form that grows equally well in lower part of tube as at surface (facultative anaerobe); *e*, an obligate anaerobe, that develops only in absence of air.

isolating process. For this purpose, it is essential that the instrument used shall be one of strong magnifying powers (600–800 diameters), combined with sharp definition.

The microscopical examination of any germ is quite as essential as the determination of culture characteristics; in fact, the two must go hand in hand. The examination reveals not only the form and size of the individual germs, but the manner in which they are united with each other, as well as any peculiarities of movement that they may possess.

In carrying out the microscopical part of the work, not only is the organism examined in a living condition, but preparations are made by using solutions of anilin dyes as staining agents. These are of great service in bringing out almost imperceptible differences. The art of staining has been carried to the highest degree of perfection in bacteriology, especially in the detection of germs that are found in diseased tissues in the animal or human body.

In studying the peculiarities of any special organism, not only is it necessary that these cultural and microscopical characters should be closely observed, but special experiments must be carried out along different lines, in order to determine any special properties that the germ may possess. Thus, the ability of any form to act as a fermentative organism can be tested by fermentation experiments; the property of causing disease, studied by the inoculation of pure cultures into animals. A great many different methods have been devised for the purpose of studying special characteristics of different bacteria, but a full description of these would necessarily be so lengthy that in a work of this character they must be omitted. For details of this nature consult standard reference books on bacteriological technique.

CHAPTER III.

CONTAMINATION OF MILK.

Milk as food for bacteria. The fact that milk undergoes decomposition changes so readily shows that it is well suited to nourish bacterial life. Not only does it contain all the substances necessary for nutrition, but they are diluted in such proportions as to render most of them available for bacterial as well as mammalian life.

The albumen which is in solution is readily assimilable. The casein can not be appropriated directly, until it is first rendered soluble, a process which occurs with those bacteria that secrete proteid-dissolving enzyms like pepsin and trypsin. Of the carbon-containing compounds, the fat is of little value for food as normally bacteria can not act on this. The milk-sugar, however, is an admirable food and the decomposition of this results in the production of acids and gases. The mineral requirements of the bacterial cell are so limited as to demand but little attention, as any organic substance contains sufficient inorganic matter to satisfy the needs of the cell in the formation of new cell substance.

Milk, germ-free in udder. Under ordinary conditions, when examined in the proper manner, milk always reveals bacterial life. This germ content, however, is due to infection from without, for in the udder of a healthy animal, as secreted, the milk like the other secretions and tissues of the body is normally sterile.

Contamination of milk. In withdrawing the milk from the udder, it invariably comes in contact with germ life.

The same is true after it is milked. From the time of milking, until it is consumed in one form or another, it is continually subject to contamination from external sources. In the main, germ life gains access while the milk is on the farm, but even in the factory, the opportunities for infection are present in greater or lesser degree. Those forms that become established early generally predominate in the milk, as their introduction enables them to develop for a longer period of time. It must be remembered that by far the greater part of these organisms are relatively harmless. While they are not concerned in the production of disease, the larger majority of them do affect, more or less seriously, the quality of the milk. They are, therefore, undesirable from the milk vendor's point of view, although in the processes of butter and cheese-making, the presence of some kinds is very desirable.

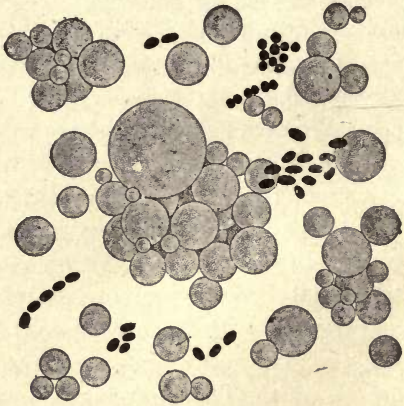

Fig. 5. Microscopic appearance of milk showing relative size of fat globules and bacteria.

Under the varying conditions in which milk is handled it must of necessity be infected with bacteria of different sorts, yet normally the type of fermentation that occurs is quite the same, showing that certain species find milk such a favorable nutrient medium that they soon gain the ascendency over other forms.

Sources of infection. The bacterial life that finds its way into milk while it is yet on the farm may be traced to several sources, which may be grouped under the following heads: unclean dairy utensils, fore milk, coat of animal, and general atmospheric surroundings. The relative importance of these various factors fluctuates in each individual instance.

Dairy utensils. Of first importance are the vessels that are used during milking, and also all storage cans and other dairy utensils that come in contact with the milk after it is drawn. By unclean utensils, actually *visible* dirt need not always be considered, although its presence in cracks and corners of pails and cans is often the case. Unless cleansed with special care, these cracks and joints are apt to be filled with foul and decomposing material that suffices to abundantly seed the milk. Soxhlet[1] found that the addition of 0.1 per cent of sour milk to fresh milk decreased the keeping quality of the latter from 15 to 30 per cent; the addition of 1.5 per cent diminished it 80 per cent. Where cans are not well cleansed the above amount could easily be added to the milk from the material that adhered to the walls of the can.

Through negligence, vessels are often used that are unfit for handling milk. A rusty milk-can often spoils more milk than sufficient to purchase a new vessel. Wooden pails are no longer tolerated in a well-regulated dairy. Where possible, vessels should be made of pressed tin. If joints are necessary, they should be well flushed with solder so that they may be easily and thoroughly cleaned as shown in Fig. 6. In much of the

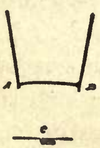

FIG. 6.

[1] Soxhlet, Ber. d. Wandervers. bayer. Landwirthe, Oct., 1894.

cheaper class of tinware now found on the market, the soldering of joints and seams is very imperfect, and this affords a place of refuge for bacteria and dirt, as shown in *c*, Fig. 6.

Use of milk-cans for transporting factory by-products. The general custom of using the milk-cans to carry back to the farm the factory by-products (skim-milk or whey) has much in it that is to be deprecated. These by-products are generally rich in bacterial life, more especially where the closest scrutiny is not given to the daily cleaning of the vats and tanks. Too frequently the cans are not cleaned immediately upon arrival at the farm, so that the conditions are favorable for rapid fermentation. Many of the taints that bother factories are directly traceable to such a cause. A few dirty patrons will thus seriously infect the whole supply. The responsibility for this defect should, however, not be laid entirely upon the shoulders of the producer. The factory operator should see that the refuse material does not accumulate in the waste vats from day to day and is not transformed into a more or less putrid mass. A dirty whey tank is not an especially good object lesson to the patron to keep his cans clean.

It is possible that abnormal fermentations or even contagious diseases may thus be disseminated.

Suppose there appears in a dairy an infectious milk trouble, such as bitter milk. This milk is taken to the factory and passes unnoticed into the general milk-supply. The skim-milk from the separator is of course infected with the germ, and if conditions favor its growth, the whole lot soon becomes tainted. If this waste product is returned to the different patrons in the same cans that are used for the fresh milk, the probabilities are strongly in favor of some of the cans being contaminated and thus infecting the milk supply of the patrons. If the organism is endowed with spores so that it can withstand unfavorable conditions, this taint may be spread from patron to patron simply through the infection of the vessels that are used in the transportation of the by-products. Connell has reported just such a case in a Canadian cheese factory where an outbreak of slimy milk was traced to infected whey vats. Quite a number of epidemics of typhoid fever have been shown to have been disseminated in this way, and in Denmark and Germany with foot and mouth disease and tuberculosis, the danger is so great as to make it necessary to heat all by-products taken back to the farm.[1]

Pollution of cans from whey vats. The danger is greater in cheese factories than in creameries, for whey usually represents a more advanced stage of fermentation than skim-milk. The higher temperature at which it is drawn facilitates more rapid bacterial growth, and the conditions under which it is stored in many factories contribute to the ease with which fermentative changes can go on in it. Often this by-product is stored in wooden cisterns or tanks, situated below ground, where it becomes impossible to clean them out thoroughly. A custom that is almost universally followed in the Swiss cheese factories, here in this country, as in Switzerland, is fully as reprehensible as any

[1] Storch (40 Rept. Danish Expt. Stat., Copenhagen, 1898) has devised a test whereby it can be determined whether this treatment has been carried out or not: Milk contains a soluble enzym known as galactase which has the property of decomposing hydrogen peroxid. If milk is heated to 176° F. (80° C.) or above, this enzym is destroyed so that the above reaction no longer takes place. If potassium iodid and starch are added to unheated milk and the same treated with hydrogen peroxid, the decomposition of the latter agent releases oxygen which acts on the potassium salt, which in turn gives off free iodine that turns the starch blue.

dairy custom could well be. In Fig. 7 the arrangement in vogue for the disposal of the whey is shown. The hot whey is run out through the trough from the factory into

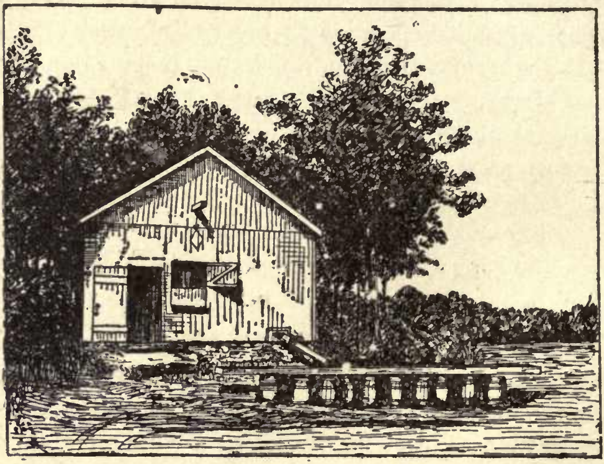

Fig. 7. Swiss cheese factory (Wisconsin), showing careless way in which whey is handled. Each patron's share is placed in a barrel, from which it is removed by him. No attempt is made to cleanse these receptacles.

the large trough that is placed over the row of barrels, as seen in the foreground. Each patron thus has allotted to him in his individual barrel his portion of the whey, which he is supposed to remove day by day. No attempt is made to clean out these receptacles, and the inevitable result is that they become filled with a foul, malodorous liquid, especially in summer. When such material is taken home in the same set of cans that is used to bring the fresh milk (twice a day as is the usual custom in Swiss factories), it is no wonder that this industry is seriously handicapped by "gassy" fermentations that injure materially the quality of the product. Not only is the above danger a very considerable one, but the quality of the factory by-product for feeding purposes, whether it is skim-milk or whey, is impaired through the development of fermentative changes.

Improved methods of disposal of by-products. The difficulties which attend the distribution of these factory by-products have led to different methods of solution. One is to use another separate set of receptacles to carry back these products to the farm. This method has been tried, and while it is deemed impracticable by many to handle two sets of vessels, yet some of the most progressive factories report excellent results where this method is in use.

Large barrels could be used for this purpose to economize in wagon space.

Another method that has met with wider acceptance, especially in creameries, is the custom of pasteurizing or scalding the skim-milk immediately after it is separated, so that it is returned to the farmer in a hot condition. In factories where the whole milk is pasteurized, further treatment of the by-product is not necessary. In most factories steam, generally exhaust, is used directly in the milk, and experience has shown that such milk, without any cooling, will keep sweet for a considerable number of hours longer than the untreated product. It is noteworthy that the most advanced and progressive factories are the ones that appreciate the value of this work, and although it involves some time and expense, experience has shown the utility of the process in that a better grade of milk is furnished by the patrons of factories which follow this practice.[1] The exclusion of all danger of animal or human disease is also possible in this way.

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[1] McKay, N. Y. Prod. Rev., Mch. 22, 1899.

Cleaning dairy utensils. The thorough cleaning of all dairy apparatus that in any way comes in contact with the milk is one of the most fundamental and important problems in dairying. All such apparatus should be so constructed as to permit of easy cleaning. Tinware, preferably of the pressed variety, gives the best surface for this purpose and is best suited for the handling of milk.

Milk vessels should never be allowed to become dry when dirty, for dried particles of milk residue are extremely difficult to remove. In cleaning dairy utensils they should first be rinsed in lukewarm instead of hot water, so as to remove organic matter without coagulating the milk. Then wash thoroughly in hot water, using soap or weak alkali. A borax solution is sometimes recommended for cleaning bottles. Strong alkalies should not be used. After washing rinse thoroughly in clean hot water. If steam is available, as it always is in creameries, cans and pails should be turned over jet for a few moments. While a momentary exposure will not suffice to completely sterilize such a vessel, yet many bacteria are killed in even a short exposure, and the cans dry more thoroughly and quickly when heated by steam.

Not only should the greatest care be paid to the condition of the cans and milk-pails, but all dippers, strainers, and other utensils that come in contact with the milk must be kept equally clean. Cloth strainers, unless attended to, are objectionable, for the fine mesh of the cloth retains so much moisture that they become a veritable hot-bed of bacterial life, unless they are daily boiled or steamed.

Germ content of milk utensils. Naturally the number of bacteria found in different milk utensils after they have received their regular cleaning will be subject to great fluctuations; but, nevertheless, such determinations are of value as giving a scientific foundation for practical methods of improvement. The following studies may serve to indicate the relative importance of the utensils as a factor in milk contamination.

Two cans were taken, one of which had been cleaned in the ordinary way, while the other was sterilized by steaming. Before milking, the udder was thoroughly cleaned and special precautions taken to avoid raising of dust; the fore milk was rejected. Milk drawn into these two cans showed the following germ content:

	No. bacteria per cc.	Hours before souring.
Steamed pail..........................	165	$28\frac{1}{2}$
Ordinary pail..........................	4265	23

Harrison[1] showed the great variation in the bacterial content in milk cans in the following way: Cans were rinsed with 100 cc. of sterile water and numerical determinations of this rinsing water made. The following data are from cans poorly cleaned (Series A), cans washed in tepid water and then scalded — the usual factory method — (Series B), and cans washed in tepid water and steamed for five minutes (Series C).

Bacterial contents of cans cleaned in various ways.

Series A, dirty cans......	238,525	342,875	215,400	618,200	806,320
	510,270	230,100	610,510	418,810	317,250
Series B, ordinary method	89,320	84,750	26,800	24,000	38,400
	76,800	15,200	13,080	44,160	93,400
Series C, approved method	1,170	1,792	890	355	416

A variation of this method was made by the writer as follows: Three pails were thoroughly washed with 100 cc.

[1] Harrison, 22 Rept. Ont. Agr'l Coll., 1896, p. 113.

of sterile water, using a sterile swab to remove all dirt. This process was repeated with two other rinse waters of the same volume, and from each of these plates were made with following results:

No. bacteria in different washings.			Total No.
I.	II.	III.	bacteria.
7,[illegible]00,000	1,450,000	49,000	9,299,000
283,000	43,400	35,000	361,400
1,685,000	105,000	61,400	1,851,400

Infection of udder cavity. While it may be true that milk as secreted in the glandular tissue of a healthy animal may be practically free from bacteria, yet it does not follow that it contains no microbes when first drawn. Indeed, a bacterial examination of the first few streams taken from each teat will invariably show a relatively high germ content; much higher, in fact, than that which is subsequently withdrawn. The reason for this is evident when the structure of the udder and its relation to the exterior is noted (Fig. 8). The udder is composed of secreting tissue (gland cells), held in place by fibrous connective tissue. Ramifying throughout this glandular structure are numerous channels (*milk sinuses*) that serve to convey the milk from the cells where it is produced into the *milk cistern*, a common receptacle just above the teat. This cavity is connected with the exterior through the *milk duct* in the teat, which is closed more or less tightly by the circular sphincter muscles, thus preventing the milk from flowing out.

According to the best authorities, the fat globules are elaborated very largely during the actual manipulation of the udder in milking, yet there is always a small residual amount of milk that is not removed even by "clean" milkers.

The ready infection[1] of the external opening of the milk duct gives an opportunity for bacteria to plant themselves on a moist mucous surface, and the result is, that some organisms, at least, find it possible to penetrate the milk duct and so enter the milk cistern. When once this reservoir is infected, further spread can be easily made, even into the glandular portion of the udder.[2] In such a habitat, ideal conditions would seem to exist, at least, for the facultative anaerobic type of bacteria. Moisture, warmth, sufficient and nutritious food, give optimum conditions for development, but these may, in part at least, be nullified by the fact that

FIG. 8. Section of udder, showing teat, milk cistern and secreting tissue (Moore and Ward).

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[1] According to Jos. Simon (Diss. Hyg. Inst. Erlangen, 1898) the udder is sterile except at outer opening.

[2] Moore and Ward, Bull. 158, Cornell Expt. Stat., Jan., 1899.

healthy mucous surfaces secrete more or less marked germicidal fluids.[1]

Number of bacteria in fore milk. If the first few streams of milk drawn from the udder are examined bacteriologically, it will invariably be found that the same contain a relatively large number of organisms, as shown by the following data collected by Harrison,[2] in which the bacterial content of the fore milk is compared with the balance of the milking.

Comparison in germ content of fore and whole milk.

Fore milk........	26,070	25,630	38,420	18,110	54,800	32,700
	43,520	27,830	18,500	29,400	45,630	48,700
Milk after removal of fore milk	1,246	1,150	1,430	3,420	1,560	890
	2,575	4,820	3,270	1,285	1,350	

If successive bacterial determinations are made of milk taken at different periods of the milking process, it is to be noted, as in the following experiment, that a sudden diminution occurs after the first few streams are removed. In this the bacterial distribution per cc. was as follows:

Bacterial content at different periods of milking.

	Fore milk.	200th cc.	2000th cc.	4300th cc.	6500th cc.	Strippings.
Expt. 1........	6,500	1,700	475	220	75	5
Expt. 2........	8,100	1,650	400	240	50	10

In these cases contamination from all other sources was excluded. The strippings will sometimes be almost sterile,

[1] The germicidal properties of freshly drawn milk discovered by Fokker (Zeit. f. Hyg., 1890, 9:41) is shown by the diminution in number of organisms that may sometimes be noted (Park, N. Y. Univ. Bull., 1901, 1:85).

[2] Harrison, 22 Rept. Ont. Agr. Coll., 1896, p. 108; also Moore, 12 Rept. Bur. Animal Ind. Washington, 1895-6, p. 261.

thus indicating that the abundance of bacteria found in the fore milk is due to the flushing out of the lower portion of the cistern and duct by the first few streams removed.

Kinds of bacteria in fore milk. The effect of these organisms on milk will depend upon the character of the same. As a rule the number of the different species found is usually small, a condition due in all probability to the fact that the surroundings in the udder favor a rapid growth of certain forms. According to Bolley[1] the bacterial flora may vary considerably, although certain types reappear with striking constancy if once found in the udder or teat. What these forms are is a question of considerable importance, for it would seem that the numerical predominance of those present in the fore milk might influence the character of the fermentation of the whole milk.

Harrison[2] claims to have found peptonizing bacteria in the fore milk, while Marshall[3] reports organisms that resist pasteurizing. Bolley, in thirty experiments, found twelve out of sixteen species to belong to the lactic class. Bolley and Hall failed to find gas-producing forms in the milk of ten cows that were examined for a period of three months; but the observations of Moore and Ward[4] show that gas-generating and taint-producing species are to be found. This fact is important in the selection of milk from a single animal for the cultivation of a starter. Hastings has made the interesting observation in the writer's laboratory, that the fore milk, although much richer in

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[1] Bolley, Cent. f. Bakt., II Abt., 1895, 1:795.

[2] Harrison, l. c., p. 108.

[3] Marshall, Bull. 147, Mich. Expt. Stat., p. 42.

[4] Moore and Ward, Bull. 158, Cornell Expt. Stat., Jan., 1899.

bacteria than the whole milk, does not coagulate nearly as soon. In a series of five trials the fore milk did not curdle at room temperature on an average until after 84 hours, while the average time of curdling of the whole milk was 38 hours.

Not all species of bacteria seem to be able to maintain themselves in the udder even if they are introduced therein. Dinwiddie[1] injected into the milk cistern a facultative anaerobic lactic acid-producing form that grew at 99° F. Several subsequent examinations failed to reveal the organism in any case. Ward[2] experimented with *B. prodigiosus* which he introduced through the milk duct. He was able to determine its presence six days later. Experiments have also been made with *B. coli communis*, *B. cloacae* and *B. lactis aerogenes*,[3] all of which are gas-generating species, but in no case did these forms thrive.

In securing milk under conditions whereby the bacterial content is reduced as much as possible, it is advisable to throw out these first few streams. In doing so, the intrinsic loss is practically negligible, for the amount of butter fat in even the first pint of a milking is only about 0.7,[4] or one fifth of the normal.

Infection directly from animal. It is a popular belief that much of the germ life that is found in milk is derived from the food that is consumed by the animal, but such a condition cannot prevail in the healthy animal for the reason that bacteria in and on fodder are not absorbed into the tissues proper, or if they are, they are quickly killed by the germicidal properties of the body fluids. The dan-

[1] Dinwiddie, Bull. 45, Ark. Expt. Stat., p. 57.

[2] Ward, Journ. of Appld. Mic., 1898, 1:205.

[3] Appel, Milch Zeit., 1900, No. 17.

[4] Snyder, Chemistry of Dairying, p. 10.

ger which does obtain directly from the animal, and which to some extent is modified by the nature of the food partaken, is due to the fecal matter that is voided from the intestine. Under careless conditions this is permitted to soil the flanks and udder of the animal. In a dried state it is readily dislodged by the movements of milking and so falls into the open milk pail. The nature of the food consumed modifies to some extent the character and consistency of the manure, physically as well as bacteriologically. The modern use of a more nitrogenous ration than formerly has resulted in the production of a softer, more fluid manure, which is more likely to soil the coat of the animal. The same is true with animals on pasture in comparison with those fed dry fodder.

Wüthrich and Freudenreich[1] find a markedly higher germ content in manure where animals are given dry feed than where kept on grass. They found as many as 375,000,000 bacteria per gram in fresh manure, the majority of which consisted of *B. coli communis*, the hay bacillus, and other species able to peptonize casein.

Organisms of this type are more abundant in winter milk than in summer, as the opportunity for infection is greatly increased by closer housing.

The nature of the animal's coat favors greatly the retention of dirt and dust. Cows wading in slime-covered pools may cover the udder with material teeming with bacteria, which falls as an impalpable powder when dry. The danger which may come from the introduction of such matter is readily seen if hairs are removed from the coat of the animal and laid on the surface of a sterile gelatin plate as in Fig. 9. Almost invariably, a number of colo-

[1] Cent. f. Bakt., II. Abt. 1895, 1:873.

nies develop under these conditions, thus indicating the infection that arises from this material. The introduction of the dirt particles themselves, however, adds relatively many more bacteria than come from the hairs themselves. The amount of pollution coming from the coat of the animal is largely dependent upon the care taken in bedding, and even the nature of the bedding material has an effect. Experience has shown where peat is used for this purpose that the bacterial life is greatly reduced, due to the antiseptic action which this strongly acid material possesses.

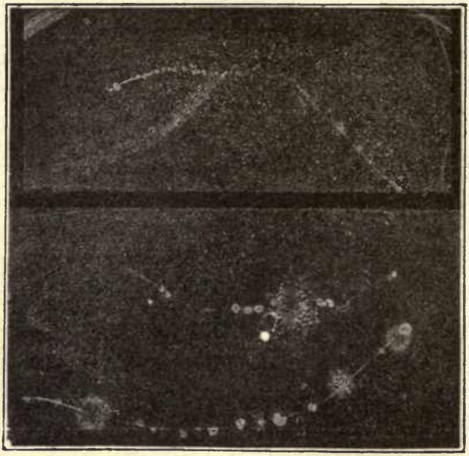

Fig. 9. Showing the bacterial contamination arising from hair. These hairs were allowed to fall on a sterile gelatin surface. The adherent bacteria developed readily in this medium, and the number of bacteria thus introduced into the milk from these hairs can be estimated by the number of developing colonies.

The amount of impurities that are often to be found in milk, even after it is strained, attest beyond dispute the careless methods of handling; it should, furthermore, be noted that about one-half of fresh manure dissolves in milk,[1] and thus does not appear as sediment. It has been determined by actual tests that the daily milk supply of

[1] Backhaus, Milch Zeit., 1897, 26:357.

the city of Berlin, Germany, contains about three hundred pounds of dirt and filth.

From a large number of determinations of the solid impurities found in market milk, Renk[1] deduces the following rule: If a sample of milk shows any evidence of impurity settling on a transparent bottom within two hours, it is to be regarded as containing too much solid impurities. These solid particles, composed largely of manure and dirt, are always teeming with bacteria, especially with putrefactive and decomposition organisms.

While the number of bacteria that are hereby introduced into milk is at times large, the character of the species is even more significant. Derived primarily, as most of them are, from fecal matter or from dirt, it is little wonder that their introduction should call forth abnormal fermentations. Undoubtedly bacteria of this class are intimately concerned in the production of intestinal troubles in infants. Eckles[2] has shown that the digesting bacteria that accompany fecal matter are closely connected with the peculiar winter flavors that impair the quality of winter butter.

Influence of the milker. The condition of the person of the milker is not to be ignored in determining all possible factors of infection, for when clothed in dust-laden garments, dislodgment of bacteria takes place readily. Particular attention should be paid to the hands of the milker. The filthy practice of moistening the hands with a few drops of milk is to be deprecated from every point of view. The milker should wash his hands in clean water just before milking. If something is needed to en-

[1] Renk, Cent. f. Bakt., 1891, 10:193.

[2] Eckles, Bull. 59, Iowa Expt. Stat., Aug. 1901.

able him to obtain a firmer grasp, a pinch of vaseline may be used. Any scales or dirt rubbed from the teat would be held by the vaseline and its effect on sore or chapped teats is healing.

Freudenreich[1] reports some experiments in which the germ content of milk was reduced from several thousand to 200 where the hands were well rubbed with vaseline before milking. Where a stringent control is exercised, it is worth while to have the milker clothed in a suit kept for this purpose, especially the upper portion of the body. An outer garment could easily be slipped over the regular working clothes. This garment should be white so as to necessitate frequent washing.

Use of milking machines. Numerous attempts have been made to reduce the process of milking to a mechanical basis by the introduction of a milking machine and with some of these devices a bacteriological examination has been made. Harrison[2] found that milk drawn from the animal with the Thistle machine was much richer in bacteria than hand-drawn milk. This was due to the suction applied to the external surface of the teat and udder, which caused the introduction of dust particles. In the Murchland machine,[3] the keeping quality of the milk was fully equal to that drawn in the usual way.

Exclusion of dirt. Scrupulous care will greatly minimize the extent of infection from dirt and dust, carding and brushing the udder and flanks will remove loose hairs and considerable adherent dirt, but so long as the coat is dry, dust particles and bacteria are readily dislodged. It is generally thought that if these visible evidences of dirt

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[1] Freudenreich, Die Bakteriologie, p. 30.

[2] Harrison, Cent. f. Bakt., II Abt. 1899, 5:183.

[3] Dyrsdale, Trans. High. & Agr. Soc. Scotland, 5 Ser., 1898, 10:166.

are removed by straining or filtering the milk, the source of trouble is eliminated. But in this operation only the visible dirt is taken out. The invisible, and by far the more dangerous material, is the bacterial life that thus becomes established, there to grow and develop. To remove the dirt after it has once come in contact with the milk only *lessens* the difficulty, but does not *overcome* it.

1. Moistening the udder. If after brushing and removing the loose hairs and dirt that can be readily dislodged in the milking, the udder and under parts are thoroughly moistened with water, the fine dust-like particles will be held in place. When moistened the surface does not want to be dripping wet. The objection has been raised to washing and cleaning the udder that the yield of milk is reduced, but Eckles[1] concludes from experiments that when the animal becomes accustomed to the treatment, no noticeable effect is produced either in amount of milk or butter-fat.

The effect of this method on reducing the number of bacteria dislodged is apparent from the following test which was made on a cow kept on pasture and milked out of doors. A sterile gelatin plate was exposed for sixty seconds under the belly in close proximity to the milk pail. Then, the udder, flank, and legs of the cow were thoroughly cleaned with water, and the milking resumed. A second plate was then exposed in the same place for an equal length of time; a control exposure being made at a distance of ten feet from the animal and six feet from the ground to ascertain the germ content of the surrounding air.

From this experiment the following instructive data

[1] Eckles, Hoard's Dairyman, July 8, 1898.

were gathered. Where the animal was milked without any special precautions being taken, there were 3.250 bacteria *per minute* deposited on an area equal to the exposed top of a ten inch milk-pail. Where the cow received the precautionary treatment as suggested above, there were only 115 bacteria per minute deposited on the same area. In the control plate sixty-five bacteria were found. This indicates that a large number of organisms from the dry coat of the animal can be kept out of milk if such simple precautions as these are carried out. A considerable number of other observations have been collected in the writer's laboratory, and it has frequently been found, that in the case of well kept herds, the germ content of the milk in the pail is increased from 20,000–40,000 bacteria per minute during the milking period by the dislodgment of organisms from the animal.

2. Diminishing exposed surface of pail. Another method of excluding the dirt, in part at least, is to use a pail having a less exposed surface. There are several different types of these sanitary or hygienic pails that are used more or less in the better type of dairies.

Eckles reports following data where a covered pail with a small opening was used in comparison with a common open pail. 43,200 bacteria per cc. were found in the milk drawn in a common pail as against 3200 per cc. in covered pail. The milk soured in 43 hours in the first case; 64 hours in the latter instance. A series of experiments made in writer's laboratory by Darrow with the two sterilized pails shown in Fig. 10 were as follows:

No. bacteria per cc. in milk.

Pail A...........	125	91	110	40	170	80	40
Pail B...........	535	240	160	115	230	45	170

Pail A is provided with a small opening in a removable top (*C*) to the pail. This top piece is arranged so that a layer of muslin or flannel (*a*, *a'*) can be stretched over opening. On this is placed a layer of absorbent cotton (*b*), which in turn is covered with another sheet of muslin.

Pail B is provided with a removable top in the lower part of which is fitted another connection *B*, that is also removable. This part is provided with a cotton filter (*a*), the milk also passing upward through a wire strainer (*b*).

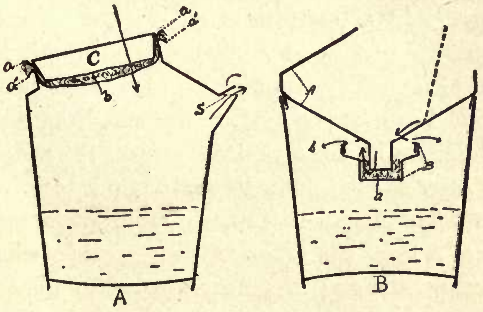

Fig. 10. Sanitary milk pails designed to diminish introduction of hairs, etc., into milk.

The efficiency of either of these pails is apparent from the data presented.

3. *Cleaning milk by centrifugal force.* Another method that is in quite common use is to pass the milk through separators. This not only removes practically all suspended particles of foreign matter, as dirt, hairs, epithelial cells or other debris,[1] but eliminates a large part of the bacteria with the centrifuge slime. By weighing the skim milk, cream and slime carefully, and then determining the germ content of each, it is possible to compute the

[1] Backhaus (Milch Ztg., 1897, 26:358) found that 95.6 per cent of impurities were thus removed.

relative distribution of bacteria. Eckles and Barnes[1] have reported a series of studies of this sort in which they found from 37 to 56 per cent of the organisms removed from the milk by centrifugal force. An average of their results showed about 29 per cent of total bacterial life in the skim milk, 24 per cent in the cream, and about 47 per cent in the slime. Quantitatively the bacterial content of the slime is always exceedingly high, ranging from tens of millions to billions of bacteria per gram.

It is surprising that the elimination of such a considerable proportion of organisms should not materially enhance the keeping quality of the purified milk. In the work above reported, although the number of bacteria was diminished 15 to 50 per cent, the diminution in development of acidity in twenty-four hours in the purified samples was only a few hundredths of one per cent.

The effect of filtration through sand, gravel and other substances is the same as when the milk is passed through the separator, the aim in all cases being to purify or free the milk from solid impurities that find their way into the milk largely from the animal herself. Comparative experiments made by Backhaus and Cronheim[2] on various filtering devices show that cellulose yields the best results. Schuppan[3] found the supply of a Copenhagen company that used a gravel filter reduced 38 to 48 per cent.

Influence of barn air. It is impossible to separate the influence of the air entirely from that of the animal, as the dust particles from the coat of the animal must of necessity pass through the air.

Germ life cannot develop in the air, but in a dried con-

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[1] Eckles and Barnes, Bull. 59, Iowa Expt. Stat., Aug. 1901.

[2] Journ. f. Landw., 1897, 45:222.

[3] Cent. f. Bakt., 1893, 13:557.

dition, organisms retain their vitality for long periods of time. The use of dry fodder, the bedding of animals with straw adds greatly to the amount of dust particles, and consequently to the germ life floating in the air, as seen in Fig. 11. Taints in milk have frequently been traced to infection arising from this source.

Fig. 11. Effect of contaminated air. The number of spots indicate the colonies that have developed from the bacteria which fell in 30 seconds on the surface of the gelatin plate (3 inches in diameter). This exposure was made at time the cows were fed.

While the stable cannot be entirely freed from dust, yet the effect of this factor can be greatly minimized by a little forethought. Feeding before milking adds materially to the germ content of the air, if feed is of dry character. If moistened and given during milking, the same objection does not inure. The following data collated by Harrison shows number of bacteria per minute deposited in a 12-inch pail. In Series A, the exposure was made during bedding; in B, one hour after this operation.

Influence of dusty air on germ life.

Series A...............	16,000	13,536	12,216	12,890	15,340
	19,200	23,400	27,342	42,750	18,730
Series B...............	483	610	820	715	1,880
	2,112	1,650	990	1,342	2,370

These results indicate that the bacteria are in the main attached to particles of considerable weight, as they settle readily to the floor.

It has long been observed that the milk of stall-kept animals does not keep as well as that milked out-of-doors. In some of the better sanitary dairies, it is customary to have a milking room, the walls of which may be kept moist, or at least free from dust, and in this way eliminate the effect of air infection.

Relative importance of foregoing factors. It is exceedingly difficult to measure the relative values of these different methods of infection that have been cited, for they are subject to so much fluctuation. Where the milk is handled without any special care, unclean dairy utensils and dirt from the animal are the most important sources of pollution, not only with reference to the actual number of bacteria introduced, but more particularly as to the effect which bacteria of this class exert on the milk. If, however, careful supervision is given to the carrying out of rational methods of cleanliness, the most important factor contributing to the germ content is often the fore milk.

Sanitary or hygienic milk. By putting into practice the various suggestions that have been made with reference to diminishing the bacterial content of milk, it is possible to greatly reduce the number of organisms found therein, and at the same time materially improve the keeping quality of the milk. Backhaus[1] estimates that the germ life in milk can be easily reduced to one-two thousandth of its original number by using care in milking. He reports a series of experiments covering two years in which milk was secured that averaged less than 10,000 bacteria per cc., while that secured under ordinary conditions averaged over 500,000.

Fig. 13 gives an illustration as to what care in milking will do in the way of eliminating bacteria. Fig. 12 shows a gelatin plate seeded with the same quantity of milk that was used in making the culture indicated by Fig. 13. The first plate was inoculated with milk drawn under ordinary conditions, the germ content of which was found to be 15,500 bacteria per cc., while the sample secured under as nearly aseptic conditions as possible (Fig. 13) contained only 330 organisms in the same volume.

Within recent years there has been more or less generally introduced into many cities, the custom of supplying high grade milk that has been handled in a way so as to diminish its germ content as much as possible. Milk of this character is frequently known as "sanitary," "hygienic" or "certified," the last term being used in connection with a certification from veterinary authorities or boards of health as to the freedom of animals from contagious disease. Frequently a numerical bacterial standard is exacted as a pre-requisite to the recommendation of the board of examining physicians. Thus, the Pediatric Society of Philadelphia requires all children's milk that receives its recommendation to have not more than 10,000 bacteria per cc. Such a standard has its value in the scrupulous cleanliness that must prevail in order to secure these re-

[1] **Backhaus, Ber. Landw. Inst. Univ. Konigsberg, 1897, 2:12.**

sults. This in itself is practically a guarantee of the absence of those forms liable to produce trouble in children.

De Schweinitz[1] has made a series of examinations extending throughout a year on such a sanitary dairy in

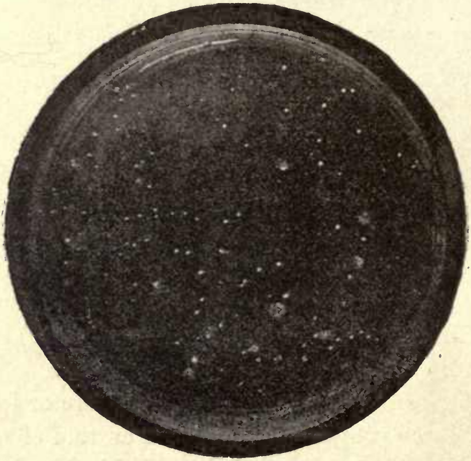

Fig. 12. Bacterial content of milk handled in ordinary way. Each spot represents a colony growing on gelatin plate. Compare with Fig. 13, where same quantity of milk is used in making culture. Over 15,000 bacteria per cc. in this milk.

Washington. The average of 113 samples was 6,485 organisms per cc. The following figures for a week in summer are taken from the regular analytical records of a Philadelphia firm that makes a specialty of children's milk.

July	1	2	3	4	5	6	7
No. bacteria per cc..	525	1,050	125	2,450	1,250	475	2,100

From a practical point of view, the improvement in quality of sanitary milk, in comparison with the ordinary product is seen in the enhanced keeping quality. During

[1] De Schweinitz, Nat. Med. Rev., Apr. 1899.

the Paris Exposition in 1900, milk and cream from several such dairies in the United States were shipped to Paris, arriving in good condition after 15–18 days transit. When milk has been handled in such a way that by the time it

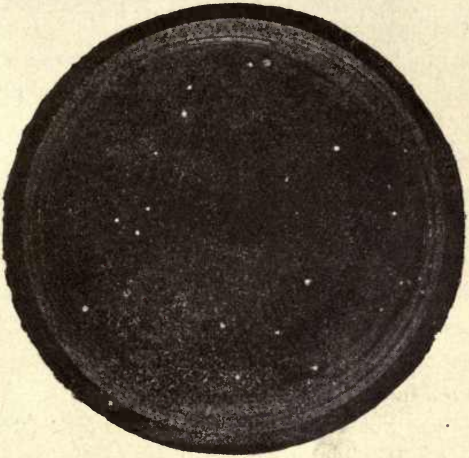

FIG. 13. Bacterial content of milk drawn with care. Diminished germ content is shown by smaller number of colonies (330 bacteria per cc.). Compare this culture with that shown in Fig. 12.

reaches the consumer it contains no more germ life than this, it is evident that it much more nearly approximates the condition which exists in the udder of the animal than the milk ordinarily sold by the milk dealer.

Considerable difference of opinion has existed in the minds of the medical profession as to the relative merits of such sanitary milk in comparison with pasteurized or sterilized milk as food for children. While it can generally be shown that properly pasteurized milk will contain less germ life than this which has been milked and handled under careful sanitary conditions, yet the fact that the low bacterial content is secured in the latter case by the elimination rather than the destruction of bacteria is a point in its favor. Unquestionably such sanitary milk is less changed from the normal secretion of the cow than that which has been subjected to heat sufficiently high to destroy the bacteria in the same.

It may not be practical under all conditions where milk is produced to put into operation all of the precautions that have been previously referred to. But there can be no doubt where milk is to be consumed as milk, that the introduction of these or similar methods would greatly improve the quality of the product. Even where milk is utilized in the factory or creamery, it is quite essential that it should be as nearly normal as possible, for in butter and cheese making, the quality of the product is directly dependent upon the character of the raw material.

Dairymen have learned many lessons in the severe school of experience, but it is earnestly to be hoped that future conditions will not be summed up in the words of the eminent German dairy scientist, Prof. Fleischmann, when he says that "all the results of scientific investigation which have found such great practical application in the treatment of disease, in disinfection, and in the preservation of various products, are almost entirely ignored in milking."

Effect of temperature on bacterial growth. After milk is once seeded with bacterial life, no one factor exerts so potent an effect as temperature upon the rate of growth.

Although different species vary in their rate of development, yet moderately warm temperatures from 75° to 90° F., encourage rapid growth. Unless the milk is quickly deprived of its original heat, the rate of the fermentative changes will be much increased as is shown in following results obtained by Freudenreich.[1]

No. of bacteria per cc. in milk kept at different temperatures.

	77° F.	95° F.
5 hrs. after milking	10,000	30,000
8 " " "	25,000	12,000,000
12 " " "	46,000	35,280,000
26 " " "	5,700,000	50,000,000

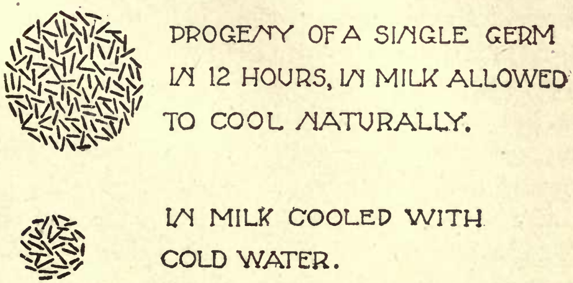

FIG. 14. Effect of cooling milk on the growth of bacteria.

If a can of milk is allowed to cool naturally, it will take several hours before it reaches the temperature of the surrounding air. During this time the organisms in the fore milk are continuing their rapid growth, while those forms which come from dust, and are presumably in a latent state, awake from their lethargy under the influence of these favorable surroundings. If bacteria once gain an entrance and begin to germinate, a considerably lower temperature is required to successfully check development than to hold latent organisms, like spores, in a condition where germination will not occur.

To hasten this lowering of temperature artificial cooling is a necessity. With good well water having a tempera-

[1] Freudenreich, Ann. de Microg., 1890, 2:115.

ture of 48°–50° F., it is possible to chill milk sufficiently to keep it. Where cold water is not available, ice water should be used. In the production of the best quality of milk for the factory, this factor of early and thorough cooling is entitled to more weight than even the matter of extreme care in milking.

Mixing night and morning milk. Common experience has often shown when old milk is mixed with new, that the fermentative changes are more rapid than would have been the case if the two milks had been kept apart. This is most frequently observed when the night milk is cooled down and mixed with the warm morning milk. This often imperfectly understood phenomenon rests upon the relation of bacterial growth to temperature. The night milk may be cooled down to 50° F., but by the next morning it has considerably more bacteria than the freshly drawn sample, the temperature of which may be 90° F. Now, if these two milkings are mixed, the temperature of the whole mass will be raised to a point that is more favorable for the growth of all of the contained bacteria than it would be if the older milk was kept chilled.

Number of bacteria in milk. The germ content of milk varies so greatly that unless the conditions are all known, it is impossible to foretell what may be found therein. An examination of milk will often reveal a difference in numbers, ranging from a few score of germs to hundreds of millions per cc. The presence of such a varying number is dependent upon certain factors, as the age of the milk, the care taken during the milking, and also the way in which it has been handled since that time. Disregarding milk of different ages, the number of germs present in any sample bears a general relation to the amount of dirt and filth with which it has come in contact since it was drawn from the cow. Bacteria and filth of all kinds are so intimately associated with each other that the presence of one rightly presupposes that of the other.

As to the numerical content of any milk, there is such a wide variation under different conditions that figures are not of much worth unless surrounding conditions are considered. No exact relation can be maintained between the number of bacteria in milk and the development of fermentative products.

Under American conditions data are gradually being accumulated, but the subject has not been exhaustively studied. Milk in this country as it reaches the consumer usually contains fewer bacteria than are to be found in European supplies, although as Conn has pointed out, it is often older. As he intimates this is explained by the relatively free use of ice in this country. A few determinations of the bacterial content of European milks that have been analyzed biologically will illustrate this point.

Renk[1] found in Halle milk supply 6 to 30,000,000 germs per cc.; Cnopf[2] in Munich milk supply 200,000 to 6,000,000 per cc.; Uhl[3] in Giessen milk 83,000 to 170,000,000 per cc.; Clauss[4] in Wurzburg 222,000 to 23,000,000 per cc.; Bujwid in Warsaw an average of 4,000,000 per cc., and Knochensteirn[5] in Dorpat 25,000,000 per cc.

Sedgwick and Batchelder[6] report fifty-seven samples of Boston milk as containing from 30,000 to 4,220,000 per cc. In the country, they found in the milk fresh from the cow

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[1] Renk, Cent. f. Bakt. 10:193.

[2] Cnopf, Ibid. 6: 553.

[3] Uhl, Zeit. f. Hyg., 1892, 12:475.

[4] Clauss, Diss. Wurzburg, 1889.

[5] Knochensteirn, Chem. Cent., 11:62.

[6] Sedgwick and Batchelder, Boston Med. Surg. Journ., Jan. 14, 1892.

30,000, and in the milk as used on the table about 70,000 organisms per cc. Loveland and Watson[1] found in the supply of Middletown, Conn., from 11,000 to 85,500,000 per cc.

Leighton[2] studied seventeen dairies at Montclair, N. J., for a three-year period with the following results:

Class I, dairies averaging below 15,000 bacteria per cc.;
Class II, those averaging from 40,000 to 70,000 per cc.;
Class III, those above 180,000.

In Class I, the dairies were found to be clean and well improved; in Class II the conditions were as satisfactory as possible with the crude appliances used; Class III was as a whole careless. McDonnell[3] sampled 352 lots from eleven American cities. The worst samples were found in restaurants and with small retail dealers. 28 per cent of all samples contained less than 100,000 bacteria per cc. while 34 per cent had less than 500,000. Park[4] finds in New York City that the milk in the shops where it is generally sold, averages during the coldest weather about 250,000 organisms per cc., during cool weather about 1,000,000, and in hot weather about 5,000,000 per cc. Eckles[5] has studied the flora of milk under factory conditions. He finds from one to five million organisms per cc. in winter, but in summer there may be from fifteen to thirty millions.

Bacterial vs. other standards. As the germ content of milk is subject to such wide variations, it is practically impossible to establish a numerical standard, al-

[1] Loveland and Watson, Ch. 7 Rep. Storrs Stat. (Conn.), 1894, p. 72.
[2] Leighton, Science, Mar. 23, 1900.
[3] McDonnell, Penn. Dept. Agr. Rept., 1897, p. 561.
[4] Park, N. Y. Univ. Bull., 1901, 1:85.
[5] Eckles, Bull. 59, Iowa Expt. Stat., Aug., 1901.

though Bitter states that 50,000 organisms per cc. should be a maximum limit in milk intended as human food. As a result of a study of the supply of New York city, Park believes it is possible for a milk producer, without adding materially to his expense, to secure milk which when first drawn will not contain on an average more than 30,000 bacteria in hot weather and 25,000 in cold weather. If such milk is chilled immediately to 50° F., it will not contain more than 100,000 per cc. in twenty-four hours. Rochester, New York, has already tried the enforcement of a standard (100,000 per cc.) with good results it is claimed. The practical difficulties to contend with in establishing a milk standard based upon a quantitative bacterial determination are such as to render its general adoption extremely problematical.

Acid test. It would seem that some other test which can be more easily employed, even though it might not be susceptible to an equal degree of accuracy, would be preferable. Such a test is to be found in the acid test which measures the acidity of the milk in question. There are of course organisms to be found in milk that do not produce acid, and therefore it might be thought that the presence of such would militate against the accuracy of such a test; but under normal conditions, the lactic acid-producing organisms find in milk so congenial a substratum for their development, that in the great majority of cases, the determination of the acid indicates the manner in which milk has been handled. High acidity is either due to old milk (long period of incubation) or insufficient cooling (rapid incubation). Either of these conditions permits of the accumulation of bacterial life, and therefore impairs the quality of the milk. The determination of the acid in milk can be made accurately by titration with standard solutions of alkali, or more readily, in general work, by employing the Farrington alkaline tablet, which is a combination of a definite amount of standard alkali and an indicator (phenolphthalein). It is possible by the use of the tablet solution to make as accurate determination of acidity as with the usual standard solutions employed in the laboratory, but the method may also be used rapidly in such a way as to give an approximate determination of acid. This modification is very serviceable at the weigh-can or intake where it is necessary to pass judgment very quickly on the quality of the milk.

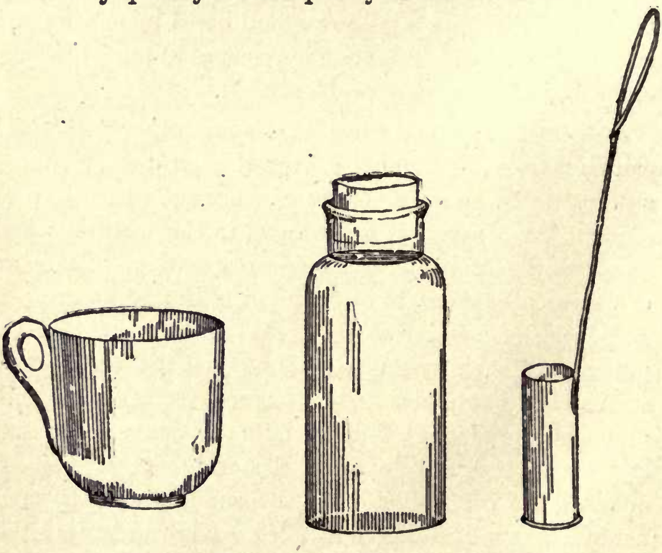

FIG. 15. Apparatus used in making rapid acid test.

Making the acid test. Fig. 15 gives the apparatus necessary for this rapid testing of the acidity of the milk. A solution of the alkaline tablets is first prepared by dissolving them in clean soft water, one tablet for each ounce of water; thus eight tablets to an eight-ounce bottle of water. In determining the acidity, a number of common white cups are used, one for each patron. Two measures full[1] of the alkali solution are placed in each cup, and then as the milk is received at the weigh-can, one measure of milk is added to the alkali solution in the cup,[2] and the whole gently, but thoroughly shaken. If the pink color of the alkali solution persists even faintly, it shows that there is not enough acid in the milk to neutralize the the same; if it disappears altogether, leaving the milk white in color, it indicates that there is more acid in the milk than can be neutralized by the alkali of the tablet solution. When these proportions of milk and alkali solution (2:1) are employed, it indicates an acidity of 0.2 per cent. figured as lactic acid. Milk should not contain more than this amount of acid, and under good methods of handling, the acidity should be brought down to 0.15 per cent if possible.

Circumstances may arise that might lead to an error if this method is blindly followed. It has been pointed out[3] that if milk is allowed to stand in rusty cans for some time its acid content is diminished materially. The average acidity of nine samples of milk brought to a factory in clean cans was .228 per cent acidity, while that of nine other patrons brought in rusty cans was only .134 per cent. Milk kept in rusty cans is sure to contain large quantities of bacteria, even though its acid content may be low.

Kinds of bacteria in milk. The number of bacteria in milk is not of so much consequence as the kind present.

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[1] A brass cartridge shell provided with a handle serves admirably for a measure.

[2] Farrington, Bull. 52, Wis. Expt. Stat.

[3] Biddick, Hoard's Dairyman, July 30, 1897.

With reference to the number of kinds present, the more dirt and foreign matter the milk contains, the larger the number of varieties found in the same. While milk may contain forms that are injurious to man, still the great majority of them have no apparent effect on human health. In their effect on milk, the case is much different. Depending upon their action in milk, they may be grouped into three classes:

1. Bacteria that exert no appreciable effect in milk.

2. Bacteria that are beneficial by reason of the products which they form.

3. Bacteria that are injurious on account of the effect which they produce in milk.

A surprisingly large number of bacteria that are found in milk belong to the first class. Undoubtedly they affect the chemical characteristics of the milk somewhat, but not to the extent that it becomes physically perceptible. Eckles[1] reports in a creamery supply from 20 to 55 per cent of entire flora as included in this class.

Those species that are concerned in the production of proper flavor and aroma in butter, and which are also concerned in the development of acid and possibly associated with formation of cheese flavor represent the second type. Many of these organisms are lactic acid-producing, but in addition to these, some of the casein ferments are also associated with aroma production in butter. Under normal conditions by far the larger proportion of bacteria present in milk belong to the lactic acid type. There are always present, though, digesting species that are able to grow if the lactic acid forms are killed, as in pasteurizing.

[1] Eckles, Bull. 59, Iowa Expt. Stat., Aug., 1901.

The third class includes those species that are able to produce deleterious and undesirable flavors in milk and milk products. The abnormal fermentations of milk referred to in the next chapter come under this head. Most of these gain access to the milk through slovenly and careless methods of handling. Those species associated with animal excreta are particularly dangerous. The number of different kinds that have been found in milk is quite considerable, something over 200 species having been described more or less thoroughly. In all probability, however, many of these forms will be found to be identical when they are subjected to a more critical study.

Direct absorption of taints. A tainted condition in milk may result from the development of bacteria, acting upon various constituents of the milk, and transforming these in such a way as to produce by-products that impair the flavor or appearance of the liquid; or it may be produced by the milk being brought in contact with any odoriferous or aromatic substance, under conditions that permit of the direct absorption of such odors.

This latter class of taints is entirely independent of bacterial action, and is largely attributable to the physical property which milk possesses of being able to absorb volatile odors, the fat in particular, having a great affinity for many of these substances. This direct absorption may occur before the milk is withdrawn from the animal, or afterwards if exposed to strong odors.

It is not uncommon for the milk of animals advanced in lactation to have a more or less strongly marked odor and taste; sometimes this is apt to be bitter, at other times salty to the taste. It is a defect that is peculiar to individual animals and is liable to recur at approximately the same period in lactation.

The peculiar "cowy" or "animal odor" of fresh milk is an inherent peculiarity that is due to the direct absorption of volatile elements from the animal herself. This condition is very much exaggerated when the animal consumes strong-flavored substances as garlic, leeks, turnips and cabbage. The volatile substances that give to these vegetables their characteristic odor are quickly diffused through the system, and if such foods are consumed some few hours before milking, the odor in the milk will be most pronounced. The intensity of such taints is diminished greatly and often wholly disappears, if the milking is not done for some hours (8–12) after such foods are consumed.

This same principle applies in lesser degree to many green fodders that are more suitable as feed for animals, as silage, green rye, rape, etc. Not infrequently, such fodders as these produce so strong a taint in milk as to render it useless for human use. Troubles from such sources could be entirely obviated by feeding limited quantities of such material immediately after milking. Under such conditions the taint produced is usually eliminated before the next milking. The milk of swill-fed cows is said to possess a peculiar taste, and the urine of animals fed on this food is said to be abnormally acid. Brewers' grains and distillery slops when fed in excess also induce a similar condition in the milk.

Milk may also acquire other than volatile substances directly from the animal, as in cases where drugs, as belladonna, castor oil, sulfur, turpentine, jalap, croton oil, and many others have been used as medicine. Such mineral poisons as arsenic have been known to appear eight hours after ingestion, and persist for a period of three weeks before being eliminated.

Absorption of odors after milking. If milk is brought in contact with strong odors after being drawn from the animal, it will absorb them readily, as in the barn, where frequently it is exposed to the odor of manure and other fermenting organic matter.

It has long been a popular belief that milk evolves odors and cannot absorb them so long as it is warmer than the surrounding air, but from experimental evidence, the writer[1] has definitely shown that the direct absorption of odors takes place much more rapidly when the milk is warm than when cold, although under either condition, it absorbs volatile substances with considerable avidity. In this test fresh milk was exposed to an atmosphere impregnated with odors of various essential oils and other odor-bearing substances. Under these conditions, the cooler milk was tainted very much less than the milk at body temperature even where the period of exposure was brief. It is therefore evident that an exposure in the cow barn where the volatile emanations from the animals themselves and their excreta taint the air will often result in the absorption of these odors by the milk to such an extent as to seriously affect the flavor.

The custom of straining the milk in the barn has long been deprecated as inconsistent with proper dairy practice, and in the light of the above experiments, an additional reason is evident why this should not be done.

Even after milk is thoroughly cooled, it may absorb odors as seen where the same is stored in a refrigerator with certain fruits, meats, fish, etc.

Distinguishing bacterial from non-bacterial taints. In perfectly fresh milk, it is relatively easy to distinguish be-

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[1] Russell, 15 Rept. Wis. Expt. Stat. 1898, p. 104.

tween taints caused by the growth of bacteria and those attributable to direct absorption.

If the taint is evident at time of milking, it is in all probability due to character of feed consumed, or possibly to medicines. If, however, the intensity of the taint grows more pronounced as the milk becomes older, then it is probably due to living organisms, which require a certain period of incubation before their fermentative properties are most evident.

Moreover, if the difficulty is of bacterial origin, it can be frequently transferred to another lot of milk (heated or sterilized is preferable) by inoculating same with some of the original milk. Not all abnormal fermentations are able though to compete with the lactic acid bacteria, and hence outbreaks of this sort soon die out by the re-establishment of more normal conditions.

Treatment of directly absorbed taints. Much can be done to overcome taints of this nature by exercising greater care in regard to the feed of animals, and especially as to the time of feeding and milking. But with milk already tainted, it is often possible to materially improve its condition. Thorough aeration has been frequently recommended, but most satisfactory results have been obtained where a combined process of aeration and pasteurization was resorted to. Where the milk is used in making butter, the difficulty has been successfully met by washing the cream with twice its volume of hot water in which a little saltpeter has been dissolved (one teaspoonful per gallon), and then separating it again.[1]

The treatment of abnormal conditions due to bacteria has been given already under the respective sources of in-

[1] Alvord, Circ. No. 9, U. S. Dept. Agric. (Div. of Bot.).

fection, and is also still further amplified in following chapter.

Aeration. Practical experience has long demonstrated the advantage of aerating the milk as soon after milking as possible. This is accomplished in a variety of ways. In some cases, air is forced into the milk; in others, the milk is allowed to distribute itself in a thin sheet over a broad surface and fall some distance so that it is brought intimately in contact with the air. The benefit claimed for aeration is that foul odors and gases which may be present in the milk are thus allowed to escape by bringing the finely divided milk into contact with the air. As ordinarily practiced, aeration is usually combined with cooling, and it is noteworthy that the most effective aerators are those that cool simultaneously. Under these conditions, the keeping quality of the milk is increased, but where milk is simply aerated without cooling, no material benefit in keeping quality is observed. A satisfactory scientific explanation of the advantages of aeration has not yet been made. It is difficult to see how the process can have any effect on the bacterial life in the milk. Its influence, undoubtedly, is on the odors directly absorbed by the milk.

Infection of milk in the factory. The problem of proper handling of milk is not entirely solved when the milk is delivered to the factory or creamery, although it might be said that the danger of infection is much greater while the milk is on the form. Then, too, contamination of milk at time of withdrawal gives a longer period of incubation for the bacteria in the milk, and consequently intensifies the effect which they produce.

In the factory, infection can be minimized because effective measures of cleanliness can be more easily applied.

Steam is available in most cases, so that all vats, cans, churns and pails can be thoroughly scalded. Special emphasis should be given to the matter of cleaning pumps and pipes. The difficulty of keeping these utensils clean often leads to neglect and subsequent infection. Care must be taken relative to the use of worn apparatus. All cans with rusty seams should be discarded. Permit no vat to be repaired by putting in a false covering over the old one. If a minute leak is established, such places become a harbor of refuge for all kinds of putrefactive organisms. In a number of cases ill-smelling factory odors have been traced to such a cause.

The influence of the air on the germ content of the milk is, as a rule, overestimated. If the air is quiet, and free from dust, the amount of germ life in the same is not relatively large. In a creamery or factory, infection from this source ought to be much reduced, for the reason that the floors and wall are, as a rule, quite damp, and hence germ life cannot easily be dislodged. The majority of organisms found under such conditions come from the person of the operators and attendants. Any infection can easily be prevented by having the ripening cream-vats covered with a canvas cloth. The clothing of the operator should be different from the ordinary wearing-apparel. If made of white duck, the presence of dirt is more quickly recognized, and greater care will therefore be taken than if ordinary clothes are worn.

The surroundings of the factory have much to do with the danger of germ infection. Many factories are poorly constructed and the drainage is poor, so that filth and slime collect about and especially under the factory. The emanations from these give the peculiar "factory odor" that indicates fermenting matter. Not only are these odors absorbed directly, but germ life from the same is apt to find its way into the milk. Connell[1] has recently reported a serious defect in cheese that was traced to germ infection from defective factory drains.

The water supply of a factory is also a question of prime importance. When taken from a shallow well, especially if surface drainage from the factory is possible, the water may be contaminated to such an extent as to introduce undesirable bacteria in such numbers that the normal course of fermentation may be changed. The quality of the water, aside from flavor, can be best determined by making a curd test (p. 76) which is done by adding some of the water to boiled milk and incubating the same. If "gassy" fermentations occur, it signifies an abnormal condition. In deep wells, pumped as thoroughly as is generally the case with factory wells, the germ content should be very low, ranging from a few score to a few hundred bacteria per cc. at most.

Harrison[2] has recently traced an off-flavor in cheese in a Canadian factory to an infection arising from the water-supply. He found the same germ in both water and cheese and by inoculating a culture into pasteurized milk succeeded in producing the undesirable flavor. The danger from ice is much less, for the reason that good dairy practice does not sanction using ice directly in contact with milk or cream. Then, too, ice is largely purified in the process of freezing, although if secured from a polluted source, reliance should not be placed in the method of purification; for even freezing does not destroy all vegetating bacteria.

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[1] Connell, Rept. of Commissioner of Agr., Canada, 1897, part XVI, p. 15.

[2] Harrison, Hoard's Dairyman, March 4, 1898.

CHAPTER IV.

FERMENTATIONS IN MILK AND THEIR TREATMENT.

It has been shown in the preceding chapter that the contamination of milk with bacteria occurs so constantly that under normal conditions it always contains a varying amount of germ life. The result of this infection is to cause in the milk, in due course of time, subsequent changes of a fermentative nature. As a rule milk sours, due to the production of acid from the decomposition of the milk sugar; but, not infrequently, this more common change is supplanted by other types of fermentative activity that result in the production of other kinds of by-products. These fermentations are sometimes designated as abnormal, because of their less frequent occurrence.

It is impossible in the present state of knowledge to satisfactorily classify these changes; but provisionally, they may be grouped according to the substances on which they act, or on the basis of the most prominent by-product formed.

Milk is such a complex substance that the changes produced by a single germ are often so numerous that the processes cannot be separated in their reactions. It must be remembered then, in referring to the different types of fermentations, that perhaps a distinct by-product is being formed, but it is more than probable that there are a series of changes, in which the most marked decomposition by-product is alone taken into consideration. For example, there is a fermentation classed under the head of the butyric changes, a decomposition process in which butyric acid is the chief product formed, but this may be associated with an alkaline condition of the milk and the production of a bitter substance in the same. Thus, the subdivision followed here will of necessity be imperfect, and occasional instances will be noted where some changes in milk might well be described under several heads. It is possible that milk may acquire an abnormal odor or taint, such as is due to direct absorption, without having undergone any fermentative change, but the introduction of various forms of bacteria is so common that fermentative changes due to living ferments are constantly at work.

Souring of milk. Milk naturally undergoes a change known as souring, if allowed to stand for several days at ordinary temperature. This is due to the formation of lactic acid, which is produced by the decomposition of the milk-sugar. While this change is wellnigh universal, it does not occur without a pre-existing cause, and that is the presence of certain living bacterial forms. These organisms develop in milk with great rapidity, and the decomposition changes that are noted in souring are due to the by-products of their development.

The milk-sugar undergoes fermentation, the chief product being lactic acid, although various other by-products, as other organic acids (acetic, formic and succinic), different alcohols and gaseous products, as CO_2, H, N and methane (CH_4) are produced in small amounts.

In this fermentation, the acidity begins to be evident to the taste when it reaches about 0.3 per cent, calculated as lactic acid. As the formation of acid goes on, the casein is precipitated and incipient curdling or lobbering of the milk occurs. This begins to be apparent when the acidity is about 0.4 per cent, but the curd becomes more solid with increasing acidity. The action of the bacteria is continued until about 0.8 to 1.0 per cent acid is formed, although the maximum amount fluctuates considerably with different organisms.[1] Further formation then ceases, by reason of the inability of the lactic acid organisms to continue their development in such acid solutions. There is always left in the milk a considerable amount of unfermented milk-sugar which can be further actcd upon by the continued growth of the bacteria, if a carbonate is added to the milk to neutralize the developing acid that inhibits their growth.

Cream never develops as much acid as milk, because a larger proportion of its volume is made up of butter-fat which is not subject to this change. In the ripening of cream in butter-making, it is necessary to take this fact into consideration where the cream varies widely in per cent of fat.

The formation of lactic acid is a characteristic that is possessed by a large number of bacteria, micrococci as well as bacilli being numerously represented. Still the preponderance of evidence is in favor of the view that one main type is responsible for most of this fermentation. The most prominent organism associated with this change is *Bacillus acidi lactici*, first described by Hüppe.[2] Günther and Thierfelder[3] working on the spontaneous souring of milk in the neighborhood of Berlin found what they think is the same germ. Esten,[4] in this country, studied milks from thirty different localities in New England and

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[1] Warrington, Jour. Chem. Soc., 1888, 53:727.

[2] Hüppe, Mitt. a. d. k. Gesundheitsamte, 1884, 2:309.

[3] Günther and Thierfelder, Arch. f. Hyg., 25:164.

[4] Esten, 9 Rept. Storrs Expt. Stat., 1896, p. 44.

the Middle States. He found a germ in all but two cases that agreed in general with Günther's description. Dinwiddie,[1] studying the same question in Arkansas, arrives at the same conclusion. This preponderance of evidence makes it quite probable that there is a widely distributed germ that is concerned in this change although undoubtedly different varieties exist. Besides this widely disseminated type, there are numerous other forms[2] that are associated with this type of decomposition the most prominent of which is known as *B. lactis aerogenes.* Conn and Aikman refer to the fact that over one hundred species are already known. It is fair to presume, however, that a careful comparative study of these would show that simply racial differences exist in many cases, and therefore, that they are not distinct species.

This class of bacteria is characterized by their inability to liquefy gelatin or develop spores. On account of this latter characteristic they are easily destroyed when milk is pasteurized. They live under aerobic or anaerobic conditions, many of them being able to grow in either environment, although, according to McDonnell,[3] they are more virulent when air is not excluded.

The temperature conditions as to growth vary somewhat with different species. With most species this occurs at 50° F., but appreciable amounts of acid are not produced until a higher temperature is reached.[4] The optimum temperatures for growth range from 90°–95° F.

While the souring of milk is a very wide-spread phenomenon, still lactic acid organisms are not universally dis-

[1] Bull. 45, Ark. Expt. Stat., May 1897; Leichmann, Hyg. Rund., 1899, p. 1267.

[2] Kayser, Ann. de l'Inst. Past., 10:737.

[3] McDonnell, Inaug. Diss., Kiel, 1899, p. 39.

[4] Kayser, Cent. f. Bakt., II Abt. 1:436.

tributed. According to Conn[1] they are not very abundant in perfectly fresh milk, but because of their ability to thrive so luxuriantly in this liquid, they grow with great rapidity, and therefore after a few hours milk always contains them in abundance.

It is a wide-spread belief that thunder storms cause milk to sour prematurely, but this idea has no scientific foundation. Experiments[2] with the electric spark, ozone and loud detonations show no effect on acid development, but the atmospheric conditions usually incident to a thunder storm are such as permit of a more rapid growth of organisms. There is no reason to believe but that the phenomenon of souring is wholly related to the development of bacteria. Sterile milks are never affected by the action of electric storms.

"Gassy" milks. A large number of bacteria possess the property of fermenting sugars and producing gases of various kinds as well as acids of a volatile or fixed character. The amount of acid formed is generally considerably less than that produced by the normal lactic species. Among the gases formed, H and CO_2 are most common, although N and CH_4 (methane) are sometimes produced. In connection with these gases, there are also other decomposition products of a more or less volatile nature that frequently impart to the milk taints of an undesirable character.

While these "gassy" defects can often be recognized in the milk itself, they are much more apt to cause trouble in the manufacture of cheese (see Fig. 16), where, in severe cases, curds may "float" or be "pin holey."[3] There are

[1] Conn, Agricultural Bacteriology, p. 191.

[2] Treadwell, Science, 1894, 17: 178.

[3] Freudenreich, Landw. Jahr. d. Schweiz, 1890, p. 17; Russell, 12 Rept. Wis. Expt. Stat., 1895, p. 139.

a large number of organisms of this class found in surface waters, soils and in decomposing organic matter. The colon bacillus of the intestinal tract is a germ of this type

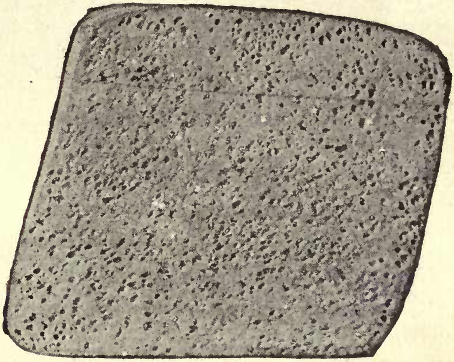

FIG. 16. Cheese made from "gassy" milk.

that finds its way into milk with manure particles. *B. lactis aerogenes*, a common inhabitant of milk is also a gas-producer. Abnormal fermentations of this class occur most frequently in the hot summer months, but are not necessarily confined to this season. Wherever carelessness prevails in the matter of cleaning utensils, troubles from gassy milks are very apt to occur.

"Sweet curdling" and digesting fermentations. Not infrequently milk, instead of undergoing spontaneous souring, curdles in a weakly acid or neutral condition, in which state it is said to have undergone "sweet curdling." The coagulation of the milk is caused by the action of enzyms of a rennet type that are formed by the growth of various species of bacteria. Later the whey separates more or less perfectly from the curd, producing a "wheyed off" condition. Generally the coagulum in these cases is soft and somewhat slimy. The curd usually diminishes in bulk, due to the gradual digestion or peptonization of the casein by proteid-dissolving enzyms (tryptic type) that are also produced by the bacteria causing the change.

A large number of bacteria possess the property of affecting milk in the above way. Generally they are able to liquefy gelatin (also a peptonizing process) and form spores. The Tyrothrix type of bacteria (so named by Duclaux on account of the supposed relation to cheese ripening) belongs to this class. The hay and potato forms are also digesters. Organisms of this type are generally associated with filth and manure, and find their way into the milk from the accumulations on the coat of the animal.

Conn[1] has separated the rennet enzym from bacterial cultures in a relatively pure condition, while Fermi[2] has isolated the digestive principle from several species.

Duclaux[3] has given to this digesting enzym the name *casease* or cheese ferment. These isolated ferments when added to fresh milk possess the power of causing the characteristic curdling and subsequent digestion quite independent of cell development. The quantity of ferment produced by different species differs materially in some cases. In these digestive fermentations, the chemical transformations are profound, the complex proteid molecule being broken down into albumoses, peptones, amido-acids (tyrosin and leucin) and ammonia as well as fatty acids.

Not infrequently these fermentations gain the ascendency over the normal souring change, but under ordinary conditions they are held in abeyance, although this type of bacteria is always present to some extent in milk. When

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[1] Conn, 5 Rept. Storrs Expt. Stat., 1892, p. 396.

[2] Fermi, Arch. f. Hyg., 1892, 14:1.

[3] Duclaux, Le Lait, p. 121.

the lactic acid bacteria are destroyed, as in boiled, sterilized or pasteurized milk, these rennet-producing, digesting species develop.

Butyric acid fermentations. The formation of butyric acid in milk which may be recognized by the "rancid butter" odor is not infrequently seen in old, sour milk, and for a long time was thought to be a continuation of the lactic fermentation, but it is now believed that these organisms find more favorable conditions for growth, not so much on account of the lactic acid formed as in the absence of dissolved oxygen in the milk which is consumed by the sour-milk organisms.

Most of the butyric class of bacteria are spore-bearing, and hence they are frequently present in boiled or sterilized milk. The by-products formed in this series of changes are quite numerous. In most cases, butyric acid is prominent, but in addition to this, other organic acids, as lactic, succinic, and acetic, are produced, likewise different alcohols. Concerning the chemical origin of butyric acid there is yet some doubt. Duclaux[1] affirms that the fat, sugar and casein are all decomposed by various forms. In some cases, the reaction of the milk is alkaline, with other species it may be neutral or acid. This type of fermentation has not received the study it deserves.

In milk these organisms are not of great importance, as this fermentation does not readily gain the ascendency over the lactic bacteria.

Ropy or slimy milk. The viscosity of milk is often markedly increased over that which it normally possesses. The intensity of this abnormal condition may vary much; in some cases the milk becoming viscous or slimy; in others

[1] Duclaux, Principes de Laiterie, p. 67.

stringing out into long threads, several feet in length, as in Fig. 17. Two sets of conditions are responsible for these ropy or slimy milks. The most common is where the milk is clotted or stringy when drawn, as in some forms of garget. This is generally due to the presence of viscid pus, and is often accompanied by a bloody discharge, such a condition representing an inflamed state of the udder. Ropiness of this character is not usually communicable from one lot of milk to another.

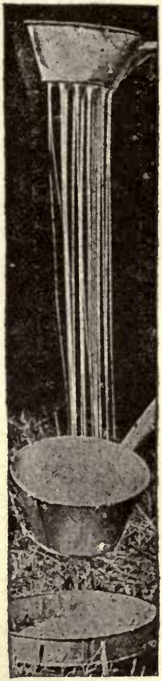

FIG. 17. Ropy milk.

The communicable form of ropy milk only appears after the milk has been drawn from the udder for a day or so, and is caused by the development of various species of bacteria which find their way into the milk after it is drawn. These defects are liable to occur at any season of the year. Their presence in a dairy is a source of much trouble, as the unsightly appearance of the milk precludes its use as food, although there is no evidence that these ropy fermentations are dangerous to health.

There are undoubtedly a number of different species of bacteria that are capable of producing these viscid changes,[1] but it is quite probable that they are not of equal importance in infecting milk under natural conditions.

In the majority of cases studied in this country,[2] the

[1] Guillebeau (Milch Zeit., 1892, p. 808) has studied over a dozen different forms that possess this property.

[2] Ward, Bull. 165, Cornell Expt. Stat., Mch., 1899; also Bull. 195, Ibid., Nov., 1901.

causal organism seems to be *B. lactis viscosus*, a form first found by Adametz in surface waters.[1] This organism possesses the property of developing at low temperatures (45°–50° F.), and consequently it is often able in winter to supplant the lactic-acid forms. Ward has found this germ repeatedly in water tanks where milk cans are cooled; and under these conditions it is easy to see how infection of the milk might occur. Marshall[2] reports an outbreak which he traced to an external infection of the udder; in another case, the slime-forming organism was abundant in the barn dust. A defect of this character is often perpetuated in a dairy for some time, and may therefore become exceedingly troublesome. In one instance in the writer's experience, a milk dealer lost over $150 a month for several months from ropy cream. Failure to properly sterilize cans, and particularly strainer cloths, is frequently responsible for a continuance of trouble of this sort.

The slimy substance formed in milk comes from various constituents of the milk, and the chemical character of the slime produced also varies with different germs. In some cases the slimy material is merely the swollen outer cell membrane of the bacteria themselves as in the case of *B. lactis viscosus;* in others it is due to the decomposition of the proteids, but often the chief decomposition product appears to come from a viscous fermentation of the milk-sugar.

An interesting case of a fermentation of this class being utilized in dairying is seen in the use of "lange wei" (long or stringy whey) which is employed as a starter in Holland to control the gassy fermentations in Edam cheese.

[1] Adametz, Landw. Jahr., 1891, p. 185.

[2] Marshall, Mich. Expt. Stat., Bull. 140.

This slimy change is due to the growth of *Streptococcus Hollandicus*.[1]

Alcoholic fermentations. Although glucose or cane-sugar solutions are extremely prone to undergo alcoholic fermentation, milk sugar does not readily decompose. The more important alcoholic ferments are the yeasts, which do not thrive readily in the milk, although Duclaux[2] reports a serious case in a dairy due to this cause.

Koumiss, a beverage originally made in the Orient from mare's milk, is an example of an alcoholic fermentation which is produced by the addition of cane sugar and yeast to ordinary cow's milk. It is used with success in gastric troubles. In addition to the CO_2 developed which gives it its effervescent qualities, alcohol, lactic acid, and casein-dissolving ferments are also formed.

Kephir is another alcoholic drink made from milk that is in common use among the people of Caucasus. It is made by adding to milk kephir grains, which are merely a mass of fermented cells (yeasts and bacteria) that start the fermentation. This milk is then mixed with fresh milk and kept in leather flasks until a mixed fermentation sets in. The nature of the change is not yet thoroughly understood,[3] although it is quite probable that the alcoholic change is produced by a yeast, while bacteria change the casein more or less.

Bitter milk. The presence of bitter substances in milk may be ascribed to a variety of causes. A number of plants, such as lupines, wormwood and chicory, possess the property of affecting milk when the same are consumed by ani-

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[1] Milch Zeit., 1889, p. 982.

[2] Duclaux, Principes de Laiterie, p. 60.

[3] Freudenreich, Landw. Jahr. d. Schweiz, 1896, 10:1.

mals. At certain stages in lactation, a bitter salty taste is occasionally to be noted that is peculiar to individual animals.

A considerable number of cases of bitter milk have, however, been traced to bacterial origin. For a number of years the bitter fermentation of milk was thought to be associated with the butyric fermentation, but Weigmann[1] showed that the two conditions were not dependent upon each other. He found that the organism which produced the bitter taste acted upon the casein.

Conn[2] observed a coccus form in bitter cream that was able to impart a bitter flavor to milk. Sometimes a bitter condition does not develop in the milk, but may appear later in the milk products, as in the case of a micrococcus which Freudenreich[3] found in cheese.

Cream ripened at low temperatures not infrequently develops a bitter flavor, showing that the optimum temperature for this type of fermentation is below the typical lactic acid change.

It has long been a question how to account chemically for the bitter taste in milk. Various ideas have been advanced, but Freudenreich has demonstrated in one case that a bitter substance is formed in the milk that can be isolated by adding alcohol.

Milk that has been cooked is likely to develop a bitter condition. The explanation of this is that the bacteria producing the bitter substances usually possess endospores, and that while the boiling or sterilizing of milk easily kills the lactic acid germs, these forms on account of their greater resisting powers are not destroyed by the heat.

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[1] Weigmann, Milch Zeit., 1890, p. 881.

[2] Conn, 3 Rept. Storrs Expt. Stat., 1890, p. 158.

[3] Freudenreich, Fühl. Landw. Ztg., 43: 361.

Soapy milk: A soapy flavor in milk was traced by Weigmann and Zirn[1] to a specific bacillus, *B. lactis saponacei*, that they found gained access to the milk in one case from the bedding and in another instance from hay. A similar outbreak has been reported in this country,[2] due to a germ acting on the casein and albumen.

Red milk. The most common trouble of this nature in milk is due to presence of blood, which is most frequently caused by some wound in the udder. The ingestion of certain plants as sedges and scouring rushes is also said to cause a bloody condition; madders impart a reddish tinge due to coloring matter absorbed. Defects of this class can be readily distinguished from those due to germ growth because they are apparent at time of milking. Where blood is actually present, the corpuscles settle out in a short time if left undisturbed.

There are a number of chromogenic or color-producing bacteria that are able to grow in milk, but their action is so slow that generally they are not of much consequence. Moreover their development is usually confined to the surface of the milk as it stands in a vessel. The most important is the well-known *B. prodigiosus.* Another form found at times in milk possessing low acidity[3] is *B. lactis erythrogenes.* This species only develops the red color in the dark. In the light, it forms a yellow pigment. Various other organisms have been reported at different times.[4]

Blue milk. Blue milk has been known for many years, its communicable nature being established as long ago as 1838. It appears on the surface of milk first as isolated

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[1] Milch Zeit. 22:569.

[2] Marshall, Bull. 146, Mich. Expt. Stat., p. 16.

[3] Grotenfelt, Milch Zeit., 1839, p. 263.

[4] Menge, Cent. f. Bakt., 6:596; Keferstein, Cent. f. Bakt., 21:177.

particles of bluish or grey color, which later become confluent, the blue color increasing in intensity as the acidity increases. The causal organism, *B. cyanogenes*, is very resistant toward drying,[1] thus accounting for its persistence. In Mecklenberg an outbreak of this sort once continued for several years. It has frequently been observed in Europe in the past, but is not now so often reported. Occasional outbreaks have been reported in this country.

Other kinds of colored milk. Two or three chromogenic forms producing still other colors have occasionally been found in milk. Adametz[2] discovered in a sample of cooked milk a peculiar form *(Bacillus synxanthus)* that produced a citron-yellow appearance which precipitated and finally rendered soluble the casein. Adametz, Conn, and List have described other species that confer tints of yellow on milk. Some of these are bright lemon, others orange, and some amber in color.

Still other color-producing bacteria, such as those that produce violet or green changes in the milk, have been observed. In fact, almost any of the chromogenic bacteria are able to produce their color changes in milk as it is such an excellent food medium. Under ordinary conditions, these do not gain access to milk in sufficient numbers so that they modify the appearance ot it except in occasional instances.

Treatment of abnormal fermentations. If the taint is recognized as of bacterial origin (see p. 57) and is found in the mixed milk of the herd, it is necessary to ascertain, first, whether it is a general trouble, or restricted to one or more animals. This can sometimes be done by separating

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[1] Heim, Arb. a. d. Kais. Gesundheitsamte, 5:578.

[2] Adametz, Milch Zeit., 1890, p. 225.

the milk of the different cows and noting whether any abnormal condition develops in the respective samples.

Fermentation tests. The most satisfactory way to detect the presence of the taints more often present is to make a fermentation test of one kind or another. These tests are most frequently used at the factory, to enable the maker to detect the presence of milk that is likely to prove unfit for use, especially in cheese making. They are based upon the principle that if milk is held at a moderately high temperature, the bacteria will develop rapidly. A number of different methods have been devised for this purpose. In Walther's lacto-fermentator samples of milk are simply allowed to stand in bottles or glass jars until they sour. They are examined at intervals of several hours. If the curdled milk is homogeneous and has a pure acid smell, the milk is regarded as all right. If it floats in a turbid serum, is full of gas or ragged holes, it is abnormal. As generally carried out, no attempt is made to have these vessels sterile. Gerber's test is a similar test that has been extensively employed in Switzerland. Sometimes a few drops of rennet are added to the milk so as to curdle the same, and thus permit of the more ready detection of the gas that is evolved.

Wisconsin curd test. The method of testing milk described below was devised at the Wisconsin Experiment Station in 1895 by Babcock, Russell and Decker.[1] It was used first in connection with experimental work on the influence of gas-generating bacteria in cheese making, but its applicability to the detection of all taints in milk produced by bacteria makes it a valuable test for abnormal fermentations in general.

In the curd test a small pat of curd is made in a glass

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[1] 12 Rept. Wis. Expt. Stat., 1895, p. 148; also Bull. 67, Ibid., June, 1898.

jar from each sample of milk. These tests may be made in any receptacle that has been cleaned in boiling water, and to keep the temperature more nearly uniform these jars should be immersed in warm water, as in a wash tub or some other receptacle. When the milk is about 95° F., about ten drops of rennet extract are added to each sample and mixed thoroughly with the milk. The jars should then remain undisturbed until the milk is completely curdled; then the curd is cut into small pieces with a case knife and stirred to expel the whey. The whey should be poured off at frequent intervals until the curd mats. If the sample be kept at blood heat (98° F.) for six to eight hours, it will be ready to examine.

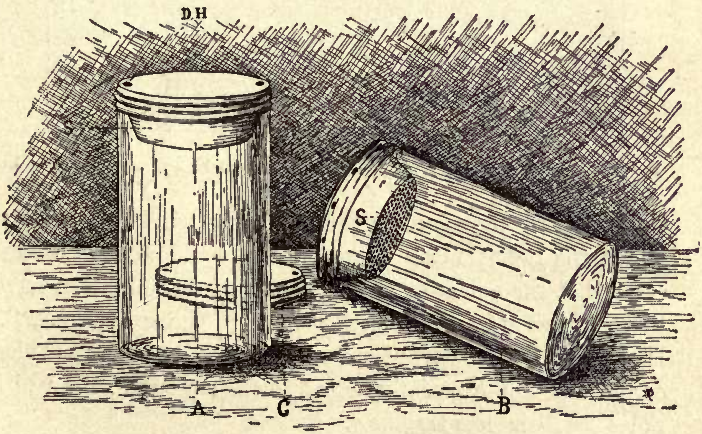

Fig. 18. Improved bottles for making curd test. *A*, test bottle complete; *B*, bottle showing construction of cover; *S*, sieve to hold back the curd when bottle is inverted; *C*, outer cover with (*D H*) drain holes to permit of removal of whey.

More convenient types of this test than the improvised apparatus just alluded to have been devised by different dairy manufacturers. Generally, they consist of a special bottle having a full-sized top, thus permitting the easy removal of the curd. The one shown in Fig. 18 is provided with a sieve of such construction that the bottles will drain thoroughly if inclined in an inverted position.

Interpretation of results of test. The curd from a good milk has a firm, solid texture, and should contain at most only a few small pin holes. It may have some large, irregular, "mechanical" holes where the curd particles have failed to cement, as is seen in Fig. 19. If gas-producing bac-

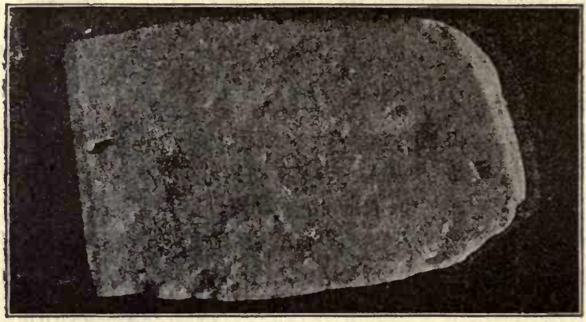

FIG. 19. Curd from a good milk. The large irregular holes are mechanical.

teria are very prevalent in the milk, the conditions under which the test is made cause such a rapid growth of the same that the evidence of the abnormal fermentation may be readily seen in the spongy texture of the curd (Fig. 20). If the undesirable organisms are not very abundant and the conditions not especially suited to their growth, the "pin holes" will be less frequent.

Sometimes the curds show no evidence of gas, but their abnormal condition can be recognized by the "mushy" texture and the presence of "off" flavors that are rendered more apparent by keeping them in closed bottles. This condition is abnormal and is apt to produce quite as serious results as if gas was formed.

Overcoming taints by use of starters. Another method of combatting abnormal fermentations that is often fruitful, is that which rests upon the inability of one kind of bacteria to grow in the same medium in competition with certain other species.

Some of the undesirable taints in factories can be controlled in large part by the introduction of starters made

FIG. 20. Curd from a badly tainted milk. Large ragged holes are mechanical; numerous small holes due to gas. This curd was a "floater."

from certain organisms that are able to obtain the ascendency over the taint-producing germ. Such a method is commonly followed when a lactic ferment, either a commercial pure culture, or a home-made starter, is added to milk to overcome the effect of gas-generating bacteria.

A similar illustration is seen in the case of the "lange wei" (slimy whey), that is used in the manufacture of Edam cheese to control the character of the fermentation of the milk.

This same method is sometimes applied in dealing with certain abnormal fermentations that are apt to occur on the farm. It is particularly useful with those tainted milks known as "sweet curdling." The ferment organisms concerned in this change are unable to develop in the presence of lactic acid bacteria, so the addition of a clean sour milk as a starter restores the normal conditions by giving the ordinary milk bacteria the ascendency.

Chemical disinfection. In exceptional instances it may be necessary to employ chemical disinfectants to restore the normal conditions. Of course with such diseases as tuberculosis, very stringent measures are required, as they are such a direct menace to human life, but with these abnormal or taint-producing fermentations, care and cleanliness, well directed, will usually overcome the trouble.

If it becomes necessary to employ chemical substances as disinfecting agents, their use should always be preceded by a thorough cleansing with hot water so that the germicide may come in direct contact with the surface to be disinfected.

It must be borne in mind that many chemicals act as deodorants, *i. e.*, destroy the offensive odor, without destroying the cause of the trouble.

Sulfur is often recommended as a disinfecting agent, but its use should be carefully controlled, otherwise the vapors have but little germicidal power. The common practice of burning a small quantity in a room or any closed space for a few moments has little or no effect upon germ life. The effect of sulfur vapor (SO_2) alone upon germ life is relatively slight, but if this gas is produced in the presence of moisture, sulfurous acid (H_2SO_3) is formed, which is much more efficient. To use this agent effectively, it must be burned in large quantities in a moist atmosphere (three lbs. to every 1,000 cubic feet of space), for at least twelve hours. After this operation, the space should be thoroughly aired.

Formalin, a watery solution of a gas known as formaldehyde, is a new disinfectant that recent experience has demonstrated to be very useful. It may be used as a gas where rooms are to be disinfected, or applied as a liquid where desired. It is much more powerful in its action than sulfur, and it has a great advantage over mercury and other strong disinfectants, as it is not so poisonous to man as it is to the lower forms of life.

Bleaching powder or *chloride of lime* is often recommended where a chemical can be advantageously used. This substance is a good disinfectant as well as a deodorant, and if applied as a wash, in the proportion of four to six ounces of the powder to one gallon of water, it will destroy most forms of life. In many cases this agent is inapplicable on account of its odor.

Corrosive sublimate ($Hg\ Cl_2$) for most purposes is a good disinfectant, but it is such an intense poison that its use is dangerous in places that are at all accessible to stock.

For the disinfection of walls in stables and barns, common thin *white wash* ($Ca\ OH$) is admirably adapted if made from freshly-burned quick lime. It possesses strong germicidal powers, increases the amount of light in the barn, is a good absorbent of odors, and is exceedingly cheap.

Carbolic acid, creosote, and such products, while excellent disinfectants, cannot well be used on account of their odor, especially in factories.

For gutters, drains, and waste pipes in factories, *vitriol salts* (sulfates of copper, iron and zinc) are sometimes used. These are deodorants as well as disinfectants, and are not so objectionable to use on account of their odor.

These suggestions as to the use of chemicals, however, only apply to extreme cases and should not be brought into requisition until a thorough application of hot water, soap, a little soda, and the scrubbing brush have failed to do their work.

CHAPTER V.

RELATION OF DISEASE-BACTERIA TO MILK.

PRACTICAL experience with epidemic disease has abundantly demonstrated the fact that milk not infrequently serves as a vehicle for the dissemination of contagion. Attention has been prominently called to this relation by Ernest Hart,[1] who in 1880 compiled statistical evidence showing the numerous outbreaks of various contagious diseases that had been associated with milk infection up to that time. Since then, further compilations have been made by Freeman,[2] and also by Busey and Kober,[3] who have collected the data with reference to outbreaks from 1880 to 1899.

These statistics indicate the relative importance of milk as a factor in the dissemination of disease.

The danger from this source is much intensified for the reason that milk, generally speaking, is consumed in a raw state; and also because a considerable number of disease-producing bacteria are able, not merely to exist, but actually thrive and grow in milk, even though the normal milk bacteria are also present. Moreover the recognition of the presence of such pathogenic forms is complicated by the fact that often they do not alter the appearance of

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[1] Hart, Trans. Int. Med. Cong., London, 1881, 4:491–544.

[2] Freeman, Med. Rec., March 28, 1896.

[3] Busey and Kober, Rept. Health Off. of Dist. of Col., Washington, D. C., 1895, p. 299. These authors present in this report an elaborate article on morbific and infectious milk, giving a very complete bibliography of 180 numbers. They append to Hart's list (which is published in full) additional outbreaks which have occurred since, together with full data as to extent of epidemic, circumstances governing the outbreak, as well as name of original reporter and reference.

the milk sufficiently so that their presence can be detected by a physical examination. These facts which have been experimentally determined, coupled with the numerous clinical cases on record, make a strong case against milk serving as an agent in the dissemination of disease.

Origin of pathogenic bacteria in milk. Disease-producing bacteria may be grouped with reference to their relation toward milk into two classes, depending upon the manner in which infection occurs:

Class I. Disease-producing bacteria capable of being transmitted directly from a diseased animal to man through the medium of infected milk.

Class II. Bacteria pathogenic for man but not for cattle which are capable of thriving in milk after it is drawn from the animal.

In the first group the disease produced by the specific organism must be common to both cattle and man. The organism must live a parasitic life in the animal, developing in the udder, and so infect the milk supply. It may, of course, happen that diseases toward which domestic animals alone are susceptible may be spread from one animal to another in this way without affecting human beings.

In the second group, the bacterial species lives a saprophytic existence, growing in milk, if it happens to find its way therein. In such cases milk indirectly serves as an agent in the dissemination of disease, by giving conditions favorable to the growth of the disease germ.

By far the most important of diseases that may be transmitted directly from animal to man through a diseased milk supply is tuberculosis, but in addition to this, foot and mouth disease (aphthous fever in children), anthrax and acute enteric troubles have also been traced to a similar source of infection.

The most important specific diseases that have been disseminated through subsequent pollution of the milk are typhoid fever, diphtheria, scarlet fever and cholera, but, of course, the possibility exists that any disease germ capable of living and thriving in milk may be spread in this way. In addition to these diseases that are caused by the introduction of specific organisms (the causal organism of scarlet fever has not yet been definitely determined), there are a large number of more or less illy-defined troubles of an intestinal character that occur especially in infants and young children that are undoubtedly attributable to the activity of microörganisms that gain access to milk during and subsequent to the milking, and which produce changes in milk before or after its ingestion that result in the formation of toxic products.

DISEASES TRANSMISSIBLE FROM ANIMAL TO MAN THROUGH DISEASED MILK.

Tuberculosis. In view of the wide-spread distribution of this disease in both the human and the bovine race, the relation of the same to milk supplies is a question of great importance. It is now generally admitted that the different types of tubercular disease found in different kinds of animals and man are attributable to the development of the same organism, *Bacillus tuberculosis*, although there are varieties of this organism found in different species of animals that are sufficiently distinct to permit of recognition.

The question of prime importance is, whether the bovine type is transmissible to the human or not. Artificial inoculation of cattle with tuberculous human sputum as well as pure cultures of this variety show that the human type is able to make but slight headway in cattle. This would indicate that the danger of cattle acquiring the infection from man would in all probability be very slight, but these experiments offer no answer as to the possibility of transmission from the bovine to the human. Manifestly it is impossible to solve this problem by direct experiment upon man except by artificial inoculation, but comparative experiments upon animals throw some light on the question.

Theo. Smith[1] and others[2] have made parallel experiments with animals such as guinea pigs, rabbits and pigeons, inoculated with both bovine and human cultures of this organism. The results obtained in the case of all animals tested show that the virulence of the two types was much different, but that the bovine cultures were much more severe. While of course this does not prove that transmission from bovine to human is possible, still the importance of the fact must not be overlooked.

In a number of cases record of accidental infection from cattle to man has been noted.[3] These have occurred with persons engaged in making post-mortem examinations on tuberculous animals, and the tubercular nature of the wound was proven in some cases by excision and inoculation.

In addition to data of this sort that is practically experimental in character, there are also strong clinical reasons for considering that infection of human beings may occur through the medium of milk. Naturally such infection should produce intestinal tuberculosis, and it is noteworthy that this phase of the disease is quite common in children

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[1] Smith, Theo., Journ. of Expt. Med., 1898, 3: 451.

[2] Dinwiddie, Bull. 57, Ark. Expt. Stat., June, 1899; Ravenel, Univ. of Penn. Med. Bull., Sept. 1901.

[3] Ravenel, Journ. of Comp. Med. & Vet. Arch., Dec. 1897; Hartzell, Journ. Amer. Med. Ass'n, April 16, 1893.

especially between the ages of two and five.[1] It is difficult to determine, though, whether primary infection occurred through the intestine, for, usually, other organs also become involved. In a considerable number of cases in which tubercular infection by the most common channel, inhalation, seems to be excluded, the evidence is strong that the disease was contracted through the medium of the milk, but it is always very difficult to exclude the possibility of pulmonary infection.

Tuberculosis as a bovine disease has increased rapidly during recent decades throughout many portions of the world. This has been most marked in dairy regions. Its extremely insidious nature does not permit of an early recognition by physical means, and it was not until the introduction of the tuberculin test[2] in 1892, as a diagnostic aid that accurate knowledge of its distribution was possible. The quite general introduction of this test in many regions has revealed an alarmingly large percentage of animals as affected. In Denmark in 1894 over forty per cent were diagnosed as tubercular. In some parts of Germany almost as bad a condition has been revealed. Slaughter-house statistics also show that the disease has increased rapidly since 1890. In this country the disease on the average is much less than in Europe and is also very irregularly distributed. In herds where it gained a foothold some years ago, often the majority of animals are frequently infected; many

[1] Stille, Brit. Med. Journ., Aug. 19, 1899.

[2] This test is made by injecting into the animal a small quantity of tuberculin, which is a sterilized glycerin extract of cultures of the tubercle bacillus. In a tuberculous animal, even in the very earliest phases of the disease, tuberculin causes a temporary fever that lasts for a few hours. By taking the temperature a number of times before and after injection it is possible to readily recognize any febrile condition. A positive diagnosis is made where the temperature after inoculation is at least 2.0° F. above the average normal, and where the reaction fever is continued for a period of some hours.

herds, in fact the great majority, are wholly free from all taint. The disease has undoubtedly been most frequently introduced through the purchase of apparently healthy but incipiently affected animals. Consequently in the older dairy regions where stock has been improved the most by breeding, more of the disease exists than among the western and southern cattle.

Infectiousness of milk of reacting animals. Where the disease appears in the udder the milk almost invariably contains the tubercle organism. Under such conditions the appearance of the milk is not materially altered at first,

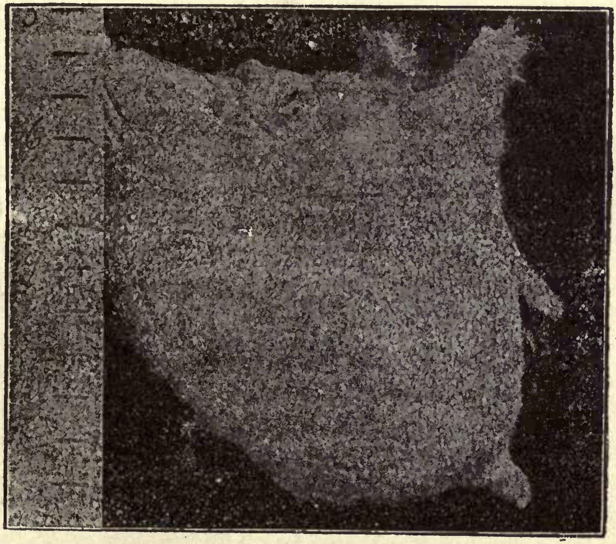

FIG. 21. Side view of a tuberculous udder, showing extent of swelling in single quarter.

but as the disease progresses the percentage of fat generally diminishes, and at times in the more advanced stages where the physical condition of the udder is changed (Fig. 21), the milk may become "watery"; but the percentage of animals showing such udder lesions is not large, usually not more than a few per cent.

On the other hand, in the earlier phases of the disease, where its presence has been recognized solely by the aid of the tuberculin test, before there are any recognizable physical symptoms in any part of the animal, the milk is generally unaffected. Between these extremes, however, is found a large proportion of cases, concerning which so definite data are not available. The results of investigators on this point are conflicting and further information is much desired. Some have asserted so long as the udder itself shows no lesions that no tubercle bacilli would be present,[1] but the findings of a considerable number of investigators[2] indicate that even when the udder is apparently not diseased the milk may contain the specific organism as revealed by inoculation experiments upon animals. In some cases, however, it has been demonstrated by post-mortem examination that discoverable udder lesions existed that were not recognizable before autopsy was made. In the experimental evidence collected, a varying percentage of reacting animals were found that gave positive results; and this number was generally sufficient to indicate that the danger of using milk from reacting animals was considerable, even though apparently no disease could be found in the udder.

The infectiousness of milk can also be proven by the frequent contraction of the disease in other animals, such as calves and pigs which may be fed on the skim milk. The very rapid increase of the disease among the swine of Ger-

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[1] Martin, Brit. Med. Journ. 1895, 1:937; Nocard, Les Tuberculoses animales, 1895.

[2] Bang. Schmidt's Jahrb., 235:22; Hirschberger, Arch. f. klin. Medicin, 1889; Ernst, Infectiousness of Milk, 1895; Ravenel, Bull. 75, Penn. Dept. Agr., 1901.

many and Denmark,[1] and the frequently reported cases of intestinal infection of young stock also attest the presence of the organism in milk.

The tubercle bacillus is so markedly parasitic in its habits, that, under ordinary conditions, it is incapable of growing at normal air temperatures. There is, therefore, no danger of the germ developing in milk after it is drawn from the animal, unless the same is kept at practically blood heat.

Even though the milk of some reacting animals may not contain the dangerous organism at the time of making the test, it is quite impossible to foretell how long it will remain free. As the disease becomes more generalized, or if tuberculous lesions should develop in the udder, the milk may pass from a healthy to an infectious state.

This fact makes it advisable to exclude from milk supplies intended for human use, all milk of animals that respond to the tuberculin test; or at least to treat it in a manner so as to render it safe. Whether it is necessary to do this or not if the milk is made into butter or cheese is a somewhat different question. Exclusion or treatment is rendered more imperative in milk supplies, because the danger is greater with children with whom milk is often a prominent constituent of their diet, and also for the reason that the child is more susceptible to intestinal infection than the adult.

The danger of infection is much lessened in butter or cheese, because the processes of manufacture tend to diminish the number of organisms originally present in the milk, and inasmuch as no growth can ordinarily take place in these products the danger is minimized. Moreover, the fact that

[1] Ostertag, Milch Zeit., 22:672.

these foods are consumed by the individual in smaller amounts than is generally the case where milk is used, and also to a greater extent by adults, lessens still further the danger of infection.

Notwithstanding this, numerous observers[1] especially in Germany have succeeded in finding the tubercle bacillus in market butter, but this fact is not so surprising when it is remembered that a very large fraction of their cattle show the presence of the disease as indicated by the tuberculin test, a condition that does not obtain in any large section in this country.

These observations on the presence of the tubercle bacillus in butter have been questioned somewhat of late[2] by the determination of the fact that butter may contain an organism that possesses the property of being stained in the same way as the tubercle organism. Differentiation between the two forms is rendered more difficult by the fact that this tubercle-like organism is also capable of producing in animals lesions that simulate those of tuberculosis, although a careful examination reveals definite differences. Petri[1] has recently determined that both the true tubercle and the acid-resisting butter organism may be readily found in market butter.

In the various milk products it has been experimentally determined that the true tubercle bacillus is able to retain its vitality in butter for a number of months and in cheese for nearly a year.

Treatment of milk from tuberculous cows. While it has been shown that it is practically impossible to foretell whether the milk of any reacting animal actually contains

[1] Obermüller, Hyg. Rund., 1897, p. 712; Petri, Arb. a. d. Kais. Ges. Amte, 1898, 14: 1; Hormann und Morgenroth, Hyg. Rund., 1898, p. 217.

[2] Rabinowitsch. Zeit. f. Hyg., 1897, 26: 90.

tubercle bacilli or not, still the interests of public health demand that no milk from such stock be used for human food until it has been rendered safe by some satisfactory treatment.

1. Heating. By far the best treatment that can be given such milk is to heat it. The temperature at which this should be done depends upon the thermal death point of the tubercle bacillus, a question concerning which there has been considerable difference of opinion until very recently. According to the work of some of the earlier investigators, the tubercle bacillus in its vegetative stage is endowed with powers of resistance greater than those possessed by any other pathogenic organism. This work has not been substantiated by the most recent investigations on this subject. In determining the thermal death point of this organism, as of any other, not only must the temperature be considered, but the period of exposure as well, and where that exposure is made in milk, another factor must be considered, viz., the presence of conditions permitting of the formation of a "scalded layer," for as Smith[1] first pointed out, the resistance of the tubercle organism toward heat is greatly increased under these conditions. If tuberculous milk is heated in a closed receptacle where this scalded membrane cannot be produced, the tubercle bacillus is killed at 140° F. in 15 to 20 minutes. These results which were first determined by Smith, under laboratory conditions, and confirmed by Russell and Hastings,[2] where tuberculous milk was heated in commercial pasteurizers, have also been verified by Hesse.[3] A great practical advantage which accrues from the treatment of milk at

[1] Th. Smith, Journ. of Expt. Med., 1899, 4: 217.

[2] Russell and Hastings, 18 Rept. Wis. Expt. Stat., 1901.

[3] Hesse, Zeit. f. Hyg., 1900, 34:346.

140° F. is that the natural creaming is practically unaffected. Of course, where a higher temperature is employed, the period of exposure may be materially lessened. If milk is momentarily heated to 185° F., it is sufficient to destroy the vitality of the tubercle bacillus. This is the plan practiced in Denmark where all skim milk and whey must be heated to this temperature before it can be taken back to the farm, a plan which is designed to prevent the dissemination of tuberculosis and foot and mouth disease by means of the mixed creamery by-products. This course renders it possible to utilize with perfect safety, for milk supplies, the milk of herds reacting to the tuberculin test, and as butter of the best quality can be made from cream or milk heated to even high temperatures,[1] it thus becomes possible to prevent with slight expense what would otherwise entail a large loss.

2. Dilution. Another method that has been suggested for the treatment of this suspected milk is dilution with a relatively large volume ot perfectly healthy milk. It is a well known fact that to produce infection, it requires the simultaneous introduction of a number of organisms, and in the case of tuberculosis, especially that produced by ingestion, this number is thought to be considerable. Gebhardt[2] found that the milk of tuberculous cows, which was virulent when injected by itself into animals, was innocuous when diluted with 40 to 100 times its volume of healthy milk. This fact is hardly to be relied upon in practice, unless the proportion of reacting to healthy cows is positively known.

It has also been claimed in the centrifugal separation of

[1] Practically all of the finest butter made in Denmark is made from cream that has been pasteurized at temperatures varying from 160°-185° F.

[2] Gebhardt, Virch. Arch., 1890, 119: 12.

cream from milk[1] that by far the larger number of tubercle bacilli were thrown out with the separator slime. Moore[2] has shown that the tubercle bacilli in an artificially infected milk might be reduced in this way, so as to be no longer microscopically demonstrable, yet the purification was not complete enough to prevent the infection of animals inoculated with the milk.

Another way to exclude all possibility of tubercular infection in milk supplies is to reject all milk from reacting animals. This method is often followed where pasteurization or sterilization is not desired. In dairies where the keeping quality is dependent upon the exclusion of bacteria by stringent conditions as to milking and handling ("sanitary" or "hygienic" milk), the tuberculin test is frequently used as a basis to insure healthy milk.

Foot and mouth disease. The widespread extension of this disease throughout Europe in recent years has given abundant opportunity to show that while it is distinctively an animal malady, it is also transmissible to man, although the disease is rarely fatal. The causal organism has not been determined with certainty, but it has been thoroughly proven that the milk of affected animals possesses infectious properties.[3]

Hertwig showed the direct transmissibility of the disease to man by experiments made on himself and others. By ingesting milk from an affected animal, he was able to produce the symptoms of the disease, the mucous membrane of the mouth being covered with the small vesicles that characterize the malady. It has also been shown that

[1] Scheurlen, Arb. a. d. k. Ges. Amte, 1891, 7: 269; Bang, Milch Zeit., 1893, p. 672.

[2] Moore, Year Book of U. S. Dept. Agr., 1895, p. 432.

[3] Weigel and Noack, Jahres. d. Ges. Med., 1890, p. 642; Weissenberg, Allg. med. Cent. Zeit., 1890, p. 1; Baum, Arch. f. Thierheilkunde, 1892, 18:16.

the virus of the disease may be conveyed in butter.[1] This disease is practically unknown in this country, although widely spread in Europe.

There are a number of other bovine diseases such as anthrax,[2] lockjaw,[3] and hydrophobia[4] in which it has been shown that the virus of the disease is at times to be found in the milk supply, but in most cases the secretion of milk becomes visibly affected, so that the danger of using such is greatly minimized.

There are also a number of inflammatory udder troubles known as garget or mammitis which are produced by bacterial action. In most of these, the physical appearance of the milk is so changed, and often pus is present to such a degree as to give a very disagreeable appearance to the milk. Pus-forming bacteria (staphylococci and streptococci) are to be found associated with such troubles.

DISEASES TRANSMISSIBLE TO MAN THROUGH INFECTION OF MILK AFTER WITHDRAWAL.

Milk is so well adapted to the development of bacteria in general, that it is not surprising to find it a suitable medium for the growth of many pathogenic species. While this statement applies primarily to milk in a sterile condition, yet in some cases, disease-producing bacteria are even able to grow in raw milk in competition with the normal milk bacteria, so that even a slight contamination may suffice to produce infection.

The diseases that are most frequently disseminated in

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[1] Schneider, Münch, med. Wochenschr., 1893, No. 27; Fröhner, Ziet. f. Fleisch u. Milchhygiene, 1891, p. 55.

[2] Feser, Deutsche Zeit. f. Thiermed., 1880, 6:166.

[3] Nocard, Bull. Gén., 1885, p. 54.

[4] Deutsche Viertelsjahr. f. offentl. Gesundheitspflege, 1890, 20:444.

this way are typhoid fever, diphtheria, scarlet fever and cholera, together with the various illy-defined intestinal troubles of a toxic character that occur in children, especially under the name of cholera infantum, summer complaint, etc.

Diseases of this class are not derived directly from animals because cattle are not susceptible to the same.

Modes of infection. In a variety of ways, however, the milk may be subject to contaminating influences after it is drawn from the animal, and so give opportunity for the development of disease-producing bacteria. The more important methods of infection are as follows:

1. *Infection directly from a pre-existing case of disease on premises.* Quite frequently a person in the early stage of a diseased condition may continue at his usual vocation as helper in the barn or dairy, and so give opportunity for direct infection to occur. In the so-called cases of "walking typhoid," this danger is emphasized. Again during the period of convalescence, a similar opportunity exists for direct infection. This method functions more frequently in scarlet fever than in typhoid. In some cases infection has been traced to storage of the milk in rooms in the house where it became polluted directly by the emanations of the patient.[1] Among the dwellings of the lower classes where a single room has to be used in common this source of infection has been most frequently observed.

2. *Infection through the medium of another person.* Not infrequently another individual may serve in the capacity of nurse or attendant to a sick person, and also assist in the handling of the milk, either in milking the animals or

[1] E. Roth, Deutsche Vierteljahresschr. f. offentl. Gesundheitspfl., 1890, 22:238.

caring for the milk after it has been drawn. Busey and Kober report twenty-one outbreaks of typhoid fever in which dairy employees also acted in the capacity of nurses.

3. *Pollution of milk utensils.* The most frequent method of infection of cans, pails, etc., is in cleaning them with water that may be polluted with disease organisms. Often wells may be contaminated with diseased matter of intestinal origin, as in typhoid fever, and the use of water at normal temperatures, or even in a luke-warm condition, give conditions permitting of infection. Intentional adulteration of milk with water inadvertently taken from polluted sources has caused quite a number of typhoid outbreaks.[1] Sedgwick and Chapin[2] found in the Springfield, Mass., epidemic of typhoid that the milk cans were placed in a well to cool the milk, and it was subsequently shown that the well was polluted with typhoid fecal matter.

4. *Pollution of udder* of animal *by wading in infected water*, or by washing same with contaminated water. This method of infection would only be likely to occur in case of typhoid. An outbreak at the University of Virginia in 1893[3] was ascribed to the latter cause.

5. *Pollution of creamery by-products, skim-milk, etc.* Where the milk supply of one patron becomes infected with pathogenic bacteria, it is possible that disease may be disseminated through the medium of the creamery, the infective agent remaining in the skim milk after separation and so polluting the mixed supply. This condition is more likely to prevail with typhoid because of the greater tolerance of this organism for acids such as would be found in raw

[1] S. W. North, London Practitioner, 1889, 43:393.

[2] Sedgwick and Chapin, Boston Med. & Surg. Journ., 1893, 129:485.

[3] Dabney, Phila. Med. News, 1893, 63:630.

milk. The outbreaks at Brandon,[1] England, in 1893, Castle Island,[2] Ireland, and Marlboro,[3] Mass., in 1894, were traced to such an origin.

While most outbreaks of disease associated with a polluted milk supply originate in the use of the milk itself, yet infected milk may serve to cause disease even when used in other ways. Several outbreaks of typhoid fever have been traced to the use of ice cream where there were strong reasons for believing that the milk used in the manufacture of the product was polluted.[4] Hankin[5] details a case of an Indian confection made largely from milk that caused a typhoid outbreak in a British regiment.

Although the evidence that milk may not infrequently serve as an agent in spreading disease is conclusive enough to satisfactorily prove the proposition, yet it should be borne in mind that the organism of any specific disease in question has rarely ever been found. The reasons for this are quite the same as those that govern the situation in the case of polluted waters, except that the difficulties of the problem are much greater in the case of milk than with water. The inability to readily separate the typhoid germ, for instance, from the colon bacillus, an organism frequently found in milk, presents technical difficulties not easily overcome. The most potent reason of failure to find disease bacteria is the fact that infection in any case must occur sometime previous to the appearance of the outbreak. Not only is there the usual period of incubation, but it rarely happens that an outbreak is investigated until a number of

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[1] Welphy, London Lancet, 1804, 2:1085.

[2] Brit. Med. Journ., 1894, 1:815.

[3] Mass. Bd. Health Rept., 1894, p. 765.

[4] Turner, London Practitioner, 1892, 49:141; Munro, Brit. Med. Journ., 1894, 2:829.

[5] Hankin, Brit. Med. Journ., 1894, 2:613.

cases have occurred. In this interim the original cause of infection may have ceased to be operative.

Typhoid fever. With reference to the diseases likely to to be disseminated through the medium of milk, infected after being drawn from the animal, typhoid fever is the most important. The reason for this is due (1) to the wide spread distribution of the disease; (2) to the fact that the typhoid bacillus is one that is capable of withstanding considerable amounts of acid, and consequently finds even in raw milk containing the normal lactic acid bacteria conditions favorable for its growth.[1] Ability to grow under these conditions can be shown not only experimentally, but there is abundant clinical evidence that even a slight infection often causes extensive outbreaks, as in the Stamford, Conn., outbreak in 1895 where 386 cases developed in a few weeks, 97 per cent of which occurred on the route of one milkman. In this case the milk cans were thoroughly and properly cleaned, but were rinsed out with *cold* water from a shallow well that was found to be polluted.

The most common mode of pollution of milk with typhoid organisms is where the milk utensils are infected in one way or another. Generally, this arises from the use of polluted water in cleansing the vessels or in intentional watering of the milk. Second in importance is the carrying of infection by persons serving in the dual capacity of nurse and dairy attendant.

Cholera. This germ does not find milk so favorable a nutrient medium as the typhoid organism, because it is much more sensitive toward the action of acids. Kitasato[2]

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[1] Heim (Arb. a. d. Kais. Gesundheitsamte, 1889, 5:303) finds it capable of living from 20–30 days in milk.

[2] Kitasato, Arb. a. d. Kais. Gesundheitsamte, 1:470.

found, however, that it could live in raw milk from one to four days, depending upon the amount of acid present. In boiled or sterilized milk it grows more freely, as the acid-producing forms are thereby eliminated. In butter it dies out in a few days (4 to 5).

On account of the above relation not a large number of cholera outbreaks have been traced to milk, but Simpson[1] records a very striking case in India where a number of sailors, upon reaching port, secured a quantity of milk. Of the crew which consumed this, every one was taken ill, and four out of ten died, while those who did not partake escaped without any disease. It was later shown that the milk was adulterated with water taken from an open pool in a cholera infected district.

Diphtheria. According to Klein[2] the diphtheria organism is capable of developing in animals, attacking among other organs the udder, and so infecting the milk; but Abbott[3] or Vladimirow[4] failed to confirm these experiments. There is abundant evidence that the diphtheria organism is able to grow luxuriantly in milk, even more so in raw than in sterilized.[5]

Infection in this disease is more frequently attributable to direct infection from patient, or indirectly through attendant.

Scarlet fever. Although it is more difficult to study the relation of this disease to contaminated milk supplies, because the causal germ of scarlet fever is not yet known, yet the origin of a considerable number of epidemics has

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[1] Simpson, London Practitioner, 1887, 39:144.

[2] Klein, 19 Loc. Gov't. Bd. (Gt. Brit.) 1889, 167.

[3] Abbott, Vet. Mag. 1: 17.

[4] Vladimirow, Arch. Sci. biol. Inst. Med., St. Petersburg, 1892, p. 84.

[5] Schottelius and Ellerhorst, Milch Zeit., 1897, pp. 40 and 73.

been traced to polluted milk supplies. An outbreak occurred at East Orange,[1] New Jersey, a few years ago in which from one to four cases developed in each of sixteen families. The cause of the outbreak was traced to the son of the milkman who, soon after convalescence from an attack of the disease, resumed his work as milker.

Diarrhoeal diseases. Milk not infrequently acquires the property of producing diseases of the digestive tract by reason of the development of various bacteria that form more or less poisonous by-products. These troubles occur most frequently during the summer months, especially with infants and children, as in cholera infantum and summer complaint. The higher mortality of bottle-fed infants[2] in comparison with those that are nursed directly is explicable alone on the theory that cows' milk is the carrier of the infection, because in many cases it is not consumed until there has been ample time for the development of organisms in it. As a cause of sickness and death these diseases exceed in importance all other specific diseases previously referred to.

The cause of these troubles is not to be ascribed to any specific kind of bacteria, but there are undoubtedly a large number of organisms which are able to develop toxic substances in food products, especially in milk. In some cases it appears that the development of the poisonous products takes place in the intestines after the food is ingested. The origin of these bacteria is in all probability due to the introduction of dirt and filth that find their way into the milk at the time of milking. Flügge[3] has pointed out the

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[1] Boston Med. Journ., 1897, 136: 44.

[2] Baginsky, Hyg. Rund., 1895, p. 176.

[3] Flügge, Zeit. f. Hyg., 17: 272.

fact that certain peptonizing species which are frequently found in milk possess a toxic property for lower animals.

Ptomaine poisoning. Many cases of poisoning from food products are also reported with adults. These are due to the formation of various toxic products, generally ptomaines, that are produced as a result of infection of foods by different bacteria. One of these substances, *tyrotoxicon*, was isolated by Vaughan[1] from cheese and various other products of milk, and found to possess the property of producing symptoms of poisoning similar to those that are noted in such cases. He attributes the production of this toxic effect to the decomposition of the elements in the milk induced by putrefactive forms of bacteria that develop where milk is improperly kept.[2] Often outbreaks of this character[3] assume the proportions of an epidemic, where a large number of persons use the tainted food.

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[1] Zeit. f. physiol. Chemie, 10:146; 9 Intern. Hyg. Cong. (London), 1891, p. 118.

[2] Vaughan and Perkins, Arch. f. Hyg., 27:308.

[3] Newton and Wallace (Phila. Med. News, 1887, 50:570) report three outbreaks at Long Branch, N. J., two of which occurred in summer hotels.

CHAPTER VI.

PRESERVATION OF MILK FOR COMMERCIAL PURPOSES.

In Chapter III it has been shown how milk becomes contaminated with various kinds of bacteria which find in this liquid most favorable conditions for development. The result of this contamination is that the period during which milk has a commercial value for food purposes, either in the form of milk, or milk products, such as butter and cheese, is greatly lessened, thereby causing losses of considerable economic importance.

Moreover, it has been further shown (Chapter V) that this food product which is so admirably adapted to serve as food may become infected with disease-producing organisms, and so be the means of disseminating contagion.

From these two points of view, therefore,

1. the *economic*, as shown by the keeping quality of the milk, and

2. the *hygienic*, as shown by its possibility to spread disease, it is highly important that means should be adopted, if possible, that will result in improving the keeping quality so as to diminish these losses, and at the same time insure freedom from bacteria capable of developing disease. Inasmuch as the fermentative changes which ordinarily occur, and which lessen the commercial life of the milk as a food, depend entirely on the development of living organisms that may find their way into the milk, an improvement in the condition of the milk may be secured (1) by excluding bacterial life so far as practicable, at the time

the milk is drawn, and subsequently holding the milk at temperatures unfavorable to the multiplication of the relatively few organisms that do gain access; or (2) by removing those organisms wholly or in part after they have once gained access to the milk. If all are not eliminated, it then becomes necessary to keep the milk under such conditions as to check the growth of those which are not removed.

Preservation by exclusion. The first method is followed in many dairies that supply high-grade milk for city delivery. The so-called "sanitary" or "hygienic" milk is usually a milk that has been handled in such a way as to prevent the introduction of most bacteria that under ordinary conditions would find their way into the same. The merits of a milk of this character in comparison with one preserved by means of other methods, as pasteurization, is a question concerning which there has been much discussion. When it is considered, as will be shown later, that methods of preservation can be successfully applied that will not apparently change the chemical and physical properties of milk, it is an open question that must be decided in each case whether exclusion of bacteria can be as economically and efficiently performed as the destruction of the living organisms by heat. Certain it is that the process of exclusion must be confined to dairies that are under individual control. The impossibility of exercising adequate control with reference to the milking process and the care of the milk immediately thereafter, when the same is produced on different farms, is evident.

In enhancing the keeping quality of milk by removing the bacteria it is necessary to do so without in any way materially interfering with the nutritive qualities of the fluid. The different methods that have been proposed to accomplish this result depend upon the removal of the contained organisms by mechanical means, or their destruction in the milk by means of either chemical or physical processes. In removing the bacteria two means have been more or less extensively employed, as filtration and centrifugal force.

Filtration of milk. Straining milk through cloth or wire strainers has always been used as a means of cleaning milk from dirt and foreign matter; but it is quite evident that the removal of such material can only diminish the germ content of the milk to the extent that bacteria would adhere to such coarse particles. The individual organisms floating in milk are capable of passing the finest strainer, and consequently, such processes are more accurately methods of cleaning and purifying the milk rather than methods that enhance the keeping quality.

Along somewhat similar lines are the various methods of filtration that have been devised. The use of germ-proof filters, such as the Pasteur or Berkefeld type, are inadmissible with milk, because the pores of these filters are so fine as to hold back practically all suspended matter, fat and casein as well as the bacteria.

For a number of years, gravel, sand or quartz filters have been employed for the double purpose of cleaning milk and preserving it. Several different types of these filters are or have been in use. The most satisfactory are built in several sections so as to permit of ready cleansing, a process which must be most thoroughly carried out with apparatus of this kind. Bolle of Berlin washes his filters first with boiling water, then dilute hydrochloric acid, and finally, with water until all trace of acid is removed. The

Copenhagen Dairy Co. sterilize their gravel filters by high heat. In other cases lime water is used in cleansing. Filters of this type remove practically all dirt and a considerable proportion of the contained bacteria, but they are intended more to clean the milk than enhance its keeping quality. Woodfiber (cellulose) has also been tested as a filtering substance with success.

Centrifugal cleaning of milk. The familiar coating of slime and dirt that collects on the inner face of the separator bowl shows that centrifugal force can be successfully used in cleaning or clarifying milk. While the ordinary types of cream separators are able to remove this material in a satisfactory way, special machines have been devised for this particular purpose. A bacteriological examination of separator slime shows it to be teeming with myriads of organisms, and the rapid decomposition which it undergoes is evidence of its high germ content, but there is practically little or no improvement in the keeping quality of milk that has been treated in this way. This is in part due to the fact that bacteria reproduce so rapidly that a marked variation in numbers is soon obscured by relatively more rapid growth. Eckles and Barnes[1] find that from 37 to 56 per cent of the total number of bacteria present in milk are thrown out by passing milk through separators. Where milk is cleaned in this way, the cream and skim milk is generally mixed again immediately, but the passage of cream through the separator bowl tends to break down the size of the normal fat-globule clusters and so lessen the consistency of the product. Such a diminution in "body" diminishes materially the ease with which cream can be whipped.

[1] Eckles and Barnes, Bull. No. 59 Iowa Expt. Stat., Aug. 1901.

Chemical preservatives. Numerous attempts have been made to find some chemical substance that could be added to milk which would preserve it without interfering with its nutritive properties, but as a general rule a substance that is toxic enough to destroy or inhibit the growth of bacterial life exerts a prejudicial effect on the tissues of the body. The use of chemicals, such as carbolic acid, mercury salts and mineral acids, that are able to entirely destroy all life, is of course excluded, except when milk is preserved for analytical purposes; but a number of milder substances are more or less extensively employed, although the statutes of practically all states forbid their use.

The substances so used may be grouped in two classes:

1. Those that unite chemically with certain by-products of bacterial growth to form inert substances. Thus bicarbonate of soda neutralizes the acid in souring milk, although it does not destroy the lactic acid bacteria.

2. Those that act directly upon the bacteria in milk, restraining or inhibiting their development. The substances most frequently utilized are salicylic acid, formaldehyde and boracic acid. These are nearly always sold to the milk handler, under some proprietary name, at prices greatly in excess of what the crude chemicals could be bought for in the open market. Formaldehyde has been widely advertised of late, but its use is fraught with the greatest danger, for it practically renders insoluble all albuminous matter and its toxic effect is greatly increased in larger doses.

These substances are generally used by milk handlers who know nothing of their poisonous action, and although it may be possible for adults to withstand their use in dilute form, without serious results, yet their addition to general milk supplies that may be used by children is little short of criminal. The sale of these preparations for use in milk finds its only outlet with those dairymen who are anxious to escape the exactions that must be met by all who attempt to handle milk in the best possible manner. Farrington has suggested a simple means for the detection of preservalin (boracic acid).[1] When this substance is added to fresh milk, it increases the acidity of milk without affecting its taste. As normal milk tastes sour when it contains about 0.3 per cent lactic acid, a milk that tests as much or more than this without tasting sour has been probably treated with this antiseptic agent.

Physical methods of preservation. Methods based upon the application of physical forces are less likely to injure the nutritive value of milk, and are consequently more effective, if of any value whatever. A number of methods have been tried more or less thoroughly in an experimental way that have not yet been reduced to a practical basis, as electricity, use of a vacuum, and increased pressure.[2] Condensation has long been used with great success, but in this process the nature of the milk is materially changed. The keeping quality in condensed milk often depends upon the action of another principle, viz., the inhibition of bacterial growth by reason of the concentration of the medium. This condition is reached either by adding sugar and so increasing the soluble solids, or by driving off the water by evaporation, preferably in a vacuum pan. Temperature changes are, however, of the most value in preserving milk, for by a variation in temperature all bacterial growth can be brought to a standstill, and under proper conditions thoroughly destroyed.

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[1] Farrington, Journ. Amer. Chem. Soc., Sept., 1896.

[2] Hite, Bull. 58, West Va. Expt. Stat., 1899.

Use of low temperatures. The effect of chilling or rapid cooling on the keeping quality of milk is well known. When the temperature of milk is lowered to the neighborhood of 45° F., the development of bacterial life is so slow as to materially increase the period that milk remains sweet. Within recent years, attempts have been made to preserve milk so that it could be shipped long distances by freezing the product, which in the form of milk-ice could be held for an indefinite period without change.[1] A modification of this process known as Casse's system has been tried on an extensive scale in Copenhagen and in several places in Germany. This consists of adding a small block of milk-ice (frozen milk) to large cans of milk (one part to about fifty of milk) which may or may not be pasteurized.[2] This reduces the temperature so that the milk remains sweet considerably longer. Such a process permits of the shipment of milk for long distances with safety. It is reported that London receives milk from Denmark and Sweden that is treated in this way.

FIG. 22. Microscopic appearance of normal milk showing the fat-globules aggregated in clusters.

Use of high temperatures. Heat has long been used as a preserving agent. Milk has been scalded or cooked to keep it from time immemorial. Heat may be used at differ-

[1] Milch Zeit., 1895, No. 9.

[2] Ibid., 1897, No. 33.

ent temperatures, and when so applied exerts a varying effect, depending upon temperature employed. All methods of preservation by heat rest, however, upon the application of the heat under the following conditions:

1. A temperature above the maximum growing-point (105°–115° F.) and below the thermal death-point (130°–140° F.) will prevent further growth, and consequently fermentative action.

2. A temperature above the thermal death-point destroys bacteria, and thereby stops all changes. This temperature varies, however, with the condition of the bacteria, and for spores is much higher than for vegetative forms.

Attempts have been made to employ the first principle in shipping milk by rail, viz., prolonged heating above growing temperature, but when milk is so heated, its physical appearance is changed.[1] The methods of heating most satisfactorily used are known as sterilization and pasteurization, in which a degree of temperature is used approximating the boiling and scalding points respectively.

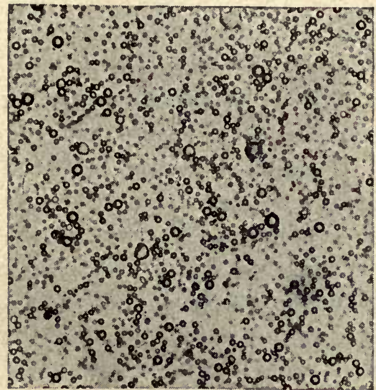

FIG. 23. Microscopic appearance of milk heated above 140° F., showing the homogeneous distribution of fat-globules. The physical change noted in comparison with Fig. 22 causes the diminished consistency of pasteurized cream.

Effect of heat on milk. When milk is subjected to the action of heat, a number of changes in its physical and chemical properties are to be noted.

[1] Bernstein, Milch Zeit., 1894, pp. 184, 200.

1. *Diminished "body."* When milk, but more especially cream, is heated to 140° F. or above, it becomes thinner in consistency or "body," a condition which is due to a change in the grouping of the fat globules. In normal milk, the butter fat for the most part is massed in microscopic clots as shown in Fig. 22. When exposed to a temperature of 140° F. or above, these fat-globule clots break down, and the globules become homogeneously distributed as in Fig. 23. Under these conditions milk does not cream readily. When cream itself is so heated, its consistency is materially reduced, giving the impression that it contains a less per cent of butter fat. These changes seriously affect the general adoption of heat as a means of preserving milk for ordinary market use, but fortunately this defect can be overcome.

2. *Cooked taste.* If milk is heated to 160° F., it acquires a cooked taste that becomes more pronounced as the temperature is further raised. Milk so heated develops on its surface a pellicle or "skin." The cause of this change in taste is not well known. Usually it has been explained as being produced by changes in the nitrogenous elements in the milk, particularly in the albumen. Recently, Thoerner[1] has pointed out the coincidence that exists between the appearance of a cooked taste and the loss of certain gases that are expelled by heating. He finds that the milk heated in closed vessels from which the gas cannot escape has a much less pronounced cooked flavor than if heated in an open vessel. The so-called "skin" on the surface of heated milk is not formed when the milk is heated in a tightly-closed receptacle. By some[2] it is asserted that this layer is composed of albumen, but there is

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[1] Thoerner, Chem. Zeit., 18: 845.

[2] Snyder, Chemistry of Dairying, p. 59.

evidence to show that it is modified casein due to the rapid evaporation of the milk serum at the surface of the milk.

3. Digestibility. Considerable difference of opinion has existed in the minds of medical men as to the relative digestibility of raw and heated milks. A considerable amount of experimental work has been done by making artificial digestion experiments with enzyms, also digestion experiments with animals, and in a few cases with children. The results obtained by different investigators are quite contradictory, although the preponderance of evidence seems to be in favor of the view that heating does impair the digestibility of milk, especially if the temperature attains the sterilizing point.[1] It has been observed that there is a noteworthy increase in amount of rickets,[2] scurvy and marasmus in children where highly-heated milks are employed. These objections do not obtain with reference to milk heated to moderate temperatures, as in pasteurization, although even this lower temperature lessens slightly its digestibility. The successful use of pasteurized milks in children's hospitals is evidence of its usefulness.

4. Fermentative changes. The normal souring change in milk is due to the predominance of the lactic acid bacteria, but as these organisms as a class do not possess spores, they are readily killed when heated above the thermal death-point of the developing cell. The destruction of the lactic forms leaves the spore-bearing types possessors of the field, and consequently the fermentative changes in heated milk

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[1] Doane and Price (Bull. 77, Md. Expt. Stat., Aug. 1901) give quite a full resumé of the work on this subject in connection with rather extensive experiments made by them on feeding animals with raw, pasteurized and sterilized milks.

[2] Rickets is a disease in which the bones lack sufficient mineral matter to give them proper firmness. Marasmus is a condition in which the ingested food seems to fail to nourish the body and gradual wasting away occurs.

are not those that usually occur, but are characterized by the curdling of the milk from the action of rennet enzyms.

5. Action of rennet. Heating milk causes the soluble lime salts to be precipitated, and as the curdling of milk by rennet (in cheese-making) is dependent upon the presence of these salts, their absence in heated milks greatly retards the action of rennet. This renders it difficult to utilize heated milks in cheese-making unless the soluble lime salts are restored, which can be done by adding solutions of calcium chlorid.

Sterilization. As ordinarily used in dairying, sterilization means the application of heat at temperatures approximating, if not exceeding, 212° F. It does not necessarily imply that milk so treated is sterile, i. e., germ-free; for, on account of the resistance of spores, it is practically impossible to destroy entirely *all* these hardy forms. If milk is heated at temperatures above the boiling point, as is done where steam pressure is utilized, it can be rendered practically germ-free. Such methods are employed where it is designed to keep milk sweet for a long period of time. The treatment of milk by sterilization has not met with any general favor in this country, although it has been more widely introduced abroad. In most cases the process is carried out after the milk is bottled; and considerable ingenuity has been exercised in the construction of devices which will permit of the closure of the bottles after the sterilizing process has been completed. Milks heated to so high a temperature have a more or less pronounced boiled or cooked taste, a condition that does not meet with general favor in this country. The apparatus suitable for this purpose must, of necessity, be so constructed as to withstand steam pressure, and consequently is considerably more expensive than that required for the simpler pasteurizing process.

Pasteurization. In this method the degree of heat used ranges from 140° to 185° F. and the application is made for only a limited length of time. The process was first extensively used by Pasteur (from whom it derives its name) in combating various maladies of beer and wine. Its importance as a means of increasing the keeping quality of milk was not generally recognized until a few years ago; but the method is now growing rapidly in favor as a means of preserving milk for commercial purposes. The method does not destroy all germ-life in milk; it affects only those organisms that are in a growing, vegetative condition; but if the same is quickly cooled, it enhances the keeping quality very materially. It is unfortunate that this same term is used in connection with the heating of cream as a preparatory step to the use of pure cultures in cream-ripening in butter-making. The objects to be accomplished vary materially and the details of the two processes are also quite different. The experiments of Bitter[1] indicate that when stored at 86° F., properly pasteurized milk will remain sweet from six to eight hours longer than raw milk; at 77° F., ten hours; at 73° F., twenty hours; and at 58° F., from fifty to seventy hours. This enhances the keeping quality enough so that it serves all practical purposes.

While pasteurizing can be performed on a small scale by the individual, the process can also be adapted to the commercial treatment of large quantities of milk. The apparatus necessary for this purpose is not nearly so expensive as that used in sterilizing, a factor of importance when other advantages are considered. In this country pasteur-

[1] Bitter, Zeit. f. Hyg., 1890, 17:272.

ization has made considerable headway, not only in supplying a milk that is designed to serve as children's food, but even for general purposes.

Conditions that determine pasteurizing limits. Considerable latitude with reference to temperature limits is permissible in pasteurizing, but there are certain conditions which should be met, and these, in a sense, fix the limits employed. They are as follows:

1. Physical requirement. Inasmuch as it is undesirable to have any material change in taste and appearance in pasteurized milk from that normally found in the raw product, the pasteurizing temperature should be limited to the degree of heat that can safely be employed without any danger of imparting a cooked or scalded flavor to milk. If the exposure is made for any considerable period of time, say fifteen to twenty minutes, this change in taste appears to be quite permanent when the milk is heated to 158° F. This condition, therefore, determines the maximum limit that should be used in pasteurizing, if one is to avoid the production of a cooked flavor. Even below this temperature a slight change in flavor occurs, although it disappears upon chilling the milk. Where access of air is excluded during heating, this cooked taste does not develop so markedly.

2. Biological requirement. To be of value in increasing the keeping quality of milk and to insure freedom from disease bacteria, it is necessary, in all cases, to exceed the thermal death-point of at least the actively developing bacteria in the milk. For most bacteria this limit is constant and quite sharply defined, ranging from 130° to 140° F. where the exposure is made for ten minutes. Where exposed for a briefer period of time, the temperature limit is necessarily higher. The organism that is invested with most interest in this connection is the tubercle bacillus. On account of its more or less frequent occurrence in milk (see p. 87) and its reputed high powers of resistance, it may well be taken as a standard in pasteurizing.

Thermal death limits of tubercle bacillus. Concerning the exact temperature at which this germ is destroyed there is considerable difference of opinion. Part of this arises from the inherent difficulty in determining exactly when the organism is killed (due to its failure to grow readily on artificial media), and part from the lack of uniform conditions of exposure. The standards that previously have been most generally accepted are those of De Man,[1] who found that thirty minutes exposure at 149° F., fifteen minutes at 155° F., or ten minutes at 167° F., sufficed to destroy this germ.

More recently it has been conclusively proven,[2] and these results confirmed by different investigators,[3] that if tuberculous milk is heated in closed receptacles where the scalded surface pellicle does not form, the vitality of this disease germ is destroyed at 140° F. in a brief period (15 to 20 minutes). If the conditions of heating are such that the surface of the milk is exposed to the air, the resistance of bacteria is greatly increased. When heated in open vessels Smith found that the tubercle organism was not killed in some cases where the exposure was made for at least an hour. Russell and Hastings[4] have shown an instance where the thermal death-point of a micrococcus isolated from pasteurized milk was increased 12.5° F., by heating it under

[1] De Man, Arch. f. Hyg., 1893, 18:133.

[2] Th. Smith, Journ. of Expt. Med., 1899, 4: 217.

[3] Russell and Hastings, 17 Rept. Wis. Expt. Stat., 1900, p. 147.

[4] Russell and Hastings, 18 Rept. Ibid., 1901.

conditions that permitted of the formation of the scalded layer. This is a point of great practical importance in the treatment of milk and necessitates the use of machinery that will prevent the formation of this surface film. It follows, therefore, from these results that a temperature of 140° F. can be used if advisable, although higher temperatures are not inadmissible.

Sanitary advantages of pasteurized milk. Not only does pasteurized milk keep longer and is also free from specific disease bacteria, but its use has been of utmost importance in checking infant mortality from diarrhoeal disturbances. This is shown in the diminished death rate in children's hospitals, and is again exemplified on a large scale in the results that have been obtained in New York City through the liberality of Nathan Strauss, who, for several years, has furnished the poor children of that city with pasteurized milk. Since the introduction of this milk, the death rate of those under five years of age has dropped over ten per thousand living persons, a condition which is explicable in large measure to the use of a relatively germ-free milk.

Pasteurized milk should be consumed within twenty-four hours if it is used by children. If left under conditions favorable to germination, bacterial growth will go on, and it has been shown that the type of fermentation produced may sometimes be deleterious.[1]

High vs. low temperature pasteurization. The limit which has been most generally employed has been the maximum at which a cooked flavor did not appear, and in practice this has been 155° F. for a period of exposure of twenty minutes. Under these conditions, pasteurization is efficiently and thoroughly performed, but the application of this degree of heat to milk results in a diminution

[1] Flügge, Zeit. f. Hyg., 1894, 17: 272.

of creaming property, and especially in cream of a marked decrease in thickness. Both of these conditions seriously interfere with the general extension of pasteurization, because the consumer does not like a milk on which the cream does not rise thoroughly. The reasons which underlie this physical change have already been noted (p. 109), and it should be further observed that if milk is not pasteurized at a temperature exceeding 140° F., this change in condition does not obtain. Milk heated to this temperature satisfactorily fills the biological requirement, in that the vegetating forms of the acid-producing as well as the disease bacteria are destroyed. The consequence is that the keeping quality of such milk is practically as good as if it was heated to a temperature of 155° F. The application of this temperature results in the preparation of a milk or cream that more closely approximates the condition of the normal product, while at the same time such milk possesses practically all of the advantages that are found in that heated to a higher temperature.

Bacteriological studies. The following bacteriological studies as to the effect which a variation in temperature exerts on bacterial life in milk are of importance as indicating the proper temperature limits to be selected. In the following table the exposures were made for a uniform period (20 minutes):

The bacterial content of milk heated at different temperatures.

	Number of bacteria per cc. in milk.						
		45°C.	50°C.	55°C.	60°C.	65°C.	70°C.
	Unheated	113°F.	122°F.	131°F.	140°F.	149°F.	158°F.
Series I.	2,895,000	———	1,260,000	798,000	32,000	5,770	3,900
Series II.	750,000	665,000	262,400	201,000	950	700	705
Series III.	1,350,000	1,100,000	260,000	215,000	575	610	650
Series IV.	1,750,000	———	87,360	———	4,000	3,500	3,600

It appears from these results that the most marked decrease in temperature occurs at 140° F. (60° C.). At 113° F. (45° C.) no marked diminution was noted; at 122° F. (50° C.) many cells were killed, but the larger part of them were not killed until a temperature of 140° F. (60° C.) was reached. It should also be observed that an increase in heat above this temperature did not materially diminish the number of organisms present, indicating that those forms remaining were in a spore or resistant condition. It was noted, however, that the developing colonies grew more slowly in the plates made from the highly heated milk, showing that their vitality was injured to a greater extent.

Applicability to general use. This method of low temperature pasteurization has now been tried under practical conditions for a sufficient period to determine its utility as a means of preserving general market milk. The fact that it does not modify in any essential particular the normal characters of milk is a point much in its favor. Enhancement in keeping quality and freedom from disease organisms are factors of such value that they readily commend such milk to the general consumer. With the improvements that have been made in pasteurizing machinery, it is now possible to handle considerable quantities and so reduce very much the cost of treatment per gallon. This method is especially applicable to the treatment of cream. The extreme perishable nature of this milk product makes it imperative that it should be handled in such a way as to check as far as possible germ growth, and this can be readily accomplished when the same is pasteurized and kept at low temperatures. The higher intrinsic value of this product lessens the relative cost of operation per unit of volume.

Within the last few years this system has been quite widely introduced into a number of cities, and the results obtained are, on the whole, successful. As a system for general use it does not meet with nearly as much opposition as is offered to the use of the higher limits.

One marked advantage accruing to this system is its general applicability. Milk can be pasteurized where it is produced under a single management as in the individual dairy, or the product of several patrons can be treated together, as in a factory. The fresher and better the milk is, though, the more suitable it is for pasteurizing. Therefore, while it is possible to somewhat improve milk that has been collected for some hours (12 to 24) if it is properly pasteurized, still better results will be obtained if the treatment is given nearer the animal. Under practical conditions, however, pasteurizing near the place of consumption has some advantages and is preferable, if it is possible to transport the raw material quickly from the place of production.

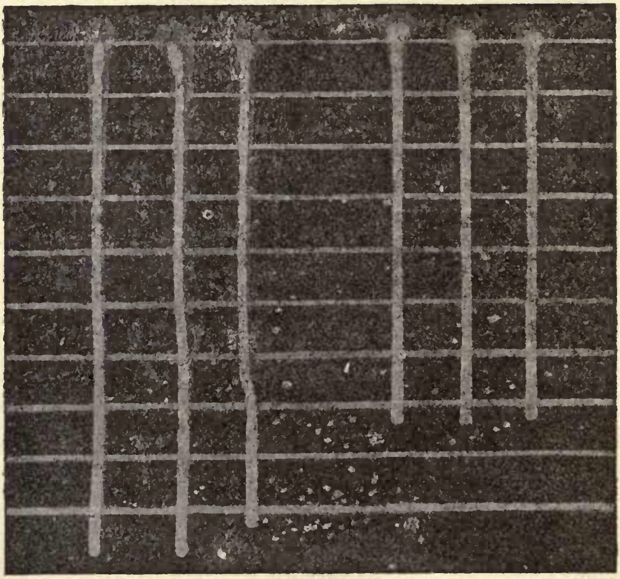
For the preparation of high-grade milk supplies it may be said that either the elimination of the bacteria by pasteurization, or preventing their gaining access to the milk, as in sanitary dairies, is the most feasible and successful way to deal with this question.

Restoration of "body" of pasteurized cream. The action of heat causes the tiny groupings of fat globules in normal milk (Fig. 22) to break up, and with this change, which occurs in the neighborhood of 140° F., the consistency of the liquid is diminished, notwithstanding the fact that the fat-content remains unchanged. Babcock and the writer[1] devised the following "cure" for this apparent

[1] Babcock and Russell, Bull. 54, Wis. Expt. Stat., also 13 Rept. Wis. Expt. Stat. 1896, p. 81.

defect. If a strong solution of cane sugar is added to freshly slacked lime and the mixture allowed to stand, a clear fluid can be decanted off. The addition of this alkaline liquid, which is called "viscogen," to pasteurized cream in proportions of about one part of sugar-lime solution to 100 to 150 of cream, restores the consistencyof the cream, as it causes the fat globules to cluster together in small groups.

The relative viscosity of creams can easily be determined by the following method (Fig. 24):



A B

Fig. 24. Relative consistency of pasteurized cream before (A) and after (B) treatment with viscogen as shown by rate of flow down inclined glass plate.

Take a perfectly clean piece of glass (plate or picture glass is preferable, as it is less liable to be wavy). Drop on one edge two or three drops of cream at intervals of an inch or so. Then incline piece of glass at such an angle as to cause the cream to flow down surface of glass. The cream, having the heavier body or viscosity, will move more slowly. If several samples of each cream are taken, then the aggregate lengths of the different cream paths may be taken, thereby eliminating slight differences due to condition of glass.

Pasteurizing details. While the pasteurizing process is exceedingly simple, yet, in order to secure the best results, certain conditions must be rigidly observed in the treatment before and after the heating process.

It is important to select the best possible milk for pasteurizing, for if the milk has not been milked under clean conditions, it is likely to be rich in the spore-bearing bacteria. Old milk, or milk that has not been kept at a low temperature, is much richer in germ-life than perfectly fresh or thoroughly chilled milk.

The true standard for selecting milk for pasteurization should be to determine the actual number of bacterial *spores* that are able to resist the heating process, but this method is impracticable under commercial conditions.

The following method, while only approximate in its results, will be found helpful: Assuming that the age or treatment of the milk bears a certain relation to the presence of spores, and that the acid increases in a general way with an increase in age or temperature, the amount of acid present may be taken as an approximate index of the suitability of the milk for pasteurizing purposes. Biological tests were carried out in the author's laboratory[1] on milks having a high and low acid content, and it was shown that

[1] Shockley, Thesis, Univ. of Wis., 1896.

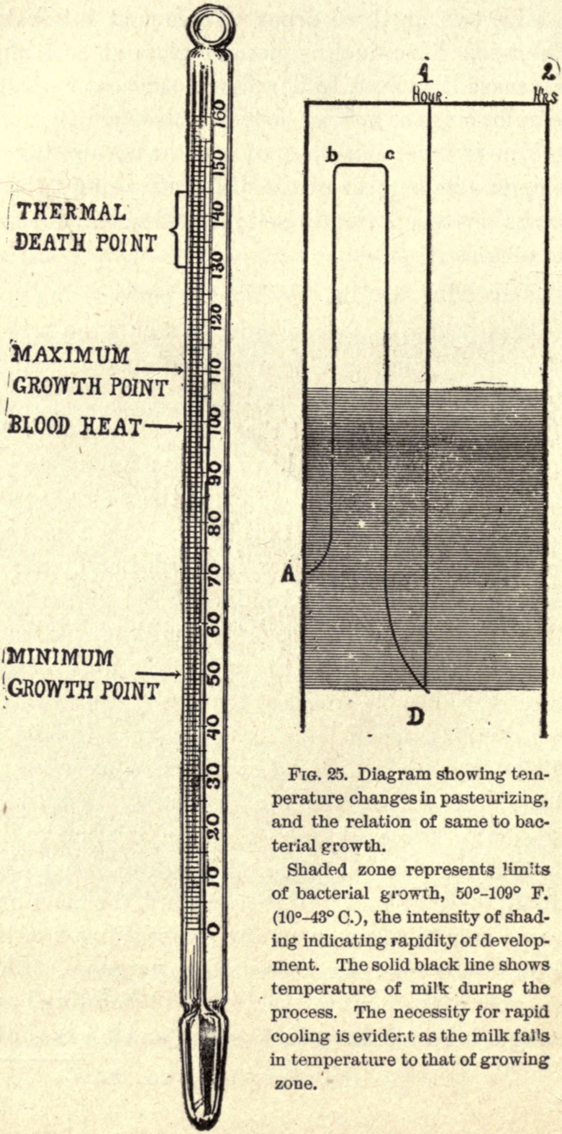


FIG. 25. Diagram showing temperature changes in pasteurizing, and the relation of same to bacterial growth.

Shaded zone represents limits of bacterial growth, 50°–109° F. (10°–43° C.), the intensity of shading indicating rapidity of development. The solid black line shows temperature of milk during the process. The necessity for rapid cooling is evident as the milk falls in temperature to that of growing zone.

the milk with the least acid was, as a rule, the freest from spore-bearing bacteria.

This acid determination can be made at the weigh-can by employing the Farrington alkaline tablet which is used in cream-ripening. Where milk is pasteurized under general creamery conditions, none should be used containing more than 0.2 per cent acidity. If only perfectly fresh milk is used, the amount of acid will generally be about 0.15 per cent with phenolphthalein as indicator.

Emphasis has already been laid on the selection of a proper limit of pasteurizing (p. 114). It should be kept constantly in mind that the thermal death-point of any organism depends not alone on the temperature used, but on the period of exposure. With the limits given, 140° to 155° F., it is necessary to expose the milk for not less than fifteen minutes. If a higher heat is employed (and the cooked flavor disregarded) the period of exposure may be curtailed.

Chilling the milk. It is very essential in pasteurizing that the heated milk be immediately chilled in order to prevent the germination of the resistant spores, for if germination once occurs, growth can go on at relatively low temperatures.

The following experiments by Marshall[1] are of interest as showing the influence of refrigeration on germination of spores:

Cultures of organisms that had been isolated from pasteurized milk were inoculated into bouillon. One set was left to grow at room temperature, another was pasteurized and allowed to stand at same temperature, while another heated set was kept in a refrigerator. The unheated cul-

[1] Marshall, Mich. Expt. Stat., Bull. 147, p. 47.

tures at room temperature showed evidence of growth in thirty trials in an average of 26 hours; 29 heated cultures at room temperature all developed in an average of 50 hours, while the heated cultures kept in refrigerator showed no growth in 45 days with but four exceptions.

After the milk is pasteurized, it must of necessity be stored and handled in germ-free receptacles. All utensils, such as cans, dippers, bottles, etc., must be thoroughly sterilized. For this purpose a sterilizing oven should be had which is fitted with steam. Material of this sort, after being thoroughly cleansed, should be steamed for one-half to three-quarters of an hour. Sterilized bottles should be kept protected from dust until they are used.

Bottling and handling the product. In bottling the product it is necessary to keep the milk protected from re-infection. It may be bottled from a large can with a bottom faucet, or, on a large scale, with commercial bottling machines that fill several bottles at once. If "viscogen" is added to restore consistency of cream, it should be done before bottling, but not before the cream is thoroughly cooled. The best bottles for the purpose are those that have a plain pulp cap. All metal fastenings or stoppers are dirt-catchers and are likely to get out of order. It is our practice to heat pulp caps in paraffin, thereby rendering them more pliable and at the same time sterilizing them. Bottles sealed with hot caps in this way are tightly closed.

In delivering pasteurized products, it is always necessary to use care in handling to prevent the cream and milk from being warmed up, and thus inciting into activity the latent spores.

Pasteurizing apparatus. The problems to be solved in the pasteurization of milk and cream designed for direct consumption are so materially different from those where butter is to be made that the type of machinery best adapted to each purpose is quite different. The equipment necessary for the first purpose may be divided into two general classes:

1. Apparatus of limited capacity designed for family use.
2. Apparatus of sufficient capacity to pasteurize on a commercial scale.

Domestic pasteurizers. In pasteurizing milk for individual use, it is not desirable to treat at one time more than will be consumed in one day; hence an apparatus holding a few bottles will suffice. In this case the treatment can best be performed in the bottle itself, thereby lessening the danger of infection. Several different types of pasteurizers are on the market; but special apparatus is by no means necessary for the purpose. The process can be efficiently performed by any one with the addition of an ordinary dairy thermometer to the common utensils found in the kitchen. Fig. 26 indicates a simple contrivance that can be readily arranged for this purpose.

The following suggestions indicate the different steps of the process:

1. Use only fresh milk.
2. Place milk in clean bottles or fruit cans, filling to a uniform level, closing bottles tightly with a cork or cover. If pint and quart cans are used at the same time, an inverted bowl will equalize the level. Set these in a flat-bottomed tin pail and fill with warm water to same level as milk. An inverted pie tin punched with holes will serve as a stand on which to place the bottles during the heating process.

3. Heat water in pail until the temperature of same reaches 155° to 160° F.; then remove from source of direct heat, cover with a cloth or tin cover, and allow the whole

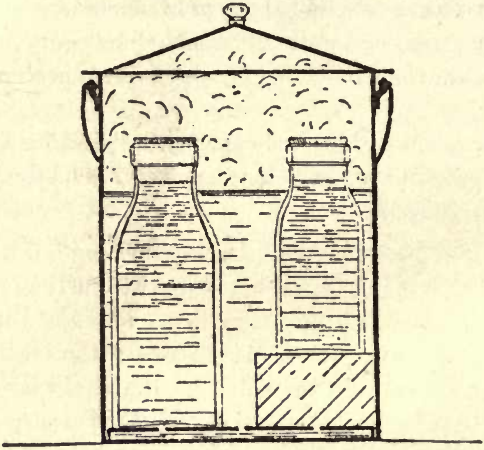


Fig. 26. A home-made pasteurizer.

to stand for half an hour. In the preparation of milk for children, it is not advisable to use the low-temperature treatment (140° F.) that is recommended for commercial city delivery.

4. Remove bottles of milk and cool them as rapidly as possible without danger to bottles and store in a refrigerator.

Commercial pasteurizers. As noted before, the object in commercial pasteurization depends upon whether it is desired to treat milk for general milk supply or to make into butter. The ends to be attained are so widely different that it naturally follows that the apparatus best suited for the respective purposes must vary considerably. In pasteurizing milk in butter-making, capacity is one of the most important desiderata, but in preparing milk for human use, fulfillment of sanitary conditions is the first requisite. It is to be regretted that milk dealers so frequently lose sight of this requirement in their attempts to secure apparatus that will handle large amounts so as to reduce the cost of operation. Pasteurizing involves considerable time and trouble, and it is better not to have the milk treated at all than to have the process imperfectly performed.

The various types of machinery that have been suggested for this use may be grouped as follows, depending upon their method of operation:[1]

1. Continuous-flow machines.
2. Intermittent machines.

The continuous-flow pasteurizers were originally designed for the treatment of milk and cream for butter-making, but in many cases they have been applied to the preservation of milk for direct consumption. The difficulty with them is not that the milk cannot be readily heated in the same, but as customarily arranged there is no provision for the retention of the milk at a temperature that would be fatal to the organisms in the same.

Continuous-flow pasteurizers. Apparatus of this class vary much in detail, but all possess this common principle, that the milk enters the machine in a continuous stream and is generally discharged in the same way. The objection to this type of apparatus is that the time of heating cannot be regulated with any certainty, although the temperature can be controlled in part by varying the speed of flow. Recent tests made at the Wisconsin Dairy School

[1] For a more detailed description of pasteurizing machinery, reference should be made to Monrad's Pasteurization of Milk, or Weigmann's Conservierung der Milch.

on a machine of this type showed that it took only one and one-half minutes for milk to pass through the apparatus, although it was claimed that it was in the machine for a period of ten minutes. Another objection is that in the rapid heating, where steam is employed, the proteids of the milk scald on to the walls of the pasteurizer.

In some of these machines (Thiel, Kuehne, Lawrence, De Laval, and Hochmuth), a ribbed surface is employed over which the milk flows, while the opposite surface is heated with hot water or steam. Monrad, Lefeldt and Lentsch employ a centrifugal apparatus in which a thin layer of milk is heated in a revolving drum.

In the Hill and Miller pasteurizers (both American machines), the milk is forced in a thin sheet between heated surfaces and overflows at the top.

One of the most economical types of apparatus is the regenerator type (a German machine), in which the milk passes over the heating surface in a thin stream and then is carried back over the incoming cold milk so that the heated liquid is partially cooled by the inflowing fresh milk.

A number of machines have been constructed on the principle of a reservoir which is fed by a constantly flowing stream. In some kinds of apparatus of this type no attempt is made to prevent the mixing of the recently introduced milk with that which has been partially heated. The pattern for this reservoir type is Fjord's heater, in which the milk is stirred by a stirrer. This apparatus was originally designed as a heater for milk before separation. Reid was the first to introduce this type of machine into America. A recently devised machine of this type (Pasteur) has been tested by Lehmann, who found that it was necessary to heat the milk as high as 176° to 185° F., in order to secure satisfactory results on the bacterial content of the cream.

Tests of apparatus. But few of the continuous-flow type of machines have been subjected to rigid bacteriological control, and their efficiency is questionable. By their use it may be possible to enhance the keeping quality of milk in a fairly satisfactory way, and yet not insure complete freedom from disease-producing bacteria. One grave defect in many of them is that all parts of the milk are not heated uniformly. It is easily possible for one part to be over-heated while the remainder is under-heated; and while the outlet may show a suitable temperature, still it does not follow that all parts of the milk have been thoroughly treated.

The following simple method enables the factory operator to test the period of exposure in the machine: Start the machine full of water, and after the same has become heated to the proper temperature, change the inflow to full-cream milk, continuing at the same rate. Note the exact time of change and also when first evidence of milkiness begins to appear at outflow. If samples are taken from first appearance of milky condition and thereafter at definite intervals for several minutes, it is possible, by determining the amount of butter-fat in the same, to calculate with exactness how long it takes for the milk to entirely replace the water.

Intermittent pasteurizers. Inasmuch as the biological and physical requirements of successful pasteurizing necessitate milk being heated between the temperatures of 140° and 160° F., it is desirable that the temperature should also be under complete control. Moreover, the treatment should also be in such a way as absolutely to insure all the milk being treated for a given period of time. A fulfill-

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ment of these conditions necessitates the use of the intermittent type of apparatus, or continuous apparatus arranged so as practically to conform to the discontinuous process.

The simplest way in which these conditions can be carried out is to employ a number of shot-gun cans immersed in a tank of hot water. By means of this crude device, milk or cream can be pasteurized more effectually than in many of the specially designed apparatus. Tanks surrounded with water spaces can also be used quite successfully.

The use of the Boyd cream ripening vat has been suggested, and this fulfills the necessary conditions as to a commercial pasteurizer. The cream in this is heated by means of a swinging coil immersed in the same, through which hot water circulates.

In some of the pasteurizers, steam is introduced directly into the milk or cream, as in Bentley's apparatus. It is obvious that while this may be a cheaper method by which to heat the milk, still the proteids of the fluid must be scalded in part, although the temperature of the whole mass may not exceed the proper pasteurizing point. The impurities in the condensed steam are also objectionable.

The first American pasteurizer to be built on the intermittent plan that was made to conform to biological requirements was devised by the writer[1] in 1894. It consists of a long, narrow vat, surrounded by a water chamber which is heated by steam. To facilitate the heating of the milk, both the milk and water reservoirs are supplied with agitators having a to-and-fro movement.

The Potts pasteurizer is another machine of the intermittent type that has since been quite generally introduced

[1] Russell, Wis. Expt. Stat., Bull. 44.

and which conforms to the necessary biological conditions. This apparatus has a central milk chamber that is surrounded with an outer shell containing hot water. The whole machine revolves on a horizontal axis, and the cream or milk is thus thoroughly agitated during the heating process.

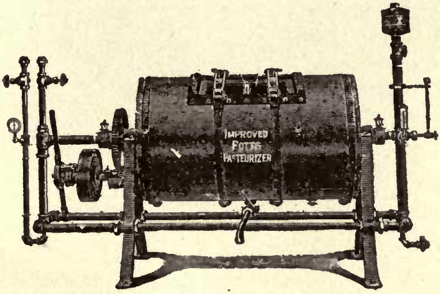

Fig. 27. Potts pasteurizer.

Coolers. A speedy cooling of the heated product is essential to success in pasteurizing. Some of the machines have been devised for a combination purpose, being used for the heating and subsequent cooling of the milk. This is an evident advantage in some ways, as it lessens the amount of apparatus necessary, also the work involved in cleaning the same, but at the same time the problems of quick heating and cooling involve somewhat different principles, so that for the most economical manipulation of the product, separate pieces of apparatus are advisable where the business warrants such expense.

The simplest method of treatment in cooling is to draw off the milk in shot-gun cans and place these first in water, then in ice-water.

To cool milk most economically, two coolers should be provided. With one of these, cold water can be used, and with this the temperature can be reduced to nearly that of the water in a short time. In order, however, to lower the temperature below a point where spore germination will readily occur, milk should be chilled by the aid of ice. This may be applied in the same cooler that is used for running cold water, by supplying ice-water for the latter part of the cooling process. To use ice economically, the ice itself should be applied as closely as possible to the milk to be cooled, for the larger part of the chilling value of ice comes from the melting of the same. To convert a pound of ice at 32° F. into a pound of water at the same temperature, if we disregard radiation, would require as much heat as would suffice to raise 142 pounds of water one degree F., or one pound of water 142° F. The absorptive capacity of milk for heat (specific heat) is not quite the same as it is with water, being .847 for milk in comparison with 1.0 for water.[1] Hot milk would therefore require somewhat less ice to cool it than would be required by an equal volume of water at the same temperature.

In the mere melting of a pound of ice, if expended on cooling heated milk, the temperature of pasteurized milk would be reduced to a keeping temperature. To take advantage of this, the ice should be brought in close contact with the milk, rather than to utilize the specific heat in cooling water which is later applied to the milk. If broken ice is used directly, it is utilized most economically if the milk surrounds it, as in this way the ice does not absorb heat from the outside.

Bacterial efficiency of pasteurizing apparatus. The bacterial content of pasteurized milk and cream will depend somewhat on the number of organisms originally present in the same. Naturally, if mixed milk brought to a creamery is pasteurized, the number of organisms remaining after treatment would be greater than if the raw material was fresh and produced on a single farm.

An examination of milk and cream pasteurized on a com-

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[1] Fleischmann, Landw. Versuchsstat., 17: 251.

mercial scale in the Russell vat at the Wisconsin Dairy school showed that over 99.8 per cent of the bacterial life in raw milk or cream was destroyed by the heat employed, i. e., 155° F. for twenty minutes duration.[1] In nearly one-half of the samples of milk, the germ content in the pasteurized sample fell below 1,000 bacteria per cc., and the average of twenty-five samples contained 6,140 bacteria per cc. In cream the germ content was higher, averaging about 25,000 bacteria per cc. This milk was taken from the general creamery supply, which was high in organisms, containing on an average 3,675,000 bacteria per cc. De Schweinitz[2] has reported the germ content of a supply furnished in Washington which was treated at 158° to 160° F. for fifteen minutes. This supply came from a single source. Figures reported were from 48-hour-old agar plates. Undoubtedly these would have been higher if a longer period of incubation had been maintained. The average of 82 samples, taken for the period of one year, showed 325 bacteria per cc.

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FIG. 28. Effect of pasteurizing on germ content of milk. Black square represents bacteria of raw milk; small white square, those remaining after pasteurization.

[1] Russell, 12 Wis. Expt. Stat. Rept , 1895, p. 160.

[2] De Schweinitz, Nat. Med. Rev., 1899, No. 11.

CHAPTER VII.

BACTERIA AND BUTTER-MAKING.

In making butter from the butter fat in milk, it is necessary to concentrate the fat globules into cream, preliminary to the churning process. The cream may be raised by the gravity process or separated from the milk by centrifugal action. In either case the bacteria that are normally present in the milk differentiate themselves in varying numbers in the cream and the skim-milk. The cream always contains per cc. a great many more than the skim-milk, the reason for this being that the bacteria are caught and held in the masses of fat globules, which, on account of their lighter specific gravity, move toward the surface of the milk or toward the interior of the separator bowl. This filtering action of the fat globules is similar to what happens in muddy water upon standing. As the suspended particles fall to the bottom they carry with them a large number of the organisms that are in the liquid.

Various creaming methods. The creaming method has an important bearing on the kind as well as the number of the bacteria that are to be found in the cream. The difference in species is largely determined by the difference in ripening temperature, while the varying number is governed more by the age of the milk.

1. Primitive gravity methods. In the old shallow-pan process, the temperature of the milk is relatively high, as the milk is allowed to cool naturally. This comparatively high temperature favors especially the development of those forms whose optimum growing-point is near the air temperature. By this method the cream layer is exposed to the air for a longer time than with any other, and consequently the contamination from this source is greater. Usually cream obtained by the shallow-pan process will contain a larger number of species and also have a higher acid content.

2. *Modern gravity methods.* In the Cooley process, or any of the modern gravity methods where cold water or ice is used to lower the temperature, the conditions do not favor the growth of a large variety of species. The number of bacteria in the cream will depend largely upon the manner in which the milk is handled previous to setting. If care is used in milking, and the milk is kept so as to exclude outside contamination, the cream will be freer from bacteria than if carelessness prevails in handling the milk. Only those forms will develop in abundance that are able to grow at the low temperature at which the milk is set. Cream raised by this method is less frequently infected with undesirable forms than that which is creamed at a higher temperature.

3. *Centrifugal method.* Separator cream should contain less germ-life than that which is secured in the old way. It should contain only those forms that have found their way into the milk during and subsequent to the milking, for the cream is ordinarily separated so soon that there is but little opportunity of infection, if care is taken in the handling. As a consequence, the number of species found therein is smaller.

Where milk is separated, it is always prudent to cool the cream so as to check growth, as the milk is generally heated before separating in order to skim efficiently.

Although cream is numerically much richer in bacteria than milk, yet the changes due to bacterial action are slower so that it usually spoils sooner than cream. For this same reason, cream will sour sooner when it remains on the milk than it will if it is separated as soon as possible. This fact indicates the necessity of early creaming, so as to increase the keeping quality of the product, and is another argument in favor of the separator process.

Ripening of cream. If cream is allowed to remain at ordinary temperatures, it undergoes a series of fermentation changes that are exceedingly complex in character, the result of which is to produce in butter made from the same the characteristic flavor and aroma that are so well known in this article. We are so accustomed to the development of these flavors in butter that they are not generally recognized as being intimately associated with bacterial activity unless compared with butter made from perfectly fresh cream. Sweet-cream butter lacks the aromatic principle that is prominent in the ripened product, and while the flavor is delicate, it is relatively unpronounced.

In the primitive method of butter-making, where the butter was made on the farm, the ripening of cream became a necessity in order that sufficient material might be accumulated to make a churning. The ripening change occurred spontaneously without the exercise of any especial control. With the development of the creamery system came the necessity of exercising a control of this process, and therefore the modern butter-maker must understand the principles which are involved in this series of complex changes that largely give to his product its commercial value.

In these ripening changes three different factors are to be taken into consideration: the development of acid, flavor and aroma. Much confusion in the past has arisen from a failure to discriminate between these qualities. While all three are produced simultaneously in ordinary ripening, it does not necessarily follow that they are produced by the same cause. If the ripening changes are allowed to go too far, undesirable rather than beneficial decomposition products are produced. These greatly impair the value of butter, so that it becomes necessary to know just to what extent this process should be carried.

In cream ripening there is a very marked bacterial growth, the extent of which is determined mainly by the temperature of the cream. Conn and Esten[1] find that the number of organisms may vary widely in unripened cream, but that the germ content of the ripened product is more uniform. When cream is ready for the churn, it often contains 500,000,000 organisms per cc., and frequently even a higher number. This represents a germ content that has no parallel in any natural material.

The larger proportion of bacteria in cream as it is found in the creamery belong to the acid-producing class, but in the process of ripening, these forms seem to thrive still better, so that when it is ready for churning the germ content of the cream is practically made up of this type.

Effect on churning. In fresh cream the fat globules which are suspended in the milk serum are surrounded by a film of albuminous material which prevents them from coalescing readily. During the ripening changes, this enveloping substance is modified, probably by partial solution, so that the globules cohere when agitated, as in churning. The result is that ripened cream churns more easily, and as it is possible to cause a larger number of the smaller fat-globules to cohere to the butter granules, the yield is

[1] Conn and Esten, Cent. f. Bakt., II Abt., 1901, 7: 746.

slightly larger—a point of considerable economic importance where large quantities of butter are made.

Development of acid. The result of this enormous bacterial multiplication is that acid is produced in cream, lactic being the principal acid so formed.

Other organic acids are undoubtedly formed as well as certain aromatic products. While the production of acid as a result of fermentative activity is usually accompanied with a development of flavor, the flavor is not directly produced by the formation of acid. If cream is treated in proper proportions with a commercial acid, as hydrochloric,[1] it assumes the same churning properties as found in normally ripened cream, but is devoid of the desired aromatic qualities. Lactic acid[2] has also been used in a similar way but with no better results.

The amount of acidity that should be developed under natural conditions so as to secure the optimum quality as to flavor and aroma is the most important question in cream ripening. Concerning this there have been two somewhat divergent views as to what is best in practice, some holding that better results were obtained with cream ripened to a high degree of acidity than where a less amount was developed.[3] The present tendency seems to be to develop somewhat more than formerly, as it is thought that this secures more of the "high, quick" flavor wanted in the market. On the average, cream is ripened to about 0.5 to 0.65 per cent acidity, a higher percentage than this giving a strong-flavored butter. In the determination of acidity, the most convenient method is to employ the Far-

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[1] Tiemann, Milch Zeit., 23: 701.

[2] Milch Zeit., 1889, p. 7; 1894, p. 624; 1895, p. 383.

[3] Dean, Ont. Agr. Coll., 1897, p. 66.

rington alkaline tablet, which permits of an accurate and rapid estimation of the acidity in the ripening cream. The amount of acidity to be produced must of necessity be governed by the amount of butter-fat present, for the formation of acid is confined to the serum of the cream; consequently, a rich cream would show less acid by titration than a thinner cream, and still contain really as much acid as the other. The importance of this factor is evident in gathered-cream factories.

The rate of ripening is dependent upon the conditions that affect the rate of growth of bacterial life, such as time and temperature, number of organisms in cream and also the per cent of butter fat in the cream. Some years ago it was customary to ripen cream at about 50° to 60° F., but more recently better results have been obtained, it is claimed, where the ripening temperature is increased and the period of ripening lessened. As high a temperature as 70° to 75° F. has been recommended. It should be said that this variation in practice may have a valid scientific foundation, for the temperature of the ripening cream is undoubtedly the most potent factor in determining what kind of bacteria will develop most luxuriantly. It is well known that those forms that are capable of producing bitter flavors are able to thrive better at a lower temperature than some of the desirable ripening species.

The importance of this factor would be lessened where a pure culture was used in pasteurized cream, because here practically the selected organism alone controls the field.

It is frequently asserted that better results are obtained by stirring the cream and so exposing it to the air as much as possible. Experiments made at the Ontario Agricultural College, however, show practically no difference in the quality of the butter made by these two methods. The great majority of the bacteria in the cream belong to the facultative class, and are able to grow under conditions where they are not in direct contact with the air.

Flavor and aroma. The basis for the peculiar flavor or taste which ripened cream-butter possesses is due, in large part, to the formation of certain decomposition products formed by various bacteria. Aroma is a quality often confounded with flavor, but this is produced by volatile products only, which appeal to the sense of smell rather than taste. Generally a good flavor is accompanied by a desirable aroma, but the origin of the two qualities is not necessarily dependent on the same organisms. The quality of flavor and aroma in butter is, of course, also affected by other conditions, as, for instance, the presence or absence of salt, as well as the inherent qualities of the milk, that are controlled, to some extent at least, by the character of the feed which is consumed by the animal. The exact source of these desirable but evancescent qualities in butter is not yet satisfactorily determined. According to Storch,[1] flavors are produced by the decomposition of the milk sugar and the absorption of the volatile flavors by the butter fat. Conn[2] holds that the nitrogenous elements in cream serve as food for bacteria, and in the decomposition of which the desired aromatic substance is produced. The change is unquestionably a complex one, and cannot be explained as a single fermentation.

There is no longer much doubt but that both acid-forming and casein-digesting species can take part in the production of proper flavors as well as desirable aromas. The researches

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[1] Storch, Nogle. Unders. over Floed. Syrning, 1890.

[2] Conn, 6 Storrs Expt. Stat., 1893, p. 66.

of Conn,[1] who has studied this question most exhaustively, indicate that both of these types of decomposition participate in the production of flavor and aroma. He has shown that both flavor and aroma production are independent of acid; that many good flavor-producing forms belong to that class which renders milk alkaline, or does not change the reaction at all. Some of these species liquefied gelatin and would therefore belong to the casein-dissolving class. Those species that produced bad flavors are also included in both fermentative types. Conn has found a number of organisms that are favorable flavor-producers; in fact they were much more numerous than desirable aroma-yielding species. None of the favorable aroma forms according to his investigations were lactic-acid species,— a view which is also shared by Weigmann.[2]

McDonnell[3] has found that the production of aroma in certain cases varies at different temperatures, the most pronounced being evolved near the optimum growing temperature, which, as a general rule, is too high for cream ripening.

The majority of bacteria in ripening cream do not seem to exert any marked influence in butter. A considerable number of species are positively beneficial, inasmuch as they produce a good flavor or aroma. A more limited number are concerned in the production of undesirable ripening changes. This condition being true, it may seem strange that butter is as good as it is, because so frequently the requisite care is not given to the development of proper ripening. In all probability the chief reason why this is so is that those bacteria that find milk and cream pre-emi-

[1] Conn, 9 Storrs Expt. Stat., 1896, p. 17.

[2] Wiegmann, Milch Zeit., 1891, p. 793.

[3] McDonnell, ü. Milchsäure Bakterien (Diss. Kiel, 1899), p. 43.

nently suited to their development, e. g. the lactic-acid class, are either neutral or beneficial in their effect on butter.

Use of starters. Experience has amply demonstrated that it is possible to control the nature of the fermentative changes that occur in ripening cream to such an extent as to materially improve the quality of the butter. This is frequently done by the addition of a "starter." While starters have been employed for many years for the purpose mentioned, it is only recently that their nature has been understood. A starter may be selected from widely divergent sources, but in all cases it is sure to contain a large number of bacteria, and the presumption is that they are of such a nature as to produce desirable fermentative changes in the cream.

In the selection of these so-called natural starters, it follows that they must be chosen under such conditions as experience has shown to give favorable results. For this purpose, whole milk from a single animal is often used where the same is observed to sour with the production of no gas or other undesirable taint. A skim-milk starter from a mixed supply is recommended by many. Butter milk is frequently employed, but in the opinion of butter experts is not as suitable as the others mentioned.

It not infrequently happens that the practical operator may be misled in selecting a starter that is not desirable, or by continuing its use after it has become contaminated.

In 1890[1] a new system of cream ripening was introduced in Denmark by Storch that possesses the merit of being a truly scientific and at the same time practical method. This consisted in the use of pure cultures of

[1] Storch, Milch Zeit., 1890, p. 304.

specific organisms that were selected on account of their ability to produce a desirable ripening change in cream. The introduction of these so-called culture starters has become almost universal in Denmark and in parts of Germany. Their use is also extending in this country, Australia and New Zealand.

Principles of pure-culture cream-ripening. In the proper use of pure cultures for ripening cream, it is necessary first to eliminate as far as possible the bacteria already present in cream before the culture starter is added. This result is accomplished by heating the cream to a temperature sufficiently high to destroy the vegetating organisms. The addition of a properly selected starter will then give the chosen organism such an impetus as will generally enable it to gain the ascendency over any other bacteria and so control the character of the ripening. The principle employed is quite like that practiced in raising grain. The farmer prepares his soil by plowing, in this way killing the weeds. Then he sows his selected grain, which is merely a pure culture, and by the rapid growth of this, other forms are held in check.

The attempt has been made to use these culture starters in raw sweet cream, but it can scarcely be expected that the most beneficial results will be attained in this way. This method has been justified on the basis of the following experiments. Where cream is pasteurized and no starter is added, the spore-bearing forms frequently produce undesirable flavors. These can almost always be controlled if a culture starter is added, the obnoxious form being repressed by the presence of the added starter. This condition is interpreted as indicating that the addition of a starter to cream which already contains developing bacteria will prevent those originally present in the cream from growing.[1] This repressive action of one species on another is a well-known bacteriological fact, but it must be remembered that such an explanation is only applicable in those cases where the culture organism is better able to develop than those forms that already exist in the cream.

If the culture organism is added to raw milk or cream which already contains a flora that is well suited to develop in this medium, it is quite doubtful whether it would gain the supremacy in the ripening cream. The above method of adding a culture to raw cream renders cream-ripening details less burdensome, but at the same time Danish experience, which is entitled to most credence on this question, is opposed to this method.

Reputed advantages of culture starters. *1. Flavor and aroma.* Naturally the flavor produced by pure-culture ferments depends upon the character of the organism used. Those which are most extensively used are able to produce a perfectly clean but mild flavor, and a delicate but not pronounced aroma. The "high, quick" flavor and aroma that is so much desired in the American market is not readily obtained by the use of cultures. It is quite problematical whether the use of any single species will give any more marked aroma than normally occurs in natural ripening.

2. Uniformity of product. Culture starters produce a more uniform product because the type of fermentation is under more complete control, and herein is the greatest advantage to be derived from their use. Even the best butter-maker at times will fail to secure uniform results if his starter is not perfectly satisfactory.

[1] Conn, 9 Storrs Expt. Stat., 1896, p. 25.

3. *Keeping quality of product.* Butter made from pasteurized cream to which a pure-culture starter has been added will keep much better than the ordinary product, because the diversity of the bacterial flora is less and the milk is therefore not so likely to contain those organisms that produce an "off" condition.

4. *Elimination of taints.* Many defective conditions in butter are attributable to the growth of undesirable bacteria in the cream that result in the formation of "off" flavors and taints. If cream is pasteurized, thereby destroying these organisms, then ripened with pure ferments, it is generally possible to eliminate the abnormal conditions.[1] Taints may also be present in cream due to direct absorption from the cow or through exposure to foul odors.[2] Troubles of this sort may thus be carried over to the butter. This is particularly true in regions where leeks and wild onions abound, as in some of the Atlantic States. The heating of the cream tends to expel these volatile taints, so that a fairly good article of butter can be made from what would otherwise be a relatively worthless product.

Characteristics desired in culture starters. Certain conditions as the following are desirable in starters made from pure cultures:

1. Vigorous growth in milk at ordinary ripening temperatures.

2. Ability to form acid so as to facilitate churning and increase the yield of butter.

3. Able to produce a clean flavor and desirable aroma.

4. Impart a good keeping quality to butter.

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[1] Milch Zeit., 1891, p. 122; 1894, p. 284; 1895, p. 56; 1896, p. 163.

[2] McKay, Bull. 32, Iowa Expt. Stat., p. 477.

5. Not easily modified in its flavor-producing qualities by artificial cultivation.

These different conditions are difficult to attain, for the reason that some of them seem to be in part incompatible. Weigmann[1] found that a good aroma was generally an evanescent property, and therefore opposed to good keeping quality. Conn has shown that the functions of acid-formation, flavor and aroma production are not necessarily related, and therefore the chances of finding a single organism that possesses all the desirable attributes are not very good.

In all probability no one germ possesses all of these desirable qualities, but natural ripening is the resultant of the action of several forms.[2] This idea has led to the attempt at mixing selected organisms that have been chosen on account of certain favorable characteristics which they might possess. The difficulty of maintaining such a composite culture in its correct proportions when it is propagated in the creamery is seemingly well nigh insuperable, as one organism is very apt to develop more or less rapidly than the other.

A very satisfactory way in which these cultures are marketed is to mix the bacterial growth with some sterile, inert, dry substance. This is the method used in most of the Danish cultures. In this country, some of the more prominent cultures employed are marketed in a liquid form.

Culture vs. home-made starters. One great advantage which has accrued from the use of culture or commercial starters has been that in emphasizing the need of closer control of the ripening process, greater attention has been

[1] Weigmann, Landw. Woch. f. Schl. Hol., No. 2, 1890.

[2] Weigmann, Cent. f. Bakt., II Abt., 3:497, 1897.

paid to the carrying out of the details. In the hands of the better operators, the differences in flavor of butter made with a culture or a natural starter are not marked,[1] but in the hands of those who fail to make a good product under ordinary conditions, an improvement is often secured where a commercial culture is used.

Pasteurization as applied to butter-making. This process, as applied to butter making, is often confounded with the treatment of milk and cream for direct consumption. It is unfortunate that the same term is used in connection with the two methods, for they have but little in common except in the use of heat to destroy the germ life of the milk. In pasteurizing cream for butter-making, it is not necessary to observe the stringent precautions that are to be noted in the preservation of milk; for the addition of a rapidly developing starter controls at once the fermentative changes that subsequently occur. Then again, the physical requirement as to the production of a cooked taste is not so stringent in butter-making. While a cooked taste is imparted to milk or even cream at about 158° F., it is possible to make butter that shows no permanent cooked taste from cream that has been raised as high as 185° or even 195° F. This is due to the fact that the fat does not readily take up those substances that give to scalded milk its peculiar flavor.

Unless care is taken in the manipulation of the heated cream, the grain or body of the butter may be injured. This tendency can be overcome if the ripened cream is

[1] At the National Creamery Buttermakers' Association for 1901, 193 out of 240 exhibitors used starters. Of those that employed starters, nearly one-half used commercial cultures. There was practically no difference in the average score of the two classes of starters, but those using starters ranked nearly two points higher in flavor than those that did not.

chilled to 48° F. for about two hours before churning.[1] It is also essential that the heated cream should be quickly and thoroughly chilled after being pasteurized.

The Danes, who were the first to employ pasteurization in butter-making, used, in the beginning, a temperature ranging from 158° to 167° F., but owing to the prevalence of such diseases as tuberculosis and foot-and-mouth disease, it became necessary to treat the milk so as to thoroughly destroy the virus of the disease. This can be done by momentarily heating the same to the temperature of 185° F., and this temperature is now generally employed. With the use of this higher temperature the capacity of the pasteurizing apparatus is considerably reduced, as not more than one-half to two-thirds as much milk can be handled at 185° as at 158° F.

When the system was first introduced in Denmark, two methods of procedure were followed: the whole milk was either heated before separation, or the cream was pasteurized afterwards, the skim milk being treated separately. At the present time the latter system is gaining ground.

The present law makes it compulsory to heat all skim milk to 185° F. to avoid the dissemination of the diseases previously mentioned.

Apparatus for pasteurizing. As it is not necessary to heat the milk or cream for butter-making under such a narrow range of conditions as when designed for direct consumption, it is permissible to employ machinery that belongs to the continuous-flow type. These pasteurizers have a large capacity and it is possible to handle in them several thousand pounds per hour. The majority of apparatus for this purpose has originated in Denmark and Germany.

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[1] N. Y. Prod. Rev., October, 1899.

A quantitative determination of the bacteria found in milk and cream when treated in machinery of this class almost always shows a degree of variation in results that is not to be noted in the discontinuous apparatus.

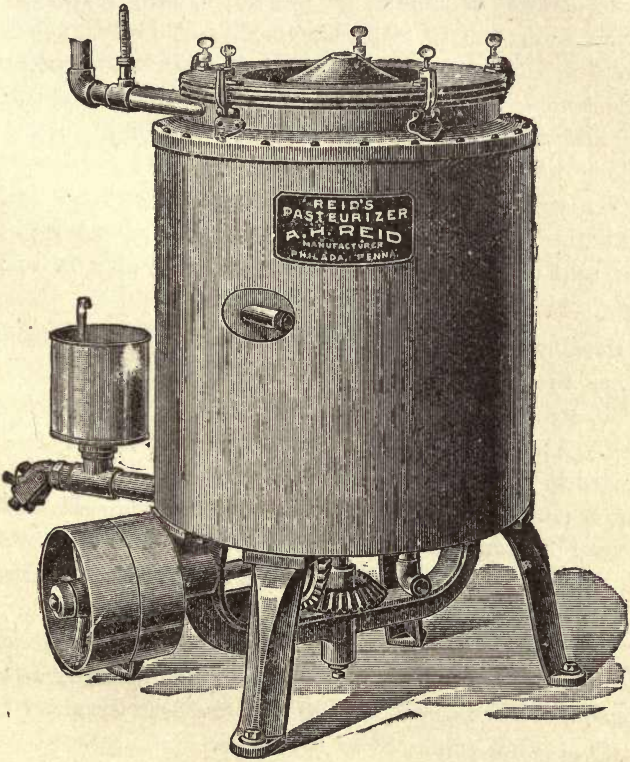

FIG. 29. Reid's Continuous Pasteurizer.

Harding and Rogers[1] have tested the efficiency of one of the Danish type of continuous pasteurizers. These experiments were made at 158°, 176° and 185° F. They

[1] Harding and Rogers, Bull. 182, N. Y. (Geneva) Expt. Stat., Dec., 1899.

found the efficiency of the machine not wholly satisfactory at the lower temperatures. At 158° F. the average of fourteen tests gave 15,300 bacteria per cc., with a maximum to minimum range from 62,790 to 120. Twenty-five examinations at 176° F. showed an average of only 117, with a range from 300 to 20. The results at 185° F. showed practically the same results as noted at 176° F. Considerable trouble was experienced with the "scalding on" of the milk to the walls of the machine when milk of high acidity was used.

The writer[1] tested Reid's pasteurizer at 155° to 165° F. with the following results: in some cases as many as 40 per cent of the bacteria survived, which number in some cases exceeded 2,000,000 bacteria per cc.

Development of pasteurization and pure-culture ripening. Since the introduction of this system into Denmark in 1890, creamery methods have been completely revolutionized. At the present time practically all of the butter exported to England is prepared in this way and by far the larger part of that which is consumed at home. There are several different selected commercial cultures that are used. In Sweden, in 1897, 67 per cent of creameries pasteurized their product.

In Germany the system has been adopted most extensively in the north, and may be said to be practically an extension of the Danish system. In southern Germany the method is not employed to any extent.

In this country considerable agitation has been given the matter, but the process has been but slowly adopted. Under the auspices of the Department of Agriculture at Washington, considerable effort has been put forth in the

[1] Russell, Bull. 69, Wis. Expt. Stat.

preparation of culture butter especially for export trade. In some cases this work has borne fruitage,[1] but in general the flavor of butter made from pasteurized cream is not as "high" and "quick" as that made in the other way, and therefore it does not meet this desired requisite of the American market. The mild, clean flavor which characterizes culture butter is particularly desired by the English market, to which the bulk of the Danish butter goes. Considerable "pasteurized" or "culture" butter has been exported from Australia[2] and New Zealand to England and it is said that the system is gaining ground slowly.

Where the market demands are satisfied with the quality of butter that can best be made by this system, the method is undoubtedly destined to be adopted more and more generally, as the uniformity of product obtained is a great advantage. The system entails considerable labor and some expense, and the question as to its more general adoption will be determined by the advantages gained.

Propagation of starters for cream-ripening. The preparation and propagation of a starter for cream-ripening is a process involving considerable bacteriological knowledge, whether the starter is of domestic origin or prepared from a pure-culture ferment. In any event, it is necessary that the starter should be handled in a way so as to prevent the introduction of foreign bacteria as far as possible. The following points should be kept in mind in manipulating the starter:

1. If a pure-culture ferment is used, see that it is fresh and that the seal has not been disturbed.

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[1] Some of the larger western creamery syndicates are pasteurizing a large part of the cream they receive.

[2] Cherry, Farm and Home, Aug., 1900.

2. If a home-made starter is employed, use the greatest possible care in selecting the milk that is to be used as a basis for the starter.

3. For the propagation and perpetuation of the starter from day to day, it is necessary that the same should be grown in milk that is as germ-free as it is possible to secure it. For this purpose sterilize some fresh skim-milk in a covered can that has previously been well steamed. This can be done easily by setting cans containing skim-milk in a vat filled with water and heating the same to 180° F. or above. The temperature should be maintained for a half hour or more. This destroys all but a few of the most resistant spore-bearing organisms. This will give a cooked flavor to the milk, but will not affect the cream to which the starter is added. Dairy supply houses are now introducing the use of starter cans that are specially made for this purpose.

4. After the heated milk is cooled down to about 70° or 80° F., it can be inoculated with the desired culture. Sometimes it is desirable to "build up" the starter by propagating it first in a smaller volume of milk, and then after this has developed, adding it to a larger amount.

This method is of particular value where a large amount of starter is needed for the cream-ripening.

5. After the milk has been inoculated, it should be kept at a temperature that is suitable for the rapid development of the contained bacteria, 65°–75° F., which temperature should be kept as uniform as possible.

6. This can best be done by setting can in vat filled with warm water and covering the same with a wooden cover or heavy cloth during the night to maintain proper temperature.

7. The starter should not be thoroughly curdled and solid when it is needed for use, but should be well soured and partially curdled. This point is of importance for the following reasons:

a. It is difficult to thoroughly break up curd particles if the starter is completely curdled. If these curd masses are added to ripening cream, white specks may appear in the butter.

b. The vigor of the starter is in all probability stronger when the milk is on the point of curdling than it is after the curd has been formed some time. The continued formation of lactic acid kills many of the bacteria and thus weakens the fermentative action. It is therefore highly important that the acidity of the starter should be closely watched.

8. The starter should be propagated from day to day by adding a small quantity to a new lot of freshly prepared milk. For this purpose two propagating cans should be provided so that one starter may be in use while the other is being prepared.

9. The butter-maker must exercise his judgment as to the condition of his starter. If the same should appear moldy or contain evidence of gas, the skim milk has been imperfectly handled.

How long should a starter be propagated? No hard-and-fast rule can be given for this, for it depends largely upon how carefully the starter is handled during its propagation. If the starter is grown in sterilized milk kept in steamed vessels and is handled with sterile dippers, it is possible to maintain it in a state of relative purity for a considerable period of time; if, however, no especial care is given, it will soon become infected by the air, and the retention of its purity will depend more upon the ability of the contained organism to choke out foreign growths than upon any other factor. Experience seems to indicate that pure-culture starters "run out" sooner than domestic starters. While it is possible, by bacteriological methods, to determine with accuracy the actual condition of a starter as to its germ content, still such methods are inapplicable in creamery practice. Here the maker must rely largely upon the general appearance of the starter as determined by taste and smell. The supply houses that deal in cultures of this class generally expect to supply a new culture at least every month.

Bacteria in butter. As ripened cream is necessarily rich in bacteria, it follows that butter will also contain germ life in varying amounts, but as butter-fat is not well adapted for bacterial food, the number of germs in butter is usually less than in ripened cream.

Sweet-cream butter is naturally poorer in germ life than that made from ripened cream. Grotenfelt[1] reports in sweet-cream butter, the so-called "Paris butter," only 120 to 300 bacteria per cc., while in butter from sour cream 2,000 to 55,000 germs per cc. were found. Pammel[2] found from 125,000 to 730,000 per gram, while Lafar[3] found in butter sold in Munich from 10,000,000 to 20,000,000 organisms per gram.

The germ content of butter on the outside of a package is much greater than it is in the middle of a mass, this doubtless being due to the freer access of air favoring the growth of aerobic forms.

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[1] Grotenfelt-Woll, Prin. Mod. Dairy Practice, p. 244.

[2] Pammel, Bull. 21, Iowa Expt. Stat., p. 801.

[3] Lafar, Arch. f. Hyg., 1891, 13:1.

Changes in germ content. The bacteria that are incorporated with the butter as it first "comes" undergo a slight increase for the first few days. The duration of this period of increase is dependent largely upon the condition of the butter. If the buttermilk is well worked out of the butter, the increase is slight and lasts for a few days only, while the presence of so nutritious a medium as buttermilk affords conditions much more favorable for the continued growth of the organisms.

While there may be many varieties in butter when it is fresh, they are very soon reduced in kind as well as number. The lactic acid group of organisms disappear quite rapidly; the spore-bearing species remaining for a somewhat longer time. Butter examined after it is several months old is often found to be almost free from germs.

In the manufacture of butter there is much that is dependent upon the mechanical processes of churning, washing, salting and working the product. These processes do not involve any bacteriological principles other than those that are incident to cleanliness. The cream, if ripened properly, will contain such enormous numbers of favorable forms that the access of the few organisms that are derived from the churn, the air, or the water in washing will have little effect, unless the conditions are abnormal.

Rancid change in butter. Fresh butter has a peculiar aroma that is very desirable and one that enhances the market price, if it can be retained; but this delicate flavor is more or less evanescent, soon disappearing, even in the best makes. While a good butter loses with age some of the peculiar aroma that it possesses when first made, yet a gilt-edged product should retain its good keeping qualities for some length of time. All butters, however, sooner or later undergo a change that renders them worthless for table use. This change is usually a rancidity that is observed in all stale products of this class. The cause of this rancid condition in butter has been attributed to the action of living organisms, particularly those that form butyric acid, to the influence of light, air, etc. Undoubtedly under certain conditions, rancidity may be produced by the operation of all of the above agents. Although the subject has been quite extensively studied, there is yet considerable variation in opinion as to the exact nature of the causal agents.[1]

BACTERIAL DEFECTS IN BUTTER.

Lack of flavor. Often this may be due to improper handling of the cream in not allowing it to ripen far enough, but sometimes it is impossible to produce a high flavor. The lack of flavor in this case is due to the absence of the proper flavor-producing organisms. This condition can usually be overcome by the addition of a proper starter. The relation between flavor and desirable bacteria is very intimate, and troubles of this kind usually arise because the proper forms commonly found in the cream have been supplanted by other species that do not possess the ability of forming these aromatic substances so necessary in sour-cream butter.

Putrid butter. This specific butter trouble has been observed in Denmark, where it has been studied by Jensen.[2] Butter affected by it rapidly acquires a peculiar putrid odor that ruins it for table use. Sometimes, this flavor may be developed in the cream previous to churning.

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[1] Reinmann, Cent. f. Bakt., 1900, 6:131; Jensen, Landw. Jahr. d. Schweiz, 1901.
[2] Jensen, Cent. f. Bakt., 1891, 11:409.

Jensen found the trouble to be due to several different putrefactive bacteria. One form which he called *Bacillus fœtidus lactis*, a close ally of the common feces bacillus, produced this rotten odor and taste in milk in a very short time. Fortunately, this organism was easily killed by a comparatively low heat, so that pasteurization of the cream and use of a culture starter quickly eliminated the trouble, where it was tried.

Turnip-flavored butter. Butter sometimes acquires a peculiar flavor recalling the order of turnips, rutabagas, and other root crops. Often this trouble is due to feeding, there being in several of these crops, aromatic substances that pass directly into the milk, but in some instances the trouble arises from bacteria that are able to produce decomposition products,[1] the odor and taste of which strongly recalls these vegetables.

"Cowy" butter. Frequently there is to be noted in milk a peculiar odor that resmbles that of the cow stable. Usually this defect in milk has been ascribed to the absorption of impure gases by the milk as it cools, although the gases and odors naturally present in fresh milk have this peculiar property that is demonstrable by certain methods of aeration. Occasionally it is transmitted to butter, and recently Pammel[2] has isolated from butter a bacillus that produced in milk the same peculiar odor so commonly present in stables.

Lardy and tallowy butter. The presence of this unpleasant taste in butter may be due to a variety of causes. In some instances, improper food seems to be the source of the trouble; then again, butter exposed to direct sunlight

[1] Jensen, Milch Zeit., 1892, 6, Nos. 5 and 6.

[2] Pammel, Bull. 21, Iowa Expt. Stat., p. 803.

bleaches in color and develops a lardy flavor.[1] In addition to these, cases have been found in which the defect has been traced to the action of bacteria. Storch[2] has described a lactic-acid form in a sample of tallowy butter that was able to produce this disagreeable odor.

Oily butter. Jensen has isolated one of the causes of the dreaded oily butter that is reported quite frequently in Denmark. The specific organism that he found belongs to the sour-milk bacteria. In twenty-four hours it curdles milk, the curd being solid like that of ordinary sour milk. There is produced, however, in addition to this, an unpleasant odor and taste resembling that of machine oil, a peculiarity that is transmitted directly to butter made from affected cream.

Bitter butter. Now and then butter develops a bitter taste that may be due to a variety of different bacterial forms. In most cases, the bitter flavor in the butter is derived primarily from the bacteria present in the cream or milk. Several of the fermentations of this character in milk are also to be found in butter. In addition to these defects produced by a biological cause, bitter flavors in butter are sometimes produced by the milk being impregnated with volatile, bitter substances derived from weeds.

Moldy butter. This defect is perhaps the most serious because most common. It is produced by the development of a number of different varieties of molds. The trouble appears most frequently in packed butter on the outside of the mass of butter in contact with the tub. Mold spores are so widely disseminated that if proper conditions are

[1] Fischer, Hyg. Rund, 5:573.

[2] Storch, 18 Rept. Danish Agric. Expt. Stat., 1890.

given for their germination, they are almost sure to develop. In some cases the mold is due to the growth of the ordinary bread mold, *Penicillium glaucum;* in other cases a black mold develops, due often to *Cladosporium butyri.* Not infrequently trouble of this character is associated with the use of parchment wrappers. The difficulty can easily be held in check by soaking the parchment linings and the tubs in a strong brine.

Fishy butter. Considerable trouble has been experienced in Australian butter exported to Europe in which a fishy flavor developed. It was noted that the production of this defect seemed to be dependent upon the storage temperature at which the butter was kept. When the butter was refrigerated at 15° F. no further difficulty was experienced. It is claimed that the cause of this condition is due to the formation of trimethylamine (herring brine odor) due to the growth of the mold fungus *Oidium lactis*, developing in combination with the lactic-acid bacteria.

CHAPTER VIII.

BACTERIA IN CHEESE.

The art of cheese-making, like all other phases of dairying, has been developed mainly as a result of empirical methods. Within the last decade or so, the subject has received more attention from the scientific point of view and the underlying causes determined to some extent. Since the subject has been investigated from the bacteriological point of view, much light has been thrown on the cause of many changes that were heretofore inexplicable. Our knowledge, as yet, is quite meager, but enough has already been determined to indicate that the whole industry is largely based on the phenomena of ferment action, and that the application of bacteriological principles and ideas is sure to yield more than ordinary results, in explaining, in a rational way, the reasons underlying many of the processes to be observed in this industry.

The problem of good milk is a vital one in any phase of dairy activity, but it is pre-eminently so in cheese-making, for the ability to make a first-class product depends to a large extent on the quality of the raw material. Cheese contains so large a proportion of nitrogenous constituents that it is admirably suited, as a food medium, to the development of bacteria; much better, in fact, than butter.

INFLUENCE OF BACTERIA IN NORMAL CHEESE PROCESSES.

In the manufacture of cheddar cheese bacteria exert a marked influence in the initial stages of the process. To produce the proper texture that characterizes cheddar cheese, it is necessary to develop a certain amount of acid which acts upon the casein. This acidity is measured by the development of the lactic-acid bacteria that normally abound in the milk; or, as the cheese-maker expresses it, the milk is "ripened" to the proper point. The action of the rennet, which is added to precipitate the casein of the milk, is markedly affected by the amount of acid present, as well as the temperature. Hence it is desirable to have a standard amount of acidity as well as a standard temperature for coagulation, so as to unify conditions. It frequently happens that the milk is abnormal with reference to its bacterial content, on account of the absence of the proper lactic bacteria, or the presence of forms capable of producing fermentative changes of an undesirable character. In such cases the maker attempts to overcome the effect of the unwelcome bacteria by adding a "starter;" or he must vary his method of manufacture to some extent to meet these new conditions.

Use of starters. A starter may be employed to hasten the ripening of milk that is extremely sweet, so as to curtail the time necessary to get the cheese to press; or it may be used to overcome the effect of abnormal conditions.

The starter that is employed is generally one of domestic origin, and is usually taken from skim milk that has been allowed to ferment and sour under carefully controlled conditions. Of course much depends upon the quality of the starter, and in a natural starter there is always the possibility that it may not be perfectly pure.

Within recent years the attempt has been made to control the effect of the starter more thoroughly by using pure cultures of some desirable lactic-acid form.[1] This has ren-

[1] Russell, 13 Rept. Wis. Expt. Stat., 1896, p. 112; Campbell, Trans. High. & Agr. Soc. Scotland, 5 ser., 1898, 10:181.

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dered the making of cheese not only more uniform, but has aided in repressing abnormal fermentations particularly those that are characturized by the production of gas.

Recently, pure cultures of Adametz's *B. nobilis*, a digesting organism that is claimed to be the cause of the breaking down of the casein and also of the peculiar aroma of Emmenthaler cheese, has been placed on the market under the name *Tyrogen.* It is claimed that the use of this starter, which is added directly to the milk and also rubbed on the surface of the cheese, results in the improvement of the curds, assists in the development of the proper holes, imparts a favorable aroma and hastens ripening.[1]

Campbell[2] states that the discoloration of cheese in England, which is due to the formation of white spots that are produced by the bleaching of the coloring matter in the cheese, may be overcome by the use of lactic-acid starters.

The use of stringy or slimy whey has been advocated in Holland for some years as a means of overcoming the tendency toward gas formation in Edam cheese which is made from practically sweet milk. This fermentation, the essential feature of which is produced by a culture of *Streptococcus Hollandicus*,[3] develops acid in a marked degree, thereby inhibiting the production of gas.

The use of masses of moldy bread in directing the fermentation of Roquefort cheese is another illustration of the empirical development of starters, although in this instance it is added after the curds have been prepared for the press.

Pasteurizing milk for cheese-making. If it were possible to use properly pasteurized milk in cheese-making,

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[1] Winkler, Milch Zeit. (Hildesheim), Nov. 24, 1900.

[2] Campbell, No. Brit., Agric., May 12, 1897.

[3] Weigmann, Milch Zeit., No. 50, 1889.

then practically all abnormal conditions could be controlled by the use of properly selected starters. Numerous attempts have been made to perfect this system with reference to cheddar cheese, but so far they have been attended with imperfect success. The reason for this is that in pasteurizing milk, the soluble lime salts are precipitated by the action of heat, and under these conditions rennet extract does not curdle the casein in a normal manner. This condition can be restored, in part at least, by the addition of soluble lime salts, such as calcium chlorid; but in our experience, desirable results were not obtained where heated milks to which this calcium solution had been added were made into cheddar cheese. Considerable experience has been gained in the use of heated milks in the manufacture of certain types of foreign cheese. Klein[1] finds that Brick cheese can be successfully made even where the milk is heated as high as 185° F. An increased weight is secured by the addition of the coagulated albumin and also increased moisture.

Bacteria in rennet. In the use of natural rennets, such as are frequently employed in the making of Swiss cheese, considerable numbers of bacteria are added to the milk. Although these rennets are preserved in salt, alcohol or boric acid, they are never free from bacteria. Adametz[2] found ten different species and from 640,000 to 900,000 bacteria per cc. in natural rennets. Freudenreich has shown that rennet extract solutions can be used in Swiss cheese-making quite as well as natural rennets; but to secure the best results, a small quantity of pure lactic ferment must be added to simulate the conditions that prevail when natural rennets are soaked in whey, which, it must be remembered, is a fluid rich in bacterial life.

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[1] Klein, Milch Zeit. (Hildesheim), No. 17, 1900.

[2] Adametz, Landw. Jahr., 18:256.

Where rennet extract or tablets are used, as is generally the case in cheddar making, the number of bacteria added is so infinitesimal as to be negligible.

Development of acid. In the manufacture of cheddar cheese, the development of acid exerts an important influence on the character of the product. This is brought about by holding the curds at temperatures favorable to the growth of the bacteria in the same. Under these conditions the lactic-acid organisms, which usually predominate, develop very rapidly, producing thereby considerable quantities of acid which change materially the texture of the curds. This acid unites to some extent with the casein, thereby producing compounds of a character different from those existing in the green curds. The acid also exerts a slight solvent effect on the casein, as is seen in the "strings" made on the "hot iron." This causes the curds to mat, producing a close, solid body free from mechanical holes. Still further, the development of this acid is necessary for the digestive activity of the pepsin in the rennet extract.

In some varieties of cheese, as the Swiss, acid is not developed and the character of the cheese is much different from that of cheddar. In all such varieties, a great deal more trouble is experienced from the production of "gassy" curds, because the development of the gas-producing bacteria is held in check by the rapid growth of the lactic acid-producing species.

Bacteria in green cheese. The conditions under which cheese is made permit of the development of bacteria throughout the entire process. The cooking or heating of curds to expel the excessive moisture is never so high as to be fatal to germ life; on the contrary, the acidity of the curd and whey is continually increased by the development of bacteria in the same.

The body of green cheese fresh from the press is, to a considerable extent, dependent upon the acid produced in the curds. If the curds are put to press in a relatively sweet condition the texture is open and porous. The curd particles do not mat closely together and "mechanical holes," rough and irregular in outline, occur. Very often,

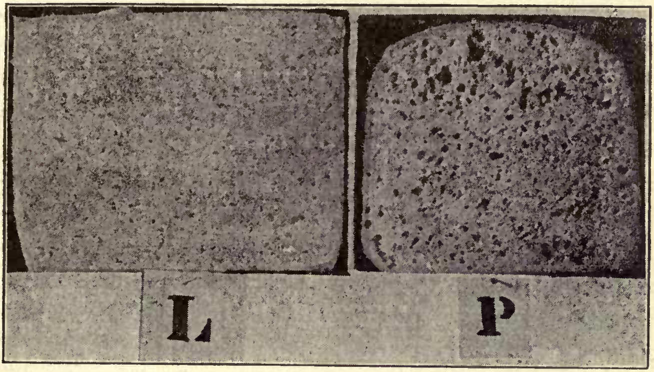

FIG. 30. *L*, a sweet curd cheese direct from the press. "Mechanical" holes due to lack of acid development; *P*, same cheese four days later, mechanical holes distended by development of gas.

at relatively high temperatures, such cheese begin to "huff," soon after being taken from the press, a condition due to the development of gas, produced by gas-generating bacteria acting on the sugar in the curd. This gas finds its way readily into these ragged holes, greatly distending them, as in Fig. 30.

Physical changes in ripening cheese. When a green cheese is taken from the press, the curd is tough, firm, but elastic. It has no value as a food product for immediate use, because it lacks a desirable flavor and is not readily digestible. It is nothing but precipitated casein and fat. In a short time, a deep-seated change occurs. Physically this change is demonstrated in the modification that the curd undergoes. Gradually it breaks down and becomes plastic, the elastic, tough curd being changed into a softened mass. This change in texture of the cheese is also accompanied by a marked change in flavor. The green cheese has no distinctively cheese flavor, but in course of time, with the gradual change of texture, the peculiar flavor incident to ripe cheese is developed.

The characteristic texture and flavor are susceptible of considerable modification that is induced not only by variation in methods of manufacture, but by the conditions under which the cheese are cured. The amount of moisture incorporated with the curd materially affects the physical appearance of the cheese, and the rate of change in the same. The ripening temperature, likewise the moisture content of the surrounding air, also exerts a marked influence on the physical properties of the cheese. To some extent the action of these forces is purely physical, as in the gradual loss by drying, but in other respects they are associated with chemical transformations.

Chemical changes in ripening cheese. Coincident with the physical breaking down of the curd comes a change in the chemical nature of the casein. The hitherto insoluble casein is gradually transformed into soluble nitrogenous substances (*caseone* of Duclaux, or *caseogluten* of Weigmann). This chemical phenomenon is a breaking-down process that is analogous to the peptonization of proteids, although in addition to the peptones and albumoses characteristic of peptic digestion, amido-acids and ammonia are to be found. The quantity of these lower products increases with the age of the cheese.

The chemical reaction of cheese is normally acid to phenolphthalein, although there is generally no free acid, as shown by Congo red, the lactic acid being converted into salts as fast as formed. In very old cheese, undergoing putrefactive changes, especially on the outside, an alkaline reaction may be present, due to the formation of free ammonia.

The changes that occur in a ripening cheese are for the most part confined to the proteids. According to most investigators the fat remains practically unchanged, although the researches of Weigmann and Backe[1] show that fatty acids are formed from the fat. In the green cheese considerable milk-sugar is present, but, as a result of the fermentation that occurs, this is rapidly converted into acid products.

Bacterial flora of cheese. It might naturally be expected that the green cheese, fresh from the press, would contain practically the same kind of bacteria that are in the milk, but a study of cheese shows a peculiar change in the character of the flora. In the first place, fresh cottage cheese, made by the coagulation of the casein through the action of acid, has a more diversified flora than cheese made with rennet, for the reason, as given by Lafar,[2] that the fermentative process is farther advanced.

When different varieties of cheese are made from milk in the same locality, the germ content of even the ripened product has a marked similarity, as is illustrated by Adametz's work[3] on Emmenthaler or Swiss hard cheese,

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[1] Milch Zeit., 1898, No. 49.

[2] Lafar, Technical Mycology, p. 216.

[3] Adametz, Landw. Jahr., 18: 228.

and Schweitzer Hauskäse, a soft variety. Of the nine species of bacilli and cocci found in mature Emmenthaler, eight of them were also present in ripened Hauskäse.

Different investigators have studied the bacterial flora of various kinds of cheese, but as yet little comparative systematic work has been done. Freudenreich[1] has determined the character and number of bacteria in Emmenhtaler cheese, and Russell[2] the same for cheddar cheese. The same general law has also been noted in Canadian[3] and English[4] cheese. At first there is found a marked decrease in numbers, lasting for a day or two. This is followed by an enormous increase, caused by the rapid growth of the lactic-acid type. The development may reach scores of millions and often over a hundred million organisms per gram. Synchronous with this increase. the peptonizing and gas-producing bacteria gradually disappear. This rapid development, which lasts only for a few weeks, is followed by a general decline.

In the ripening of cheese a question arises as to whether the process goes on throughout the entire mass of cheese, or whether it is more active at or near the surface. In the case of many of the soft cheese, such as Brie and limburger, bacterial and mold development is exceedingly active on the exterior, and the enzyms secreted by these organisms diffuse toward the interior. That such a condition occurs in the hard type of cheese made with rennet is extremely improbable. Most observers agree that in this type of cheese the ripening progresses throughout the entire mass, although Adametz opposes this view and considers that in

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[1] Freudenreich, Landw. Jahr. d. Schweiz, 4: 17; 5: 16.

[2] Russell, 13 Rept. Wis. Expt. Stat., 1896, p. 95.

[3] Harrison, Unpublished Data.

[4] Lloyd, Bath and West of Eng. Soc. Rept., 1892, 2: 180.

Emmenthaler cheese the development of the specific aroma-producing organism occurs in the superficial layers. Jensen has shown, however, that the greatest amount of soluble nitrogenous products are to be found in the innermost part of the cheese, a condition that is not reconcilable with the view that the most active ripening is on the exterior.[1]

The course of development of bacteria in cheddar cheese is somewhat influenced by the ripening temperature. In cheese ripened at relatively low temperatures (50°–55° F.),[2] the bacterial flora retains for a considerable period the same general aspect as in the milk. Under these conditions the lactic-acid type does not gain the ascendancy so readily. In cheese cured at high temperatures (80°–86° F.), the number of organisms is greatly diminished, and they fail to persist in appreciable numbers for as long a time as in cheese cured at temperatures more frequently employed.

Influence of temperature on curing. Temperature exerts a most potent influence on the quality of the cheese, as determined not only by the rate of ripening but the nature of the process itself. Much of the poor quality of cheese is attributable to the effect of improper curing conditions. Probably in the initial stage of this industry cheese were allowed to ripen without any sort of control, with the inevitable result that during the summer months the temperature generally fluctuated so much as to impair seriously the quality. The effect of high temperatures (70° F. and above) is to produce a rapid curing, and, therefore, a short lived cheese; also a sharp, strong flavor, and generally a

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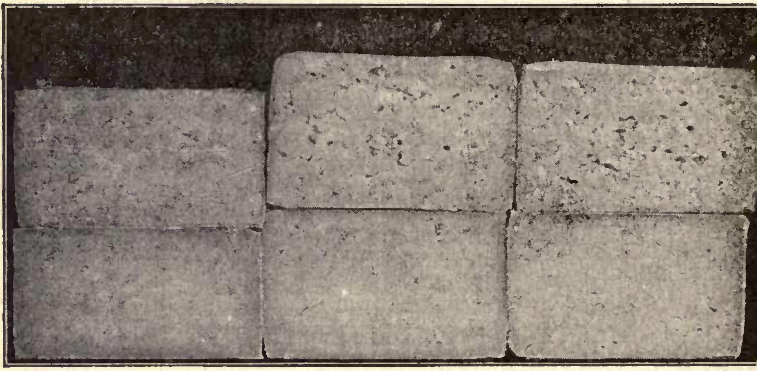
[1] Freudenreich, Landw. Jahr. d. Schweiz, 1900; Adametz, Oest. Molk. Zeit., 1899, No. 7.

[2] Russell, 14 Wis. Expt. Stat., 1897, p. 203.

more or less open texture. Unless the cheese is made from the best quality of milk, it is very apt to undergo abnormal fermentations, more especially those of a gassy character.

Where cheese is ripened at low temperatures, ranging from 50° F. down to nearly the freezing temperatures, it is



3 ozs. 6 ozs. 9 ozs.

Fig. 31. Influence of curing temperature on texture of cheese. Upper row ripened eight months at 60° F.; lower row at 40° F.

found that the quality is greatly improved.[1] Such cheese are thoroughly broken down from a physical point of view even though they may not show such a high per cent of soluble nitrogenous products. They have an excellent texture, generally solid and firm, free from all tendency to openness; and, moreover, their flavor is clean and entirely devoid of the sharp, undesirable tang that so frequently appears in old cheese. The keeping quality of such cheese is much superior to the ordinary product. The introduc-

[1] Babcock and Russell, 18 Rept. Wis. Expt. Stat., 1901.

tion of this new system of cheese-curing promises much from a practical point of view, and undoubtedly a more complete study of the subject from a scientific point of view will aid materially in unraveling some of the problems as to flavor production.

Theories of cheese curing. Within the last few years considerable study has been given the subject of cheese curing or ripening, in order to explain how this physical and chemical transformation is brought about.

Much of the misconception that has arisen relative to the cause of cheese ripening comes from a confusion of terms. In the ordinary use of the word, ripening or curing of cheese is intended to signify the sum total of all the changes that result in converting the green product as it comes from the press into the edible substance that is known as cured cheese. As previously shown, the most marked chemical transformation that occurs is that which has to do with the peptonization or breaking down of the casein. It is true that under ordinary conditions this decomposition process is also accompanied with the formation of certain flavor-producing substances, more or less aromatic in character; but it by no means follows that these two processes are necessarily related to each other. The majority of investigators have failed to consider these two questions of casein decomposition and flavor as independent, or at least as not necessarily related. They are undoubtedly closely bound together, but it will be shown later that the problems are quite different and possibly susceptible of more thorough understanding when considered separately.

In the earlier theories of cheese ripening it was thought to be purely a chemical change, but, with the growth of bacteriological science, evidence was forthcoming that seemed to indicate that the activity of organisms entered into the problem. Schaffer[1] showed that if milk was boiled and made into cheese, the casein failed to break down. Adametz[2] added to green cheese various disinfectants, as creolin and thymol, and found that this practically stopped the curing process. From these experiments he drew the conclusion that bacteria must be the cause of the change, because these organisms were killed; but when it is considered that such treatment would also destroy the activity of enzyms as well as vital ferments, it is evident that these experiments were quite indecisive.

A determination of the nature of the by-products found in maturing cheese indicates that the general character of the ripening change is a peptonization or digestion of the casein.

Until recently the most widely accepted views relating to the cause of this change have been those which ascribed the transformation to the activity of micro-organisms, although concerning the nature of these organisms there has been no unanimity of opinion. The overwhelming development of bacteria in all cheeses naturally gave support to this view; and such experiments as detailed above strengthened the idea that the casein transformation could not occur where these ferment organisms were destroyed.

The very nature of the changes produced in the casein signified that to take part in this process any organism must possess the property of dissolving the proteid molecule, casein, and forming therefrom by-products that are most generally found in other digestive or peptonizing changes of this class.

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[1] Schaffer, Milch Zeit., 1889, p. 146.

[2] Adametz, Landw. Jahr., 18:261.

Digestive bacterial theory. The first theory propounded was that of Duclaux,[1] who in 1887 advanced the idea that this change was due to that type of bacteria which is able to liquefy gelatin, peptonize milk, and cause a hydrolytic change in proteids. To this widely-spread group that he found in cheese, he gave the generic name *Tyrothrix* (cheese hairs). According to him, these organisms do not function directly as ripening agents, but they secrete an enzym or unorganized ferment to which he applies the name *casease.* This ferment acts upon the casein of milk, converting it into a soluble product known as *caseone.* These organisms are found in normal milk, and if they function as casein transformers, one would naturally expect them to be present, at least frequently, if not predominating in the ripening cheese; but such is not the case. In typical cheddar or Swiss cheese, they rapidly disappear (p. 168), although in the moister, softer varieties, they persist for considerable periods of time. According to Freudenreich, even where these organisms are added in large numbers to the curd, they soon perish, an observation that is not regarded as correct by the later adherents to the digestive bacterial theory, as Adametz and Winkler.

Duclaux's experiments were made with liquid media for isolation purposes, and his work, therefore, cannot be regarded as satisfactory as that carried out with more modern technical methods. Recently this theory has been revived by Adametz,[2] who claims to have found in Emmenthaler cheese a digesting species, one of the Tyrothrix type, which is capable of peptonizing the casein and at the same time producing the characteristic flavor of this class of cheese.

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[1] Duclaux, Le Lait, p. 213.

[2] Adametz, Oest. Molk. Zeit., 1900, Nos. 16–18.

This organism, called by him *Bacillus nobilis*, the Edelpilz of Emmenthaler cheese, has been subjected to comparative experiments, and in the cheese made with pure cultures of this germ better results are claimed to have been secured. Sufficient experiments have not as yet been reported by other investigators to warrant the acceptance of the claims made relative to the effect of this organism.

Lactic-acid bacterial theory. It has already been shown that the lactic-acid bacteria seems to find in the green cheese the optimum conditions of development; that they increase enormously in numbers for a short period, and then finally decline. This marked development, coincident with the breaking down of the casein, has led to the view which has been so ably expounded by Freudenreich [1] that this type of bacterial action is concerned in the ripening of cheese. This group of bacteria is, under ordinary conditions, unable to liquefy gelatin, or digest milk, or, in fact, to exert, under ordinary conditions, any proteolytic or peptonizing properties. This has been the stumbling-block to the acceptance of this hypothesis, as an explanation of the breaking down of the casein. Freudenreich has recently carried on experiments which he believes solve the problem. By growing cultures of these organisms in milk, to which sterile, freshly precipitated chalk had been added, he was able to prolong the development of bacteria for a considerable period of time, and as a result finds that an appreciable part of the casein is digested; but this action is so slow compared with what normally occurs in a cheese, that exception may well be taken to this type of experiment alone. Weigmann [2] inclines to the view that the

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[1] Freudenreich, Landw. Jahr. d. Schweiz, 1897, p. 85.

[2] Weigmann, Cent. f. Bakt., II Abt., 1898, 4:593; also 1899, 5:630.

lactic-acid bacteria are not the true cause of the peptonizing process, but that their development prepares the soil, as it were, for those forms that are more directly concerned in the peptonizing process. This they do by developing an acid substratum that renders possible the more luxuriant growth of the aroma-producing species. According to Gorini,[1] certain of the Tyrothrix forms function at high temperatures as lactic acid producing bacteria, while at lower temperatures they act as peptonizers. On this basis he seeks to reconcile the discrepancies that appear in the experiments of other investigators.

Milk enzym (galactase) theory. In 1897 Babcock and the writer[2] showed experimentally that milk is digested spontaneously when treated with various anaesthetics like ether, chloroform and benzol. Under these conditions it was demonstrated that bacterial activity was entirely suppressed. Furthermore they showed that the nature of the by-products produced in such cases was identical with those found in a maturing cheese, albumoses, peptones, amido-acids and ammonia being present in varying amounts. When milk or curd was heated to 175° F. or above, or treated with strong chemicals, this digestive process was stopped.

Under these conditions the only agents capable of producing such changes were enzyms, and they found that it was possible to concentrate this milk enzym in centrifuge slime. The addition of these slime extracts to boiled milk started anew the digestive process, and produced by-products identical with those occurring in normal cheese. This enzym, called by them *galactase*, on account of its origin in milk, is somewhat closely related to the tryptic type

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[1] Gorini, Abs. in Expt. Stat. Rec., 11:388.

[2] Babcock and Russell, 14 Rept. Wis. Expt. Stat., 1897, p. 161.

of ferments, but yet sufficiently distinct to be separated from trypsin. Jensen[1] has also shown that the addition of pancreatic extracts to cheese accelerated the formation of soluble nitrogenous products.

The action of galactase in milk and cheese has been confirmed by Freudenreich[2] and Jensen,[3] as well as by American investigators, and this enzym is now quite generally accepted as the cause of the decomposition of the casein. Freudenreich admits that it plays a role in converting the casein into albumose and peptones, but that the lactic-acid bacteria are chiefly responsible for the further decomposition of the nitrogen to amid form.

Failure beforc to recognize the presence of galactase in milk is attributable to the fact that all attempts to secure sterile milk had been made by heating the same, in which case galactase was necessarily destroyed. A brief exposure at 176° F. is sufficient to destroy its activity, and even an exposure at lower temperatures weakens its action considerably, especially if the reaction of the medium is acid. This undoubtedly explains the contradictory results obtained in the ripening of cheese from pasteurized milk, such cheese occasionally breaking down in an abnormal manner.

The results mentioned on page 172, in which cheese failed to ripen when treated with disinfectants,—experiments which were supposed at that time to be the foundation of the bacterial theory of casein digestion — are now explicable on an entirely different basis. In these cases the casein was not peptonized, because these strong disinfectants destroyed the activity of the enzyms as well as the bacteria.

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[1] Jensen, Cent f. Bact. II Abt., 3:752.

[2] Freudenreich, Cent. f. Bakt., II Abt., 1900, 6:332.

[3] Jensen, Ibid., 1900, 6:734.

Influence of rennet on ripening. The addition of increased quantities of rennet extract facilitate the breaking down of the casein in cheese. This is due to the fact that such extracts always contain pepsin, the digestive enzym found in the stomach. This enzym exerts a digestive effect on the casein of cheese, producing those decomposition products (albumoses and higher peptones) that characterize peptic action. This effect is dependent upon the acidity of the milk, and does not become marked until there is about 0.3 per cent of lactic acid, which is about the amount developed in the cheddar process. The effect of the rennet then is to aid the galactase in the peptonization of the casein.[1]

Conditions determining quality. In determining the quality of cheese, several factors are to be taken into consideration. First and foremost is the flavor, which determines more than anything else the value of the product. This should be mild and pleasant, although with age the intensity of the same generally increases but at no time should it have any bitter, sour, or otherwise undesirable taste or

FIG. 32. Showing texture of cheese cured at different temperatures. Right hand, 60° F., crumbly texture; left hand, 40° F., waxy texture.

[1] 17 Rept. Wis. Expt. Stat., 1900, p. 102.

aroma. Texture registers more accurately the physical nature of the ripening. The cheese should not be curdy and harsh, but should yield quite readily to pressure under the thumb, becoming on manipulation waxy and plastic instead of crumbly or mealy. Body refers to the openness or closeness of the curd particles, a close, compact mass being most desirable. The color of cheese should be even, not wavy, streaked or bleached.

For a cheese to possess all of these characteristics in an optimum degree is to be perfect in every respect — a condition that is rarely reached.

So many factors influence this condition that the problem of making a perfect cheese becomes exceedingly difficult. Not only must the quality of the milk — the raw material to be used in the manufacture — be perfectly satisfactory, but the factory management while the curds are in the vat demands great skill and careful attention; and finally, the long period of curing in which variation in temperature or moisture conditions may seriously affect the quality,— all of these stages, more or less critical, must be successfully gone through, before the product reaches its highest state of development.

It is of course true that many phases of this complex series of processes have no direct relation to bacteria, yet it frequently happens that the result attained is influenced at some preceding stage by the action of bacteria in one way or another. Thus the influence of the acidity developed in the curds is felt throughout the whole life of the cheese, an over-development of lactic-acid bacteria producing a sour condition that leaves its impress not only on flavor but texture. An insufficient development of acid fails to soften the curd-particles so as to permit of close matting, the consequence being that the body of the cheese remains loose and open, a condition favorable to the development of gas-generating organisms.

Production of flavor. The importance of flavor as determining the quality of cheese makes it imperative that the nature of the substances that confer on cheese its peculiar aromatic qualities and taste be thoroughly understood. It is to be regretted that the results obtained so far are not more satisfactory, for improvement in technique is hardly to be expected until the reason for the process is thoroughly understood.

The view that is most generally accepted is that this most important phase of cheese curing is dependent upon bacterial activity, but the organisms that are concerned in this process have not as yet been satisfactorily determined. In a number of cases, different species of bacteria have been separated from milk and cheese that have the power of producing aromatic compounds that resemble, in some cases, the peculiar flavors and odors that characterize some of the foreign kinds of cheese; but an introduction of these into curd has not resulted in the production of the peculiar variety, even though the methods of manufacture and curing were closely followed. The similarity in germ content in different varieties of cheese made in the same locality has perhaps a bearing on this question of flavor as related to bacteria. Of the nine different species of bacteria found in Emmenthaler cheese by Adametz, eight of them were also present in ripened Hauskäse. If specific flavors are solely the result of specific bacterial action, it might naturally be expected that the character of the flora would differ.

Some suggestive experiments were made by Babcock and Russell on the question of flavor as related to bacterial growth, by changing the nature of the environment in cheese by washing the curds on the racks with warm water. In this way the sugar and most of the ash were removed. Under such conditions the character of the bacterial flora was materially modified. While the liquefying type of bacteria was very sparse in normal cheddar, they developed luxuriantly in the washed cheese. The flavor at the same time was markedly affected. The control cheddar was of good quality, while that made from the washed curds was decidedly off, and in the course of ripening became vile. It may be these two results are simply coincidences, but other data[1] bear out the view that the flavor was to some extent related to the nature of the bacteria developing in the cheese. This was strengthened materially by adding different sugars to washed curds, in which case it was found that the flavor was much improved, while the more normal lactic-acid type of bacteria again became predominant.

Ripening of moldy cheese. In a number of foreign cheeses, the peculiar flavor obtained is in part due to the action of various fungi which grow in the cheese, and there produce certain by-products that flavor the cheese. Among the most important of these are the Roquefort cheese of France, Stilton of England, and Gorgonzola of Italy.

Roquefort cheese is made from goat's or cow's milk, and in order to introduce the desired mold, which is the ordinary bread-mold, *Penicillium glaucum*, carefully-prepared moldy bread-crumbs are added to the curd.

At ordinary temperatures this organism develops too rapidly, so that the cheese to ripen properly must be kept at a low temperature. The town of Roquefort is situated

[1] Babcock and Russell, 18 Rept. Wis. Expt. Stat., 1901.

in a limestone country, in a region full of caves, and it is in these natural caves that most of the ripening is done. These caverns are always very moist and have a temperature ranging from 35° to 44° F., so that the growth of the fungus is retarded considerably. The spread of the mold throughout the ripening mass is also assisted in a mechanical way. The partially-matured cheese are run through a machine that pricks them full of small holes. These slender canals allow the mold organism to penetrate the whole mass more thoroughly, the moldy straw matting upon which the ripening cheese are placed helping to furnish an abundant seeding of the desired germ.

When new factories are constructed it is of advantage to introduce this necessary germ in quantities, and the practice is sometimes followed of rubbing the walls and cellars of the new location with material taken from the old established factory. In this custom, developed in purely an empirical manner, is to be seen a striking illustration of a bacteriological process crudely carried out.

In the Stilton cheese, one of the highly prized moldy cheeses of England, the desired mold fungus is introduced into the green cheese by exchanging plugs taken with a cheese trier from a ripe Stilton.

Ripening of soft cheese. The type of ripening which takes place in the soft cheeses is materially different from that which occurs in the hard type. In many cases, the peptonizing action does not go on uniformly throughout the cheese, but is hastened on the exterior by the development of organisms that exert a solvent effect on the casein. For this reason, soft cheeses are usually made up in small sizes, so that this action may be facilitated. The bacteria that take part in this process are those that are able to form enzyms (similar in their action to trypsin, galactase, etc.), and these soluble ferments gradually diffuse from the outside through the cheese.

Most of these peptonizing bacteria are hindered in their growth by the presence of lactic acid, so that in many cases the appearance of the digesting organisms on the surface is delayed until the acidity of the mass is reduced to the proper point by the development of other organisms, principally molds, which prefer an acid substratum for their growth.

In Brie cheese a blue coating of mold develops on the surface. In the course of a few weeks, a white felting appears which later changes to red. This slimy coat below the mold layer is made up of diverse species of bacteria and fungi that are able to grow after the acid is reduced by the blue mold. The organisms in the red slimy coat act upon the casein, producing an alkaline reaction that is unfavorable to the growth of the blue mold. Two sets of organisms are, therefore essential in the ripening process, one preparing the soil for the ferment that later produces the requisite ripening changes. As ordinarily carried on, the process is an empirical one, and if the red coat does not develop as expected, the maker resorts to all kinds of devices to bring out the desired ferment. The appearance of the right form is dependent, however, upon the proper reaction of the cheese, and if this is not suitable, the wished-for growth will not appear.

INFLUENCE OF BACTERIA IN ABNORMAL CHEESE PROCESSES.

The reason why cheese is more subject to abnormal fermentation than butter is because its high nitrogen content favors the continued development of bacteria for some time after it is made. It must be borne in mind, in considering the more important of these changes, that not all defective conditions in cheese are attributable to the influence of living organisms. Troubles frequently arise from errors in manufacturing details, as too prolonged cooking of curds, too high heating, or the development of insufficient or too much acid. Then again, the production of undesirable flavors or impairment in texture may arise from imperfect curing conditions.

Our knowledge regarding the exact nature of these indefinite faults is as yet too inadequate to enable many of these undesirable conditions to be traced to their proper source; but in many cases the taints observed in a factory are due to the abnormal development of certain bacteria, capable of evolving unpleasant or even putrid odors. Most of them are seeded in the milk before it comes to the factory and are due to careless manipulation of the milk while it is still on the farm. Others gain access to the milk in the factory, owing to unclean conditions of one sort or another. Sometimes the cheese-maker is able to overcome these taints by vigorous treatment, but often they pass on into the cheese, only to detract from the market value of the product. Most frequently these "off" flavors appear in cheese that are cured at too high temperatures, say above 65° F.

"Gassy" fermentations in cheese. One of the worst and at the same time most common troubles in cheese-making is where the cheese undergoes a fermentation marked by the evolution of gas. The presence of gas is recognized by the appearance either of spherical or lens-shaped holes of various sizes in the green cheese; often they appear in the curd before it is put to press. Usually in this condition the curds look as if they had been punctured with a pin, and are known as "pin holey" curds. Where the gas holes are larger, they are known as "Swiss holes" from their resemblance to the normal holes in the Swiss product. If the development of gas is abundant, these holes are restricted in size. Often the formation of gas may be so intense as to cause the curds to float on the surface of the whey before they are removed. Such curds are known as "floaters" or "bloaters."

If "gassy" curds are put to press, the abnormal fermentation may continue. The further production of gas causes the green cheese to "huff" or swell, until it may be considerably distorted as in Fig. 33. In such cases the texture

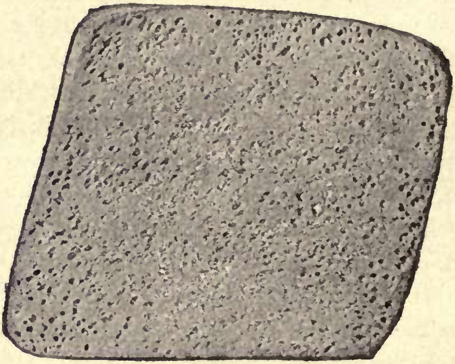

FIG. 33. Cheese made from gassy milk.

of the cheese is greatly injured, and the flavor is generally impaired.

Such abnormal changes may occur at any season of the year, but the trouble is most common in summer, especially in the latter part.

This defect is less likely to occur in cheese that is well cheddared than in sweet curd cheese. When acidity is produced, these gassy fermentations are checked, and in good cheddar the body is so close and firm as not readily to permit of gaseous changes.

In Swiss cheese, which is essentially a sweet curd cheese, these fermentations are very troublesome. Where large holes are formed in abundance (blähen), the trouble reaches its maximum. If the gas holes are very numerous and

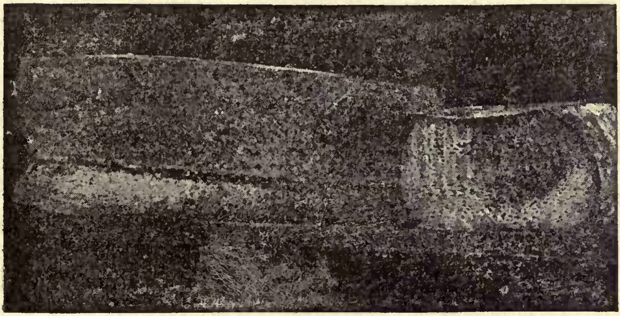

FIG. 34. Block Swiss cheese showing "gassy" fermentation.

therefore small it is called a "nissler." Sometimes the normal "eyes" are even wanting when it is said to be "blind" or a "gläsler."

One method of procedure which is likely to cause trouble in Swiss factories is often produced by the use of sour, fermented whey in which to soak the natural rennets. Freudenreich and Steinegger[1] have shown that a much more uniform quality of cheese can be made with rennet extract if it is prepared with a starter made from a pure lactic ferment.

The cause of the difficulty has long been charged to va-

[1] Cent. f. Bakt. 1899, p. 14.

rious sources, such as a lack of aeration, improper feeding, retention of animal gases, etc., but in all these cases it was nothing more than a surmise. Very often the milk does not betray any visible symptom of fermentation when received, and the trouble is not to be recognized until the process of cheese-making is well advanced.

Studies from a biological standpoint have, however, thrown much light on this troublesome problem; and it is now known that the formation of gas, either in the curd or after it has been put to press, is due entirely to the breaking down of certain elements, such as the sugar of milk, due to the influence of various living germs. This trouble is, then, a type fermentation, and is, therefore, much more widely distributed than it would be if it was caused by a single specific organism. These gas-producing organisms are to be found, sparingly at least, in almost all milks, but are normally held in check by the ordinary lactic species. Among them are a large number of the bacteria, although yeasts and allied germs are often present and are likewise able to set up fermentative changes of this sort. In these cases the milk-sugar is decomposed in such a way as to give off CO_2 and H, and in some cases, alcohol.

According to Guillebeau, a close relation exists between those germs that are able to produce an infectious inflammation (mastitis) in the udder of the cow and some forms capable of gas evolution. Several outbreaks of "gassy" milk have been traced directly to animals suffering from an acute udder inflammation in which it has been shown that the organisms producing this disease were the direct cause of the gas production in the milk.

If pure cultures of these gas-producing bacteria are added to perfectly sweet milk, it is possible to artificially produce the conditions in cheese that so frequently appear in practice.

Treatment of "pin-holey" curds. When this type of fermentation appears during the manufacture of the cheese, the maker can control it in part within certain limits. These methods of treatment are, as a rule, purely mechanical, as when the curds are piled and turned, and subsequently ground in a curd mill. After the gas has been forced out, the curds are then put to press and the whole mats into a compact mass.

Another method of treatment based upon bacteriological principles is the addition of a starter to induce the formation of acid. Where acid is developed as a result of the growth of the lactic-acid bacteria, the gas-producing species do not readily thrive. Another reason why acid aids in repressing the development of gas is that the curd particles are partially softened or digested by the action of the acid. This causes them to mat together more closely, and there is not left in the cheese the irregular mechanical openings in which the developing gas may find lodgment.

Another method that is also useful with these curds is to employ salt. This represses gaseous fermentations, and the use of more salt than usual in making the cheese will very often restrain the production of gas. Tendency to form gas in Edam cheese is controlled by the addition of a starter prepared from slimy whey (lange wei) which is caused by the development of an acid-forming organism.

Some have recommended the custom of washing the curds to remove the whey and the gas-producing bacteria contained therein. Care must be taken not to carry this too far, for the removal of the sugar permits taint-producing organisms to thrive.[1]

The temperature at which the cheese is cured also materially affects the development of gas. At high curing temperatures, gas-producing organisms develop rapidly; therefore more trouble is experienced in summer than at other seasons.

If milks which are prone to undergo "gassy" development are excluded from the general supply, it would be possible to eliminate the source of the entire trouble. To aid in the early recognition of such milks that are not apparently affected when brought to the factory, fermentation or curd tests (p. 76) are of great value. The use of this test in the hands of the factory operator often enables him to detect the exact source of the trouble, which may frequently be confined to the milk delivered by a single patron.

"Fruity" or "sweet" flavor. Not infrequently the product of a factory may acquire during the process of ripening what is known as a "sweet" or "fruity" flavor. This flavor resembles the odor of fermented fruit or the bouquet of certain kinds of wine. It has been noted in widely different sections of the country and its presence bears no relation to the other qualities of the cheese. The cause of this trouble has recently been traced[2] to the presence of various kinds of yeasts. Ordinarily yeasts are rarely present in good cheese, but in cheese affected with this trouble they abound. The addition of starters made from yeast cultures resulted in the production of the undesirable condition.

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[1] Babcock and Russell, 18 Rept. Wis. Expt. Stat., 1901.

[2] Harding, Rogers and Smith, Bull. 183, N. Y. (Geneva) Expt. Stat., Dec., 1900.

Mottled cheese. The color of cheese is sometimes cut to that extent that the cheese presents a wavy or mottled appearance. This condition is apt to appear if the ripening temperature is somewhat high, or larger quantities of rennet used than usual. The cause of the defect is obscure, but it has been demonstrated that the same is communicable if a starter is made by grating some of this mottled cheese into milk. The bacteriology of the trouble has not yet been worked out, but the defect is undoubtedly due to an organism that is able to grow in the ripening cheese. It has been claimed that the use of a pure lactic ferment as a starter enables one to overcome this defect.

Bitter cheese. Bitter flavors are sometimes developed in cheese especially where the ripening process has not been fully completed, or where improper temperatures have been maintained for a considerable length of time. Several organisms associated with this abnormal fermentation have been noted.

Guillebeau[1] isolated several forms from Emmenthaler cheese which he connected with udder inflammation that were able to produce a bitter substance in cheese.

Von Freudenreich[2] has described a new form *Micrococcus casei amari* (micrococcus of bitter cheese) that was found in a sample of bitter cheese. This germ is closely related to Conn's micrococcus of bitter milk. It develops lactic acid rapidly, coagulating the milk and producing an intensely bitter taste in the course of one to three days. When milk infected with this organism is made into cheese, there is formed in a few days a decomposition product that imparts a marked bitter flavor to the cheese.

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[1] Guillebeau, Landw. Jahr., 1890, p. 27.

[2] Freudenreich, Fuehl. Landw. Ztg., 43:361.

It is peculiar that some of the organisms that are able to produce bitter products in milk do not retain this property when the milk is worked up into cheese.

Putrid or rotten cheese. Sometimes cheese undergoes a putrefactive decomposition in which the texture is profoundly modified and various foul smelling gases are evolved. These often begin on the exterior as small circumscribed spots that slowly extend into the cheese, changing the casein into a soft slimy mass. Then, again, the interior of the cheese undergoes this slimy decomposition. The soft varieties are more prone toward this fermentation than the hard, although the firm cheeses are by no means exempt from the trouble. The "Verlaufen" or "running" of limburger cheese is a fermentation allied to this. It is where the inside of the cheese breaks down into a soft semi-fluid mass. In severe cases, the rind may even be ruptured, in which case the whole interior of the cheese flows out as a thick slimy mass, having sometimes a putrid odor. The conditions favoring this putrid decomposition are usually associated with an excess of moisture, and an abnormally low ripening temperature.

Rusty spot. This name is applied to the development of small yellowish-red or orange spots that are formed sometimes throughout the whole mass of cheddar cheese. A close inspection shows the colored points to be located along the edges of the curd particles. According to Harding,[1] this trouble is most common in spring and fall. The cause of the difficulty has been traced by Connell[2] to the development of a chromogenic bacterium, *Bacillus rudensis.* The organism can be most readily isolated on a po-

[1] Bull. 183, N. Y. (Geneva) Expt. Stat., Dec. 1900.

[2] Connell, Bull. Canadian Dept. of Agr., 1897.

tato surface rather than with the usual isolating media, agar or gelatin.

Other pigment changes. Occasionally, with the hard type of cheese, but more frequently with the softer foreign varieties, various abnormal conditions arise that are marked by the production of different figments in or on the cheese. More frequently these are merely superficial and affect only the outer layers of the cheese. Generally they are attributable to the development of certain chromogenic organisms (bacteria, molds and yeasts), although occasionally due to other causes, as in the case of a blue discoloration sometimes noted in foreign cheese made in copper kettles.[1]

De Vries[2] has described a blue condition that is found in Edam cheese. It appears first as a small blue spot on the inside, increasing rapidly in size until the whole mass is affected. This defect he was able to show was produced by a pigment-forming organism, *B. cyaneo-fuscus*. By the use of slimy whey (lange wei) this abnormal change was controlled.

Moldy cheese. With many varieties of cheese, especially some of the foreign types, the presence of mold on the exterior is not regarded as detrimental; in fact a limited development is much desired. In hard rennet cheese as cheddar or Swiss, the market demands a product free from mold, although it should be said that this condition is imposed by the desire to secure a good-looking cheese rather than any injury in flavor that the mold causes. Mold spores are so widely distributed that, if proper temperature and moisture conditions prevail, these spores will always develop. At temperatures in the neighborhood of 40° F.

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[1] Schmöger, Milch Zeit., 1883, p. 483.

[2] De Vries, Milch Zeit., 1888, pp. 861, 885.

and below, mold growth is exceedingly slow, and often fructification does not occur, the only evidence of the mold being the white, felt-like covering that is made up of the vegetating filaments. The use of paraffin has been suggested as a means of overcoming this growth, the cheese being dipped at an early stage into melted paraffin. Recent experiments have shown that "off" flavors are apt to develop where cheese are paraffined directly from the press. Furthermore, the paraffin has a tendency to crack and separate from the rind, thus allowing molds to develop beneath the paraffin coat, where the conditions are ideal as to moisture, for evaporation is excluded and the air consequently saturated. The use of formalin (2% solution) has been suggested as a wash for the outside of the cheese. This substance or sulfur is also applied in a gaseous form. Double bandaging is also resorted to as a means of making the cheese more presentable through the removal of the outer bandage.

The nature of these molds has not been thoroughly studied as yet. The ordinary blue-green bread mold, *Penicillium glaucum*, is most frequently found, but there are numerous other forms that appear, especially at low temperatures.

Poisonous cheese. Cases of acute poisoning arising from the ingestion of cheese are reported from time to time. Vaughan has succeeded in showing that this condition is due to the formation of a highly poisonous alkaloid which he has isolated, and which he calls *tyrotoxicon.*[1] This poisonous ptomaine has also been demonstrated in milk and other milk products, and is undoubtedly due to the development of various putrefactive bacteria that find their way into the milk. It seems quite probable that the development

[1] Zeit. f. physiol. Chemie, 10:146.

of these toxic organisms can also go on in the cheese after it is taken from the press.

Prevention of cheese defects. The defective conditions previously referred to can rarely be overcome in cheese so as to improve the affected product, for they only become manifest in most cases during the later stages of the curing process. The only remedy against future loss is to recognize the conditions that are apt to prevail during the occurrence of an outbreak and see that the cheese are handled in such a way as to prevent a recurrence of the difficulty.

Many abnormal and undesirable results are incident to the manufacture of the product, such as "sour" or "mealy" cheese, conditions due to the development of too much acid in the milk or too high a "cook." These are under the direct control of the maker and for them he alone is responsible. The development of taints due to the growth of unwelcome bacteria that have gained access to the milk while it is yet on the farm are generally beyond the control of the cheese maker, unless they are so pronounced as to appear during the handling of the curds. If this does occur he is sometimes able, through the intervention of a starter or by varying some detail in making, to handle the milk in such a way as to minimize the trouble, but rarely is he able to eliminate it entirely.

One of the most strenuous duties which the maker must perform at all times is to point out to his patrons the absolute necessity of their handling the milk in such a way as to prevent the introduction of organisms of a baleful type.

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