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WORKS OF PROF. F. W. WOLL

A Handbook for Farmers and Dairymen. Fifth Edition, New York, 1908. xv+496 pp. $1.50.

Grotenfelt's Modern Dairy Practice. American Edition, by F. W. Woll. Third Edition. New York, 1913. 286 pp. $2.00.

A Book on Silage. Second Edition. Chicago, Ill., 1900. 234 pp. (Out of print.)

Decker's Cheese Making, Cheddar, Swiss, Brick, etc. Fifth Revised Edition by F. W. Woll. Madison, Wis., 1909. 214 pp. $1.75.

Jointly with Prof. E. H. Farrington.

Testing Milk and Its Products. Twenty-first Edition. Madison, Wis., 1912. 297 pp. $1.25.

THE PRINCIPLES

OF

MODERN DAIRY PRACTICE

FROM A

BACTERIOLOGICAL POINT OF VIEW

BY

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AUTHORIZED AMERICAN EDITION

BY

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PREFACE TO AMERICAN EDITION.

It is doubtful whether any industry has changed more during the past twenty years than has that of the production of milk and its manufacture into butter and cheese. Progress has been made in every direction. The present generation has seen the shallow-setting system of cream-raising superseded by the deep-setting systems, and these again largely by hand or power separators. The wonderful growth of the creamery movement, the invention of the cream-separator and the butter-extractor, the introduction of pure cultures in the manufacture of butter, have all come to us during this time, as have also the various methods of preserving milk for direct consumption; and still more, underlying it all, an increased knowledge has been gained and a fuller understanding of the nature and properties of dairy products and the changes to which they are subject.

In this advance of the dairy industry the Scandinavian countries have taken the most prominent part, Denmark and Sweden having given the cream-separator to the world—the former country also contributing the method of ripening cream by means of pure cultures, and the latter the butter-extractor. Also Finland—Scandinavian by language, if not by government—has contributed her share to the advancement of dairying; and for a long time past large quantities of "gilt-edged" butter have every year found their way from her distant borders to the large markets of the world.

The author of this book is well known to Scandinavian dairymen from his numerous and important publications on dairy subjects; and in the broader field of science, which knows no boundary of nationality or language, his investigations relating to milk have made his name familiar to students of dairying and bacteriology. A study of the present work will, I think, show the reader that it is written by a thorough scholar, closely acquainted with all the different operations of the dairy.

The work has been revised by the author at my suggestion, and several additions have been made—e.g., the whole of Part V, on "Cheese." It has been my effort in preparing the translation to make it directly applicable to our methods of dairying. It was therefore found necessary to edit the original in places to adapt it to the changed conditions. Numerous explanatory foot-notes and references have been added, which I trust will prove of value to the student of dairying and dairy bacteriology without detracting from the value of the book to the practical dairyman. I have endeavored to include all recent American and European work in this line in my additions, so as to make the record of the investigations complete.

I wish to acknowledge the assistance of Dr. H. L. Russell, Assistant Professor of Bacteriology of this University, in preparing the translation. Dr. Russell has also kindly furnished me with several valuable additions giving the results of original investigations.

F. W. Woll.

Madison, Wisconsin.

TABLE OF CONTENTS.

PART IV.—BUTTER.

PART V.—CHEESE.

MODERN DAIRY PRACTICE.

INTRODUCTION.

BACTERIA AND THEIR RELATION TO DAIRYING.

> "Dairying is an art the success of which depends almost entirely on the extent to which we succeed in controlling the various fermentation processes in their course."
>
> —ERNST KRAMER.

THE great importance of bacteria in the dairy industry is at present admitted by all who have given the subject any thought. A knowledge of the nature and characteristics of these minute organisms will help us to understand more thoroughly the various manufacturing processes of the dairy and will throw light on problems that often perplex the dairyman. Since the changeable nature of dairy products makes it especially desirable to study all means at our disposal in order, if possible, to increase their keeping quality, an inquiry into the influence of the bacteria in the dairy will be of the highest value to the practical dairyman and to all who handle milk and milk products. It will teach us not only to produce goods that will keep well, but to care for them afterwards so that they do not prematurely spoil.

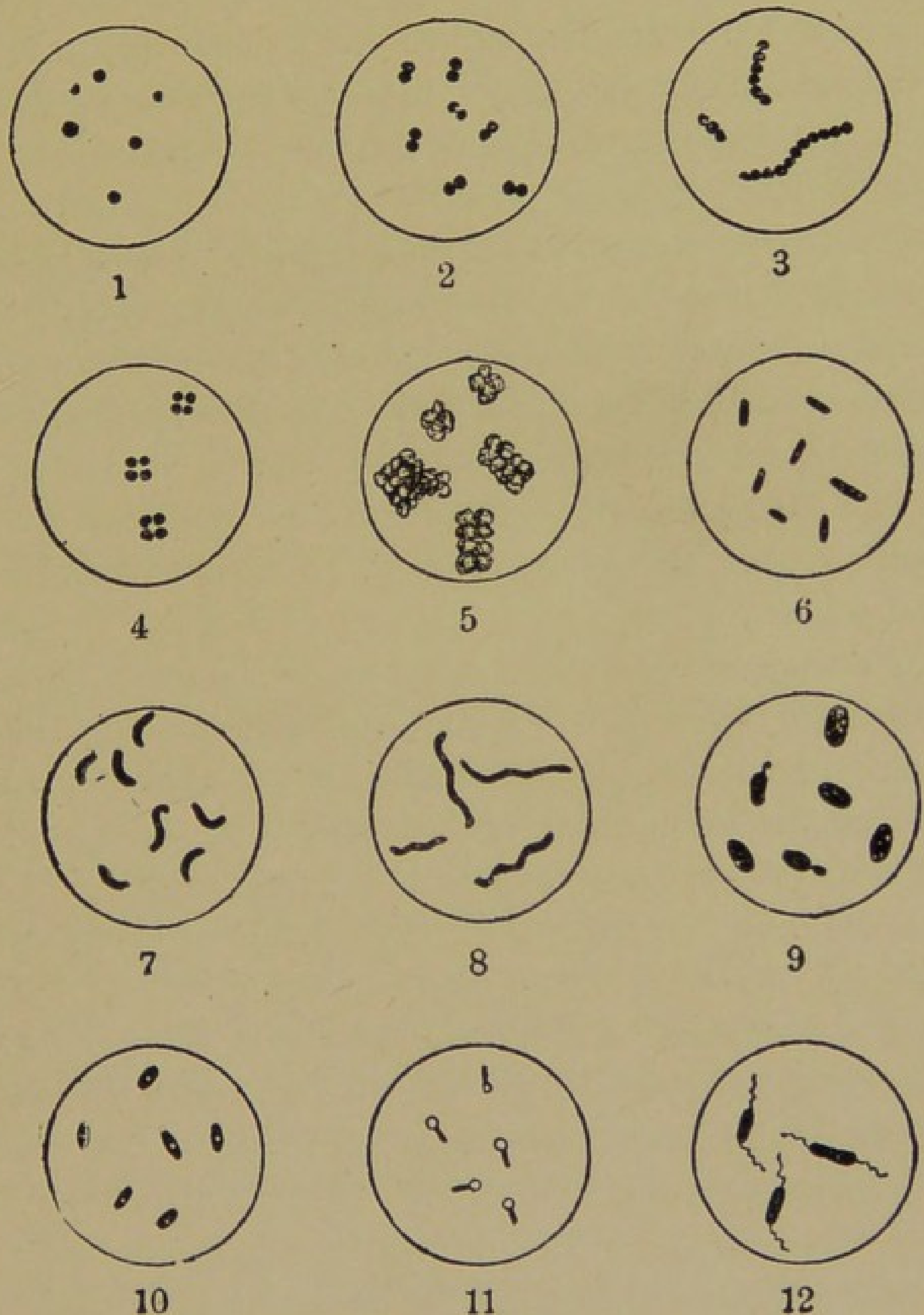
Before proceeding to the consideration of these problems it will, however, be necessary to give some general information concerning bacteria and their prominent characteristics of life, so that the reader will be able to follow the discussions entered upon in the main part of this work.

Bacteria.—Bacteria are the tiniest forms of organic life known; they are single cells belonging to the lowest type of plant life.

They vary somewhat in form and there is considerable difference in size. The different species of bacteria cannot be readily distinguished by their form and shape as with the higher order of plant or animal life, because so many of them have such strong similarities in this respect. The usual method of classifying them, which is admitted to be imperfect, bases the distinguishing characters entirely upon shape.

There are three fundamental types known, that may be compared in shape to a *ball*, a *short rod*, and a *cork-screw*. These three types are called (1) *coccus*, (2) *bacillus*, and (3) *spirillum*. All forms of bacteria may be referred to these three fundamental types, although there are gradations between them. Other names are given to certain species on account of the way in which the individual cells may be joined to each other: i.e., if the cell is isolated it is called a *micrococcus;* two coccus forms joined closely are spoken of as *diplococcus*. Sometimes the cells may adhere in long chains and are then known as *streptococcus*. If they form clusters instead of chains they are called *staphylococcus*. A few coccus forms grow out in a platelike expansion, when they are called *tetrads*. If they multiply in three directions of space instead of in two they form cubical masses known as *sarcina*.

The *bacilli* include the elongated rodlike cells. They vary greatly in length and are sometimes divided into subdivisions, such as *bacterium*, meaning a short cell devoid



FIGS. 1–12.

Fig. 1, *micrococci*; Fig. 2, *diplococci*; Fig. 3, *streptococci*; Fig. 4, *tetrads*; Fig. 5, *sarcina*, Fig. 6, *bacilli*; Fig. 7, *comma bacilli*; Fig. 8, *spirilli*; Fig. 9, *yeast fungi*; Figs. 10 and 11, *bacilli* with spores; Fig. 12, *bacilli* with *cilia*,—all highly magnified.

of any spore-bodies within; *bacillus*, the normal rodlike type, reproducing by spores under certain conditions; and *leptothorix*, where the filaments are extremely long and slender.

The *spirilla* are the curved forms, and vary most in their outward appearance. They may be merely undulating in appearance or in segments merely curved, when they are sometimes spoken of as *vibrios*. To this class belongs the cholera germ, often called the *comma bacillus* on account of its curved appearance. Many times the *spirilla* are curved into several sharply-defined turns.

Size and Weight of Bacteria.—As already mentioned the bacteria vary much in size, for which reason it is impossible to give their average dimensions. A couple of examples will convey some idea of their extraordinary minuteness.

A common lactic-acid bacterium is generally 3 micromillimeters long and 1 micromillimeter wide. One micromillimeter (μ) is $\frac{1}{1000}$ millimeter or $\frac{1}{25000}$ of one inch. How exceedingly small must, then, the organism be, 25,000 of which may be placed side by side without spanning over more than an inch! Not less than 10,000 million single bacteria would be needed to fill a cubic millimeter. Their weight is also exceedingly small. If we assume that the specific gravity of the bacterium mentioned is equal to that of the water (this may not be exact, but is not very much out of the way) it weighs a little over .0000000001 milligram; and something over 900 billions of such organisms are required to reach a weight of 1 gram ($\frac{1}{28}$ of an ounce).

Distribution of Bacteria.—It is evident that such small organisms may hide everywhere in nature. They have been found in air, soil, water, dust; on our clothes, on our skin; in the alimentary canal of man and animals, in our food; on the trees and the flowers, on the smallest as well as the largest animals,—in short, in almost every place on earth. Among the few exceptions to the omnipresence of bacteria may be mentioned that they are never found in the uninjured animal and vegetable cells or in fresh, unwounded animal and vegetable organs. Their wonderful general distribution is due largely to their exceedingly small weight; they are easily carried around in the air, and when dry are moved by the least current. Certain bacteria furthermore possess power of locomotion in the fluids adapted to their development, and they can therefore spread in these substrata with wonderful rapidity.

Multiplication of Bacteria.—The main reason of the universal presence of bacteria is, however, not to be found in any of the conditions mentioned, but in their enormously rapid reproductive capacity. This takes place partly by *division*, partly by *spores*.

a. Multiplication by Division.—Bacteria may divide in different ways. The most common method is by the simple division of a single cell-element into two equal parts (*fission*). This may continue in a linear direction, giving rise to long threads or chains of cells. In the case of coccus forms the continued division into twos may give rise to the *streptococci* (*chain cocci*); or, if irregular and in two planes, it may form flattened surfaces or bunches—*pus bacteria.*

If division occurs in three planes we have the formation of the cubical masses or *sarcina* groups.

Under favorable conditions the multiplication through division may take place very rapidly. It has been observed in case of some bacteria that the time elapsing between the division of the mother bacterium and the moment when the new bacterium in its turn begins to multiply amounts to only twenty minutes. As a rule the interval may not be as short, but it often does not amount to more than about an hour. A bacterium which grows and divides into two organisms during this time may, under ideal conditions, within 24 hours be the ancestor of 16,777,214 organisms. A *sarcina* which produces, e.g., eight new bacteria in an hour by dividing in three directions, may after 20 hours have an offspring so enormous that it is 1,111,-152,347 times larger than the number of human beings found on our planet; the figure indicating the number of this progeny would contain nineteen ciphers!

As a corollary of this enormously rapid multiplication it follows that the bacteria in general must exist in nature under highly unfavorable conditions, as they would otherwise soon fill the whole earth and annihilate everything else living.

b. Multiplication by Spores. — The multiplication through spores (Figs. 10–11) occurs in the manner that small round or egg-shaped bodies with a characteristic power of refraction are formed within the bacterium, and later on these grow to ordinary bacteria, under proper conditions of heat and moisture. The spores possess far greater power of resistance against drought, heat, cold, etc., than do the bacteria themselves. The fact that these often prove almost indistinguishable from the material to which they have once gained access depends in most instances on the fact that spores have been formed there. If, e.g., sporeless bacteria dry up, they die comparatively soon, within a day, or perhaps a week. If the conditions are not too unfavorable, the spores, on the other hand, may often continue to live for years after the nutritive solution has died out. It must be noted, however, that there are exceptions to the rule in both cases. The spores are far less susceptible to changes in temperature than the bacteria themselves. While, e. g., sporeless bacteria generally are killed under favorable conditions within about ten minutes, when exposed to a moist heat of 158°–176° F. (70°–80° C.), the spores of several species survive after having been exposed even to live steam for hours. The spores of a certain potato bacillus can stand this treatment for almost six hours without succumbing. A large number of spores are not killed except by dry heat at 266°–284° F. (130°–140° C.). We thus find among the spores of bacteria some of the most tenacious organisms in the vegetable or the animal world.

Some bacteria (above all a large number of bacilli) are supplied with fine cilia (Fig. 12), and have under favorable external conditions a lively power of locomotion.

Pathogenic and Non-pathogenic Bacteria.—Some bacteria have become known and feared from their power of producing infectious diseases in the animal body. Owing to this fact, everything known by the name of bacteria has been the object of fear and suspicion to most people. This is, however, without any foundation. By far the larger number of bacteria are not disease-producing and are not injurious to the animal organism. Some of the harmless majority distinguish themselves by the fact that they call forth fermentation in all kinds of fermentable fluids, while others, as far as known to modern science, are entirely indifferent.

In these studies and investigations we shall first of all consider the bacteria producing fermentations. For this reason the following short account of the conditions of life of bacteria holds good primarily in case of this group.

Nutrition of Bacteria.—The bacteria are usually exceedingly unpretentious in their demands for the good things of life, a fact which, of course, is one of the main reasons for their universal distribution in nature. The smallest quantities of organic matter are sufficient for their support ; and wherever they find such a substance which possesses the moisture and heat necessary for their development and a reaction favorable to their activity, they will grow and multiply there.

The bacteria live on the ready-formed carbonaceous compounds of organic origin, and do not as a rule possess the ability to make use of carbonic acid. The different species of bacteria usually select different kinds of carbohydrates. Some thrive best when the nutritive solution contains grape-sugar ; others when it contains cane-sugar or milk-sugar, etc. Hence we find that the different nutritive substances often are contaminated with their own peculiar kinds of bacteria. Only a few bacteria are omnivorous and satisfied with almost any organic substratum.

The nitrogen in the nutritive substratum required by the bacteria may be obtained not only from organic substances, but from certain inorganic materials, like nitric acid and ammonia compounds. The bacteria, however, usually prefer albuminoids. Very few bacteria can do entirely without nitrogeneous substances. The need of the different species of nitrogen varies greatly. The bacteria living mainly on carbohydrates need only very minute quantities of nitrogen for their development, while a high nitrogen content in the substratum is an absolute condition of life with others. As regards the need of bacteria of salts (mineral matter) they behave usually like ordinary fungi. It must be especially noted that alkali salts are very important for the nutrition of bacteria.

Bacteria and Moisture.—Not only the chemical composition of the substratum: but also the degree of moisture in the same is, as already mentioned, of importance for the development of bacteria. Organic life is inconceivable without a certain content of moisture in the nutritive substratum. We saw above that sporeless bacteria die comparatively rapidly in the absence of moisture, while the spores, on the other hand, retain their power of life even a long time after the substratum is completely dried out.

Bacteria and Heat.—Heat, this mighty spring in the machinery of organic nature, is also of great importance for bacteria, although the various species have very different demands in this respect. It may be said in general that 39° F. (4° C.) is the lowest temperature at which bacteria can multiply and grow. Below this temperature they fall into a torpor from which they are awakened only by increasing temperature.

With most bacteria the torpor-like condition appears even before this temperature has been reached. Some species have been found in ocean water and in the soil, however, which can multiply even at 0°. While the development of bacteria is arrested by a low temperature, a large number of them are able to stand intense cold without being destroyed. The bacteria of splenic fever are said to live even after having been subjected to a cold of −166° F. (−110° C.) for an hour, a temperature which only few organisms can stand ; the cholera bacteria can stand a cold of 14°F. (−10° C.) for the same length of time without being destroyed; and typhoid bacteria have been known to remain alive for 100 days frozen in the ice. A special account is given later on of the influence of cold on certain fermentation bacteria.

It is, however, not only cold but also high heat which arrests the development and multiplication of bacteria. Temperatures between 39° and 122° F. (4° and 50° C.) are most favorable to their development. At 140°–158° F. (60°–70° C.) their vegetative forms are usually killed, provided this temperature is allowed to act for a sufficiently long time, while the spores can stand a much higher heat. The optimum temperature, i.e., the most favorable temperature, for the development of the *pathogenic* bacteria (the disease bacteria) coincides nearly with the body temperature of animals; for the greater portion of the other bacteria and especially for the fermentation bacteria it is from 59°–77° F. (15°–25° C.). There are, however, numerous exceptions to these rules. There are thus, e.g., some soil and water bacteria which only develop at 122°–158° F. (50°–70° C.). I have further found bacteria in milk that were not only alive but multiplied at 140°–149° F. (60°–65° C.). At lower temperatures the development of these bacteria was practically suspended.

Chemical Reaction Necessary for Bacteria.—The development of bacteria also depends on the chemical reaction of the nutritive substratum. An alkaline or at least a neutral reaction is an essential condition for a large majority. Some few bacteria can, on the other hand, thrive in an acid substratum, (e.g., lactic-acid bacteria). An acid reaction of the nutritive substratum is especially favorable to the development of the moulds.

Finally, two factors must here be noted which have the greatest influence on bacterial life, viz., air and light.

Bacteria and the Air.—A large number of bacteria are entirely dependent on the oxygen of the air, and perish if they do not have access to the same. These are called *aerobic* bacteria. On the other hand, oxygen acts as a poison, or at least as a narcotic, to other forms (*anaerobic* bacteria). Some bacteria can further exist both in an atmosphere of oxygen and in its absence. Many of the latter organisms differ in behavior according to whether they have access to air or not.

Bacteria and Light.—The large majority of bacteria like total darkness, and only a few thrive in direct light. Direct sunshine as a rule acts as a poison on all organisms included under the term bacteria; and if ordinary daylight is allowed to act on them for a sufficiently long time and with proper intensity, not only most of the vegetative forms but even their spores will be destroyed. Sunlight is therefore the most common, the cheapest, and the most effective means at our disposal of fighting the bacteria. Light exercises its power of destruction of bacteria on a large scale. In nature the destruction is most intense during the summer months. A putrefactive liquid, the condition of which, as is well known, is due to a fermentation brought about by bacteria, can even become sterile through the action of sunlight alone. The more generous the supply of air while the bacteria are exposed to the sunlight, the more rapidly they and their spores are destroyed.

Bacteria and Disinfectants.—It must furthermore be stated as a characteristic of bacteria, as well as of all other living organisms, that they shun certain chemicals which either arrest their growth or entirely destroy them. These materials are called either disinfectants or antiseptics. Further information concerning the disinfectants especially adapted for use in dairy practice will be found later on in this work.

Bacteriological Methods of Investigation.—We cannot here enter into a detailed account of bacteriological methods of investigation. It may be proper, however, to explain briefly the nature and general characteristics of these methods, in order that the discussions entered upon in the body of this book may be more easily understood by persons not familiar with bacteriological science. Those intending to study in a more systematic manner the relations dwelt on, are referred first of all to the splendid text-books: C. J. Salomonsen's "Bakteriologisk Teknik for Medicinere," published in 1889, and Hueppe's comprehensive work, "Die Methoden der Bakterienforschung," 1889. An interesting and plain presentation of the subject is given in the Swedish language in Prof. Curt Wallis' book, "Bakteriologi" (1888).*

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* The following is a list of the more important works on Bacteriology, besides those mentioned above:

STERNBERG, Text-book of Bacteriology, New York, 1901. ABBOTT, Principles of Bacteriology, Philadelphia, 1899. HEWLETT, Manual of Bacteriology, Philadelphia, 1898. FRÄNKEL, Text-book of Bacteriology, tr. by Linsley, New York, 1891. PEARMAIN and MOOR, Applied Bacteriology, London, 1897. MIGULA, Practical Bacteriology, London, 1893. FLÜGGE, Die Micro-organismen, I–II, Leipzig, 1896. JÖRGENSEN, The Micro-organisms of Fermentation, London, 1893. LAFAR, Technical Mycology, London, 1898. McFARLAND, Pathogenic Bacteria, Philadelphia, 1900. WOODHEAD, Three methods are generally used in the study of bacteria, viz.: (a) *microscopic examination*; (b) *culture of the bacteria on different nutritive substrata;* and (c) *inoculation experiments with animals.* As we are here dealing especially with non-pathogenic bacteria, we shall only dwell on the first two methods, since inoculation is only used in the study of pathogenic bacteria.

a. Microscopic Examination.—In applying the first method, a compound microscope is essential. This ought to magnify at least 500 times, and preferably more. With such an instrument the presence of bacteria can be directly proved in several liquids, as in case of slops from creamery-gutters, standing liquid-manure pools, etc. In other liquids and in mediums where the bacteria present either appear in smaller numbers or are extremely small or are hidden by other bodies (as in the cream and milk) they cannot be observed in this easy manner. In such cases the bacteria must be stained,—an operation usually performed by means of different anilin colors,—and they will then appear plainly when seen through a microscope. Although this method in many instances will lead to important observations, it seldom gives decisive results as regards the question of the characteristics of single species. The bacteria are extremely simple organisms, which offer

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Bacteria and their Products, London, 1893. CONN, The Story of Germ Life, New York, 1897, and Agricultural Bacteriology, Philadelphia, 1901. RUSSELL, Dairy Bacteriology, Madison, Wis., 1902. MIGULA, Bakterienkunde f. Landwirte, Berlin, 1890. KRAMER, Die Bakteriologie in ihrer Beziehung zur Landwirtschaft, Wien, 1892. FREUDENREICH, Bakteriologie in der Milchwirtschaft, Basel, 1893. WEIGMANN, Die Methoden der Milchconservirung, Bremen, 1893. MACÉ, Traité pratique de bacteriologie, Paris, 1897. CHESTER, Manual of Determinative Bacteriology, New York, 1901. FROST, Laboratory Bacteriology, Madison, Wis., 1902.—W.

but few dissimilarities in their outward appearance. There are, e.g., a large number of species among the micrococci which appear entirely similar by examination with a microscope, but which show great differences in their effects and general behavior in one and the same substratum, and thus indicate beyond a doubt that they are in reality different species. It has therefore been found necessary to seek a more certain method of identification than the microscopic examination, and such a one has also been found in the culture method.

b. Culture Method of Bacteria Investigation.—Bacteria can develop in several kinds of media, both liquid and solid. In the former they form all kinds of flocculent and sandy growths, while in the latter they grow into more or less characteristic isolated masses, technically called colonies. In the culture of bacteria for scientific objects French bacteriologists previously used mainly liquid substrata and German preferably solid ones. Both kinds are of late made use of by all bacteriologists. The liquid nutritive media distinguish themselves by the fact that the conditions which they offer to the bacteria resemble those found in nature, and that all kinds of fermentations may be more easily observed in them; the solid substrata, on the other hand, are the more convenient ones to use when the question of the specific growth of different species is studied. Among the liquid substrata used in bacterial investigations may be mentioned beef-broth, milk, malt-extract, sugar solutions prepared in different ways, and extracts of various fruits; among the solid nutrients, prepared potatoes and beef-tea, to which pepton and all kinds of gelatinizing substances have been added, as gelatine, agar-agar, etc. Coagulated blood-serum and soaked wheat-bread are also often used.

Sterilization of Culture Media.—When these nutritive media are used for the culture of bacteria they must be sterile, i.e., free from all living organisms, as the culture would otherwise be impure from bacteria found in the substratum before the organism to be studied was seeded or inoculated in it. Sterilization is usually effected by heating to such a temperature that both bacteria and their spores are killed. As we saw in the preceding, the vitality of different species of bacteria differs greatly: while some bacteria are killed at rather low temperatures, others require a temperature considerably above the boiling point. To be absolutely certain that all bacteria, and above all their spores, are destroyed, we should heat intensively for every sterilization. In some cases this is impossible, as many substrata cannot be heated very high without being changed in one way or another. In case of such nutritive substrata we must therefore make use of other methods of procedure. A lower heat acting for a longer time or repeatedly may, e.g., be applied. This last method (*intermittent sterilization*) has to be used, among other cases, in the sterilization of milk and its products.

Intermittent Sterilization.—Having killed the vegetative forms of the bacteria through a careful heating, the substratum is allowed to stand at ordinary temperature for some time, so that the spores, which of course retained their vitality, may develop into ordinary bacteria; and these are then in their turn killed by a second heating. As all spores may not then have reached the vegetative stage, or as some new spores may have been formed during the interval, it is safest to repeat the operation one or more times, according to necessities in each case. To be entirely safe, the milk is never used until its sterility has been ascertained by its being kept for some time at a temperature favorable to the development of the spores possibly still remaining in it.

Method of Sterilization.—Several different apparatus have been constructed for sterilization of nutritive media through heat. The steam sterilizing apparatus introduced into bacteriology by Koch and Gaffky is generally used in Northern laboratories.* If this is to be used for the sterilization of milk, e.g., the substratum must be exposed in the apparatus to a temperature of 212° F. (100° C.) for three quarters of an hour each time on three consecutive days. Other substrata require of course a different treatment in order that the sterilization may be successful. Milk may also be sterilized in a very short time by being heated under pressure at 248° F. (120° C.) in a Chamberland

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* The Arnold Steam-cooker, an ordinary domestic utensil in America, is admirably adapted for purposes of sterilization. (Fig. 13).

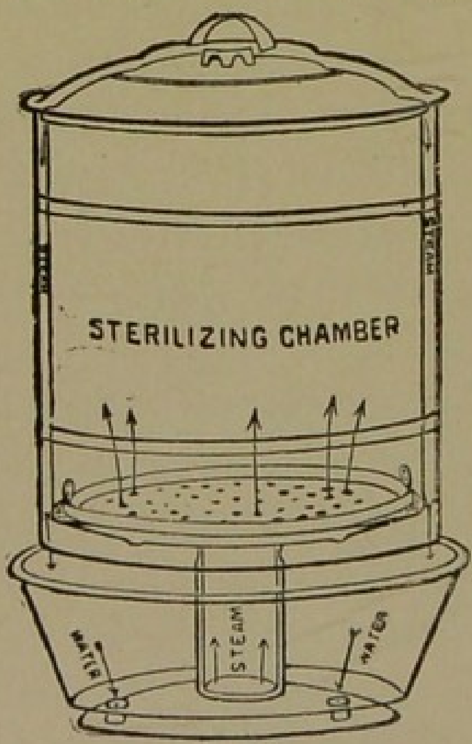
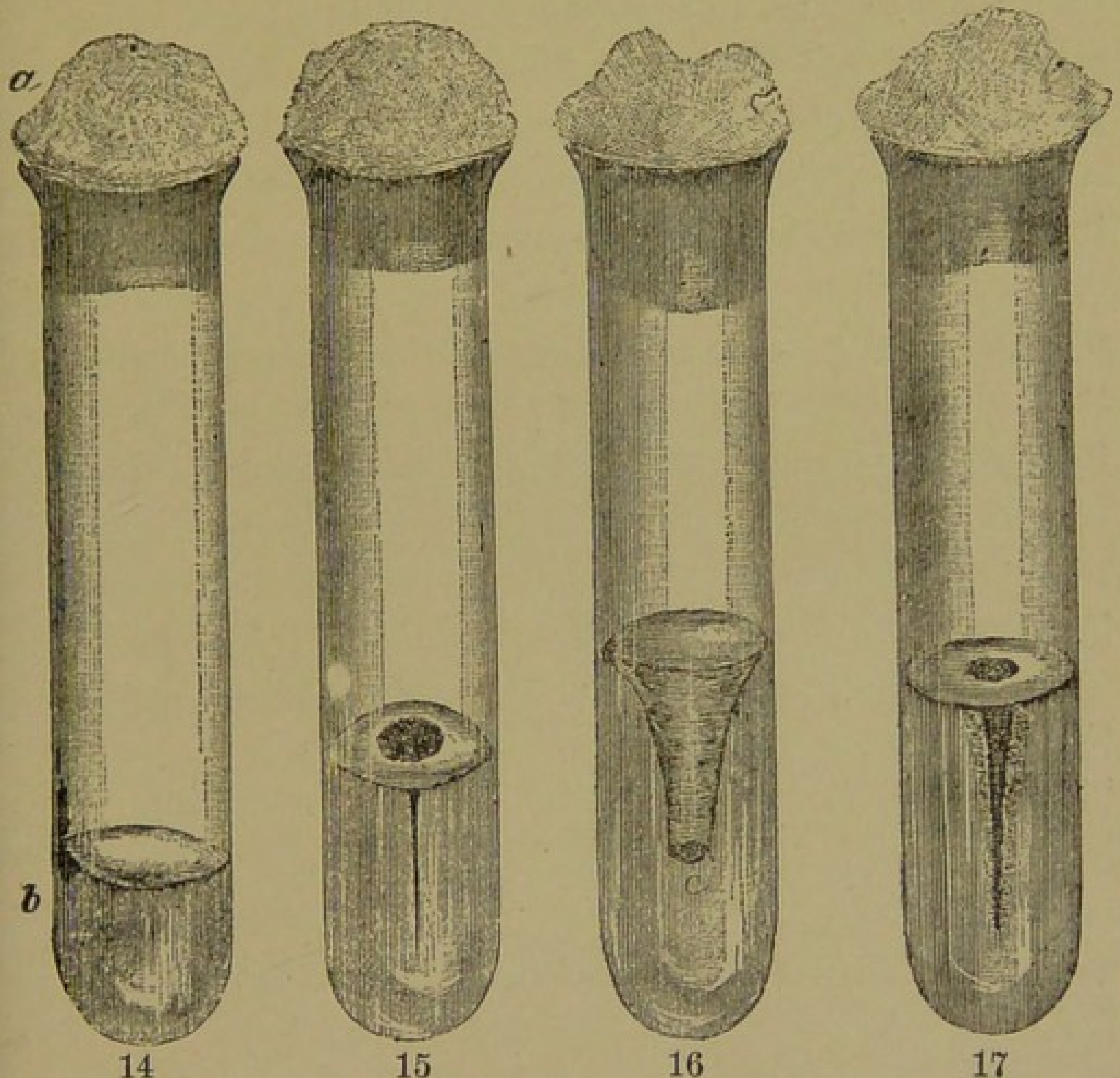


Fig. 13.

Water is poured into the pan (or reservoir), whence it passes slowly through three small apertures into the shallow copper vessel (generator) beneath, becomes converted into steam, and rises through the funnel in the center to the sterilizing chamber above. Here it accumulates under moderate pressure at a temperature of 212° F. The excess of steam escapes about the cover, becomes imprisoned under the hood, and serves to form a steam jacket between the wall of the sterilizing chamber and the hood. As the steam is forced down from above and meets the air it condenses and drips back into the reservoir.—W.

Steam Sterilizer. When this method is followed, the milk is, however, often brown colored



14 15 16 17

FIGS. 14–17.

FIG. 14.—Test-tube closed with a cotton plug and filled with gelatine. The inner surface of the tube, the cotton plug, and the gelatine are sterilized.

FIG. 15.—Culture of a bacterium in a test-tube. The bacterium has formed a large colony on the surface of the gelatine, and a weak bacterial growth is shown in the inoculation-needle track "stick."

FIG. 16.—Shows a culture which peptonizes (liquefies) the gelatine. A colony is also in this case first formed on the surface of the substratum, but as the bacteria liquefied this it gradually sank into the liquid formed. At the stage shown in the cut the bacteria appear as a small precipitate, *c*, at the bottom of the funnel-shaped, liquefied gelatine.

FIG. 17.—Shows a culture of bacteria which also liquefied the gelatine, but to a smaller extent than the one last mentioned. Before the liquefaction, short filaments grow out into the solid gelatine from the "stick."

The sterilization of some substrata may be accomplished by filtration through clay, gypsum, porcelain, asbestos paper, layers of sand, and so on, all prepared especially for the purpose. These filters retain all solid particles found in the liquids, and consequently also the bacteria. This method of sterilization is not, however, applied as often as the one previously given.

Methods of Examination.—The culture of the bacteria takes place in the laboratory in sterilized glass vessels of different shapes. Ordinary test-tubes or glass flasks are most commonly used; in either case the mouth of the vessel is closed by a sterilized cotton plug. This allows the air to pass in and out, but prevents bacteria from gaining access to the vessel from the outside. Sterilized gelatine plates, properly protected against infection from the bacteria of the air, are also used.

In the bacteriological examination of a liquid substance this is first examined through the microscope; the different kinds of bacteria in the substance are then isolated. This is done according to the method invented by Koch: one or two drops of the liquid are introduced into a test-tube containing some gelatine which has previously been liquefied by careful heating. The sample is shaken carefully and rapidly, so that the gelatine cannot congeal, and is then poured on a glass plate protected from infection of bacteria and allowed to solidify. By the thorough shaking the individual bacteria in the drops of the liquid are scattered in the gelatine, so that on the congelation of the latter they are fixed at different places in the same. If the plate be now kept under favorable conditions of temperature, light, and moisture, each one of the single bacteria will multiply and form colonies of varying sizes, as a rule visible to the naked eye (see Fig. 18).

If the sample does not contain such an abundance of bacteria that the colonies go over into one another, different nutritive substrata may be inoculated with a part of the different colonies, and pure cultures are in that way obtained of the various organisms; provided, however, that the whole process has been conducted with due care and dexterity. When the various species of bacteria found in the liquid have been isolated in this manner, they are grown in different substrata to study their manner of growth and effects. The determination of the bacterial

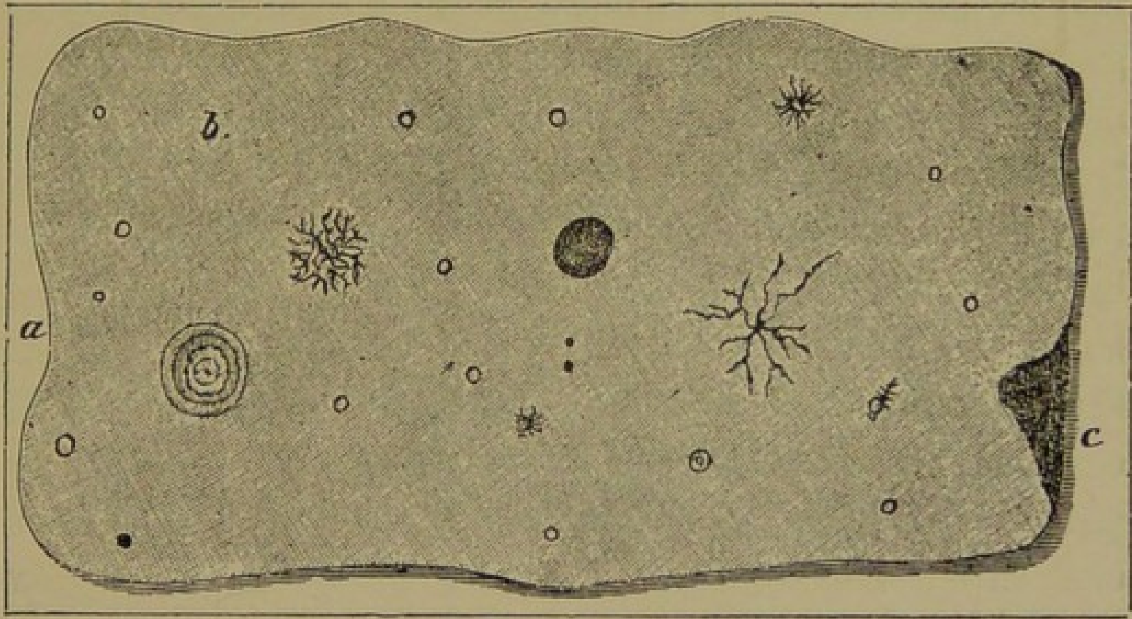


FIG. 18.

a. glass plate; *b*. solidified gelatine, in which may be found all kinds of colonies; the colony at *c* liquefies the gelatine, the others do not. The ramified colonies consist of moulds, the others of bacteria.

contents of water or milk is as a rule conducted according to the method here given. By this and other bacteriological operations it is, however, not enough to make only a single examination; a number of control cultures must always be made.

Unfortunately all bacteria cannot be isolated and grown in this easy manner; but the method of procedure in other cases cannot here be explained in detail, and interested readers are referred to the text-books already mentioned concerning this point, as well as all details in bacteriological technic.

Before concluding this short explanation of bacteriological methods of investigation I will state that a large number of bacteriological studies—at least in their beginning—do not necessarily require for their execution a complete laboratory, equipped with expensive and delicate apparatus. A number of simple pieces of apparatus fit for sterilizing material for bacterial cultures at a high temperature, etc., may be found in almost any modern kitchen. This is of great importance, since the field of investigation cannot always be near laboratories. A large portion of the bacteriological studies upon which this book is founded could not, in the nature of things, be made in a city laboratory, but were only made possible because a small so-called bacteriological hand-laboratory was amply sufficient for their pursuit. Thanks to this fact I have been able to conduct my investigations in the midst of the industries whose conditions I intended to study from a bacteriological point of view.

As an illustration of the importance of bacteria in the dairy industry, I will report an event which strikingly shows how the dairy products on a farm may for a long time be entirely spoiled on account of infection from a single harmful species of bacteria. On the estate *Duelund* in Denmark, belonging to *Hofjägermester Friis*, who is so well known in the Danish dairy world, the principles of rational dairying have been followed since the introduction of the dairy movement into Denmark. High-grade butter to which premiums were often awarded has long been made on the estate. But about a year ago it suddenly became impossible to produce first-class, fine-flavored butter in the dairy of the estate in spite of the fact that the butter-making was conducted with every possible care and according to the same method as before.

The milk was evidently not diseased when drawn from the udder, but on standing for a time it invariably assumed a putrid smell and taste, which even reappeared in the butter made from the milk. The accident of course caused the loss of large sums of money to the owner, the product of butter from the estate being very large. The best dairy experts were consulted, but their directions were of no avail. It was then suspected that the cause of the evil was of a bacteriological nature, and Professor C. O. Jensen, the bacteriologist at the Copenhagen experiment station, was called in to investigate the matter. After having carefully studied the case he ascertained that the rapid spoiling of the milk was caused by a single small bacterium which had infected all the places where the milk was handled. He showed that the small disastrous organism had spread not only over the barn, where it was even found on the udders of the cows, but also all over the dairy. He isolated the bacterium and made it the object of lengthy investigations. By introducing cultures of it into sterilized milk he brought about the same peculiar changes which characterized the diseased milk at Duelund.

The organism which caused so much harm and loss proved, however, comparatively harmless, thanks to its poor power of resistance. It dies at as low a temperature as 149° F. (65° C.), and besides may be killed by means of ordinary disinfectants. After a disinfection of barn and dairy it soon disappeared from Duelund, and first-class butter could again be produced there.

If energetic remedies for the eradication of this bacterium had not been resorted to in time, and if it had not possessed such slight resisting properties, a milk epidemic might easily have spread far around from this "pest-house," which, in spite of our modern highly-lauded rational dairy industry, had formed at one of the most carefully-conducted dairies in the great dairy country of Denmark.

PART I.

MILK.

> "Sauberes Euter, reine Hose und Hand
> Bringen zur Ehre den Melkerstand."
>
> *Swiss Proverb.*

CHAPTER I.

MILK AS DRAWN FROM THE UDDER.

WHEN the milk is drawn from the udder of a healthy cow it is germ-free or sterile. Lister, Meissner, Duclaux, and other scientists have shown that such milk will remain unchanged for all time without any preservatives being added, if it is only carefully protected from all bacterial infection. The original sterility of normal milk is due to the fact that the bacteria cannot gain access to the milk-glands from without as long as the udder is not injured in any way, and that the udder can only be infected by bacteria from within, from the different internal parts of the animal body, when these parts themselves are infected with bacteria, i.e., are not in their normal, healthy condition.

It is a comparatively easy bacteriological experiment to show the original sterility of milk after the experience gathered by the above-given scientists. It is, however, necessary strictly to observe certain precautions. The udder and its environments must be carefully cleaned with soap and water, treated with corrosive sublimate solution and washed with boiled, rapidly cooled water. The milker's hands should be washed in ether and alcohol, then rinsed with sublimate solution, and carefully washed in boiled water. The milk is drawn into sterilized glass vessels. Good results are generally secured when these precautions are followed, and when the milking is done rapidly and with precision, preferably at some place away from the cow-stable and other places filled with micro-organisms.*

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* The difficulty which bacteriologists have often found in obtaining absolutely sterile milk, when it has been drawn under observation of all possible precautions, is explained by the observation made by Lehmann, that bacteria found in the drop of milk at the opening of the teat are able to work their way into the milk-cistern, where they then multiply very rapidly, favored both by the high temperature and the rich nutritive medium. At milking the bacteria in the milk-cistern will be largely washed out in the first portions of milk drawn, but all are not removed until the milking has progressed for some time. Lehmann (*17te Versammlung d. deut. Ver. f. öffent. Gesundheitspflege*) thus found that the first milk drawn (300 cubic centimeters, about 10 oz.) contained 50,000 to 100,000 bacteria per cubic centimeter, while the main quantity of the milk drawn contained 5000 bacteria per cc. on an average, and the last 300 cc. were almost or entirely free from bacteria. Schulz (*Arch. f. Hyg.*, **14**, 260) in the same way showed that the first portion of a milking contains a large number of bacteria, while the last portions of milk are sterile when proper precautions have been taken. See also Gernhardt, Quant. Spaltpilzunters. d. Milch, Inaug. Dissert. Univ. Jurjew, 1893, Harrison, Rep. Ont. Agr. College, 1896, p. 108, and Ward, Cornell Exp. Station, Bull. 178.—W.

In investigations concerning the original sterility of the milk I have followed a somewhat different plan from the one given. When the udder has been cleaned I have drawn the milk by means of a sterilized silver milking-tube, kept carefully protected from infection till it is used. Following this method I have succeeded in obtaining good results, even when the experiment was made in the barn. Nearly all the samples of milk remained unchanged, although they were kept for several days in an incubator (thermostat) at a temperature of 86°–90° F. (30°–32° C.). This speaks decidedly in favor of this simple method, which doubtless is to be preferred to the older one, as the milk in the latter is far more liable to infection.

Since the milk when drawn from a sound udder is absolutely sterile and will keep,—i.e., does not contain any micro-organisms,—our efforts must be directed toward protecting it from infection in the handling and further manufacture in the dairy and creamery. We shall see in the next chapter that infection of the milk by bacteria is inevitable, and shall learn the best means of protecting the milk and its products from the same.

CHAPTER II.

SOURCES OF INFECTION IN THE STABLE, AND ITS PREVENTION.

On its arrival at the dairy the milk is always more or less infected with bacteria, it being impossible to protect it entirely from infection in practical dairying. This is apparent from the mere fact that it is not always possible to keep the milk sterile even when all precautions of a scientific investigation are taken. Lister's experiments concerning the original sterility of milk form an interesting illustration of this matter ; although the greatest precautions were taken, he obtained only a very few milk samples that would keep as long as the milking was done in the stable. If the milking, on the other hand, took place in the open air, the experiments were nearly always successful. It would therefore seem that the air in the cow-stable at the time of these experiments was so mixed with bacteria that in spite of all care it proved almost impossible for him to protect the milk from infection.

It is therefore evident that the milk already in the barn must be highly infected with bacteria in its ordinary handling. It is, however, out of the question to introduce scientific, exact means of precautions in the practical work in the barn, in order to prevent all infection of the milk, as this would make the work too complicated and expensive, and some of the precautions that would have to be taken (e.g.), the application of corrosive sublimate) are furthermore dangerous. Milk as found in practical dairying has therefore lost its ability to keep for an indefinite period of time, and the various bacteria contained in it are trying to change it in one way or another. Fortunately we are so situated that the milk does not need to be entirely germ-free (sterile) for the purposes for which it generally is used, a truth which practical experience has long ago taught us. Experience has also taught us that the better we succeed in preserving the original qualities of the milk before the process of manufacture begins, the finer will the products be, and above all the better will they keep. However intelligent and experienced a dairyman may be, he cannot make first-class products from milk that has been carelessly handled.

Since bacteria are found everywhere, some one may object that it cannot be worth the trouble to fight them. A fight against omnipresent and even invisible enemies must at any rate be hopeless. This reasoning is not, however, justified; for we do possess strong means of fighting the bacteria. In several kinds of manufacturing enterprises it is already possible to limit and govern the activities of the bacteria. As an example may be mentioned that the standpoint was long ago reached by the manufacturers of beer that they no longer need fear being disturbed in the normal progress of their work through invasion of bacteria, but on the contrary may determine at will the kinds of yeast that are to start the fermentations desired. Not until after this was reached it was possible to make well-keeping and always uniform products in this industry—a goal toward which dairying, of course, also must aim.

While we cannot hope to make a raw product of absolute keeping qualities in dairying, we must try to make it keep as long as possible, i.e., we must protect the milk from being spoiled by bacteria by all means at our disposal.

Precautions against Infection of Bacteria.—The precautions used against infection of bacteria are of two kinds,—(1) *such as aim at the protection of the milk from infection from without*; and (2) *such as aim to check the development and multiplication of the micro-organisms already found in the milk.* In practical work these two methods go hand in hand, however, for which reason we shall not here attempt a strict separation.

Infection during Milking.—The milk is exposed to infection from the moment it is drawn from the udder. Being pressed out of the teats in a fine spray, it comes in contact with the air on a very large surface; the air in the cow-stable, and especially under the udder region of the cow, is nearly always filled with such bacteria as are the feudal enemies, so to speak, of the milk. If the milking is done in the open air, e.g., in the pasture, the danger of infection is of course less. It can easily be shown by a bacteriological examination, however, that there is a danger also in this case. By the shaking to which the udder and the parts of the skin next to the same are subjected in milking, bacteria are always loosened in large numbers and infect the air and the milk. This is plainly shown by the following simple experiment:

Of two sterilized culture-plates with nutritive gelatine, which had been freed from all bacterial life by sterilization, one was placed five to six feet away from the milker and the cow, and the other directly under the udder, next to the upper rim of the milk-pail. When the milking began both plates were uncovered at the same time, so that the bacteria gained free access to the gelatine. After a moment both specimens were again covered at the same time. The bacteria were then allowed to develop in the gelatine for twenty-four hours or more, when they formed colonies; and it could be observed with the naked eye that a many times larger number of bacteria fell into the dish placed under the belly of the cow than into the one placed farther away.

If this experiment is made in a stable filled with cows, the infection arising from the body of the cows will be shown still more plainly, as the cows are then far more infected by bacteria than in the free air. It is important in experiments of this kind in the stable to place the dishes at the same height from the floor, as there is a considerable difference between the bacterial contents of the upper and lower layers of the atmosphere in a stable. If the directions given are followed it will be found, as in my experiments, that although a goodly number of bacteria will fall into both plates, the sample placed under the udder will contain a much larger number of bacteria than the plate placed a little away from the cow.

These experiments show the truth of the fact known long ago, but often overlooked, that it is very important to keep the skin of the cows as clean as possible.

Importance of Proper Bedding.—The first point to observe in this regard is to provide the cows with bedding of dry, clean straw. The cows are often left to lie in manure and other filth—a condition which nullifies all precautions taken later on. Remnants of manure, etc., may be seen by a microscope in the milk from cows taken fairly good care of.* What an abundance of such filth and of the bacteria always prolific in such environments must there not be found in the milk from stables where uncleanliness of this kind reigns supreme.

Relation of Grain-raising to Cleanliness in the Stable.— In days gone by, when the production of grain was the most important system of agriculture practised, there was an abundant supply of straw on the farms, and plenty could be used as litter for the cows. The fact that the feeding was not as intense as now also made it easier to keep the cows clean. The feed consisted mainly of hay and straw, and produced a dry, only slightly offensive manure. Now, on the other hand, there is only a limited supply of straw on the farms, and the high feeding practised makes it considerably harder to keep the cows clean, as it makes the dung watery and of a very offensive smell. In our days, when the demands for cleanliness in the stable are becoming more and more strict, the farmer has therefore greater difficulties to overcome in trying to fulfil these demands, at the same time as he often has lost the best remedy previously at his disposal to reach this end. The explanation of the above-mentioned fact that a large number of dung and food particles and other impurities may be found by a microscope even in strained milk from comparatively well-kept cow-stables, doubtless lies here. The danger to the keeping qualities of the milk from this source arises from the fact that these particles are carriers of a considerable number of bacteria. I have repeatedly observed that a large number of spore-bearing bacteria

* See Gripenberg and Grotenfelt: Illustrations of Cows' Milk, Cream, etc. (Afbildningar af komjölk, grädde m. m.), Helsingfors, 1889, p. 11, Fig. VIIa.

and free spores were found on the contaminating particles in milk fresh from the cow, while such ones did not appear to any appreciable extent in the milk itself. After some time the impurities showed a far smaller number of bacteria than before, while the milk itself teemed with them; the milk may therefore be infected even from the impurities introduced in the same.

At the same time as I made these observations I found micro-organisms and spores outside of the milk of exactly the same kinds as those found on the impurities of the milk, viz., in the manure remnants which had had a chance to remain for a time in the warm and moist atmosphere of the stable, and thereby became the seat of a luxuriant bacterial growth, and also in the dirt on the skin of the cows, where the bacteria may develop rapidly, greatly benefited by the animal heat and moisture.

Impurities in the Milk.—As the impurities which get into the milk even during the milking itself play such an important part in the infection of bacteria, it is important to learn their origin. The microscopic examination gives a good indication of their origin. I have found the following kinds of impurities in *unstrained* milk fresh from the cow:

1. Manure-particles (numerous).
2. Fodder-particles (which have not passed the alimentary canal of the animals).
3. Molds and other fungi.
4. Cow-hair (numerous).
5. Particles of the skin.
6. Human hair.
7. Parts of insects.
8. Down from birds.

9. Small wooden pieces, shavings, and pieces of fir-leaves.

10. Woolen threads.

11. Linen threads.

12. Soil-particles (rather frequent) and moss-particles.

13. Fine threads (most likely cobwebs), etc.

In these investigations I also found several impurities in the milk whose presence I was unable to explain, as, e.g., cheesy lumps, slimy substances with a firmer nucleus, shining, fat-like bodies, fine floss and grains, and similar matters. As regards the liquid impurities appearing in the milk, it need hardly be mentioned that they cannot be detected by microscopic examination.*

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* The quantities of solid impurities in milk have been determined by Renk (*Münchner Med. Wochenschr.*, 1891, Nos. 6 and 7; *Centralbl. f. Bact.*, **10**, 193), Schulz (*Arch. f. Hyg.*, **14**, 260), Vogel (*Ber. Ges. Verh. v. Nürnberg*, 1891, 78), Uhl (*Zeitschr. f. Hygiene*, **12**, 475), and Ostermayer (*Inaug. Dissert. Univ. Halle, 1891*). Renk examined ninety samples of market milk and found the following average quantities of impurities (mainly dung particles) in the milk of the cities given. The fresh substance is calculated on basis of an 80-per-cent water-content of the impurities:

	Leipsic.	Munich.	Berlin.	Halle a. S.
Dry substance, milligrams per liter	3.8	9.0	10.3	14.9
Fresh substance, " " "	19.0	45.0	51.3	74.6

The maximum quantities of impurities were found in case of a sample of Halle milk, containing 372.5 milligrams of fresh impurities per liter (nearly 6 grains per quart).

Schulz determined the quantities of microscopic impurities in Wurzburg milk, as sold in the city (I), as bought in the country (II), and as milked into a glass jar (III):

	I.	II.	III.
Dry substance, milligrams per liter.................	3.0	1.7	2.3
Fresh substance, " " "	15.1	8.6	11.5

The milk in case of I and II was strained through a fine gauze

It is natural to suppose that a good many of the contaminating particles mentioned above came into the milk through the litter used ; this may thus both indirectly and directly contribute to the infection of the milk. Proper litter must not only form a good bed and quickly absorb the liquids, but must also as far as possible be free from dust and all kinds of soil particles, fungi, etc. We often find litter in our stables, however, which does not come up to these requirements. I may mention as an example that in several places where the generally excellent peat dirt has been introduced they have neglected to remove its dust particles as directed. As a result I have found large quantities of humus and sphagnum particles in the milk from farms where this practice was followed. I have also found fungi of all kinds in the milk from a stable where the fodder and straw litter were impure and moldy owing to bad weather during the harvest. The milk from a farm where they used pine leaves as a litter was found very impure, especially from manure particles, an observation which would indicate that this material, which also for other reasons is undesirable, ought not to be used as litter on dairy-farms. The sample of milk mentioned last also contained large masses of molds.

The Flooring of the Stable.—An improper floor may also be the cause of infection of the milk, as may appear from the fact that the sample of milk which proved most filled with soil particles in my investigations came from a farm where the floor in the stable consisted of bowlders

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strainer. Vogel found 12.9 milligrams dry impurities per liter of Nürnberg milk, and Uhl found 19.7 milligrams per liter of Giessen milk (average results). See also *Milch-Ztg.*, 1895, p. 634 ; *Exp. Sta. Rec.* VI, p. 342 ; and IX, p. 805.—W.

partly covered with clay. At the front feet of the cows this was usually dry as powder and dustlike, while in the back of the stall it was solid and moist. At milking the cows often stamp their front feet, and it is highly probable that the milk in this way became filled with soil particles.

Cow Stalls.—A too long stall may indirectly be the cause of infection of the milk. The hindquarters of the cow will, under this condition, be soiled by the manure when she lies down. This is especially the case with the tail, to which particular attention must always be paid in cleaning the cows. The cow will often swing her tail during the milking, and if it is soiled, filth will of course be spread to all sides. I have found that the milk may in this manner be mixed with dirt of the most offensive kind. At a farm where the stalls were too short, and where there was no litter in the liquid-manure gutter, the cows' tails were always wet and dirty; when the cows lay down their tails lay in the gutters, which did not thoroughly drain off the liquid manure. Although the gutters were new holes and recesses had already formed in them, in which the urine and liquid manure remained and formed pools. By applying wooden shavings in the gutters the difficulties mentioned were later on avoided. The cows could then be kept clean, and the milk became as a consequence cleaner, and kept better than was previously the case. I have met with liquid-manure gutters of even worse defects than the ones described in a large number of stables in our country.

On another farm, considered a dairy-farm *par excellence*, all the stalls were too short for the large fine cows, so that the hind quarters and the tails always lay in the low gutter; the udders of a number of the cows were also dirty. What made the matter still worse was the fact that the stalls were lower than the barn-yard outside, where the manure-heap was placed. As a consequence the liquid-manure gutter was always full of urine. Only a couple of months after the herd came in from pasture, these sad conditions had conquered all the efforts of the farm-hands to keep the animals clean to such an extent that the hind quarters and parts of the udders were covered with a thick manure-crust, and the tail formed one solid, sticky mass. How impure the milk from this farm must have been may easily be imagined. I cannot give any exact data to what extent it was mixed with impurities, as I was not able to examine it closely; but, judging from the large quantity of slime gathered in the separator bowl when the milk was separated, it was as one would expect from its antecedents.

Conditions similar to those given above, although not carried to such an extreme, may be found on other of our "dairy farms"—i.e., on farms where they try, at least in the stable, to maintain a high standard of cleanliness. What can then be expected of the cow-stables in the places where they do not try at all to follow the fundamental principle of modern dairying—strict cleanliness? The poor animals are kept in such places in undisturbed peace throughout the winter, uncarded and uncleaned; they are furthermore often confined in darkness for several months, as the very small windows are often wholly snowed or frozen over. Cow-stables where such bad conditions exist are still found in many places; and still people wonder that the milk coming from these primitive stables is of poor quality, and that the products made from it do not keep well.

We saw in the preceding what a microscopic examination of such milk would reveal. It is perhaps not possible to express through exact figures how such milk compares with milk from well-conducted farms as regards the quantity of impurities which they contain, but by a very simple examination everybody possessing a microscope—a very cheap one will do—may satisfy himself that the difference is very large.* In the milk produced on farms where strict cleanliness is observed, the contaminating particles are not only far less numerous, but also of another kind than in the milk from poorly-kept stables. It may of course happen that considerable quantities of fodder particles may be found in the former kind of milk; but with a few exceptions these have not passed through the animals, and are therefore not so well suited to being hotbeds for the development of bacteria as the numerous manure particles in the latter kind of milk. The milk from a poorly-kept farm also contains a much larger number of spores of bacteria than milk from a well-kept farm. In extreme cases it is possible to tell these two kinds of milk from one another without a microscopic examination, since the more viscous and slimy milk from poorly-kept farms will pass through a fine strainer much more slowly than milk produced on carefully-conducted farms.

Importance of Keeping Cows Clean.—The importance of carefully carding, brushing, and cleaning the cows is

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* Renk (*Münchner Med. Wochenschr.* 1891, Nos. 6 and 7) found the following quantities of solid impurities in the milk from different farms around Halle,—viz., 2.9, 7.3, 7.5, 9.4, 17.9, 37.2 milligrams per liter (quart) of milk. He says that the high content of impurities in Halle milk is due to "insufficient inspection, the feeding of roots, and the use of peat for bedding."—W.

apparent from the investigations reported. If the skin is smooth and shining, even a little uncleanliness is easily discovered, besides which a cow well taken care of does not lose her hairs so often, and they are not so loose that they easily rub off during the milking.* In cleaning a cow we ought not to have our attention mainly directed to the upper parts of her body, as is usually the case; but her lower parts must first of all be kept properly cleaned, since it is from these parts that hair and other impurities preferably fall into the milk.

If the more tender lower parts of the cows cannot be carded, they must be brushed and washed so much the more frequently. The tenderness of these parts will, however, disappear as the cow becomes accustomed to their being cleaned. If these parts of the bodies of the animals are badly soiled, they can only be cleaned again with a good deal of trouble, through repeated moistening and washing with soap and water. If it becomes necessary to wash the udder it should be done rapidly, and the udder must then be well dried with a dry rag, as it will otherwise easily take cold if exposed to draught, etc.

In summer-time the cleaning of the cows is often neg-

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* Aside from the purely bacteriological aspects of the question there is a no less important advantage in carding and brushing cows in the resulting increased feeling of well-being of the cows, which may find expression in a larger production of milk and fat. Dietzch ("Die Kuhmilch," p. 21) states that "it has been found by experiments that cows kept in a clean condition gave, on an average, 1 liter (quart) of milk daily more than the same cows in a dirty condition. Backhaus (*Journal f. Landwirtschaft*, 41, 332–42) also found an appreciable increase in the milk-yield of cows on two different experiments. Cf. the German adage, *Gut geputzt ist halb gefüttert* ("Well cleaned is half fed"). See also Backhaus, *Milch-Ztg.*, 1895, p. 634.—W.

lected in the belief that they keep themselves clean in the pasture. It is, however, easy to satisfy one's self that it is both useful and necessary even then to brush them occasionally. The udders and bellies of the cows are easily soiled by dust, dirt, and the like, which is fastened loosely in the skin, and by the milking shaken down into the milk. In this connection I want to tell our farmers that they ought not to think too much of the trouble of driving the cows from the pasture to some neighboring lake or stream to bathe, where any such is at hand. The cattle gain not a little in general health thereby, and their bodies, and above all the lower parts, in that way get a thorough washing. In our land, rich in lakes, such summer baths might be given the cattle much oftener than is now usually the case.

Even if all due care is taken in regard to the cleaning of the cows it is always necessary just before the milking to give the udder and its surroundings a further brushing, to remove all dust and filth, which otherwise would fall into the milk. It will not do to excuse the neglect of this act of cleanliness by saying that the milk will be strained and the dirt thus be removed from it anyway. First, a large portion of the impurities is so finely divided that it is not arrested by the strainer; and, secondly, the short time elapsing between the milking and straining is often sufficiently long to allow large numbers of bacteria to be washed from the impurities and to begin multiplying in the milk. The udders must not remain wet, as in such cases bacteria and dirt would accompany drops of water which may fall down, and would infect the milk. The parts mentioned ought, on the other hand, to retain some moisture, as dust and dirt particles possibly remaining will then not so easily be shaken down.

Cleanliness in the Milker.—The milker must be aware of the fact that he may spoil the milk by untidiness and carelessness. He himself must be cleanly, should wear neat clothes and a clean apron.

In what contrast to this, as it would seem, simple rule is the manner in which our milkers usually appear in the cow-stable. It seems to have become almost a tradition that the farm-hands may be dressed carelessly and slovenly while doing their work, and in most places the clothes are the same for all kinds of work done in the barn. They often go to the milking in the same costume and with the same unclean hands as to the cleaning of the stable. And we often see that the milkers as they get out of bed in the morning go unwashed and unkempt to the milking, dressed in the most ragged and dirty articles of clothes in their possession. It is certainly strange that such carelessness is allowed to pass unnoticed on most farms.

In this connection attention may properly be called to the unfortunate condition that clothes especially used for the work in the barn in many places are kept day after day in the cow-stable; they are never aired or washed,—a fact which is but too plain from their offensive smell. It is almost impossible to calculate how much mischief such dirty articles of clothing may cause in regard to both the health of the milkers and the taste and keeping quality of the milk. Such "small matters" often give a clue to diseases of the milk, of which many complain without understanding their cause. One condition of getting rid of these diseases is therefore that the clothes of the milkers be made of wash-goods, and that they be often aired and washed. The milking is certainly so important that due attention ought to be paid to all circumstances in connection with it.

The observation of constant and strict cleanliness and the wearing of proper clothing on the part of the milkers would furthermore help to raise their moral and social standing. Here is not, however, the place to dwell on this side of the question, and I shall only call attention to the motto at the beginning of this part, which expresses what the Swiss think about this matter.

Wash-water for Milkers' Hands.—The milker must be particularly careful to clean his hands previously to the milking. They may easily come in contact with the milk during the milking, and thus cause a direct infection. After having milked a cow he ought to carefully rinse his hands in clean water.* I have found a bad practice in this line in many places—viz., that the water used for washing the hands is not changed; no

* This may seem an unnecessary precaution to many, but at least in case of sick or diseased cows in a herd the direction given should be strictly followed. Nocard and Mollereau (see Bang, Report 14, Copenhagen experiment station, 1885, p. 15) have called attention to the fact that the milker may often be the cause of carrying contagion from one cow to another. They give the following experience: "A cow was sent to Paris by rail and as she came from the car she was milked by a milker from a neighboring stable, where inflammation of the udder for a long time had appeared. Hardly six weeks after she had been placed in a previously healthy herd it was noticed that her udder was caked; the milk became unsalable, and the disease soon spread to the majority of the other cows in the stable. It was ascertained that the disease did not appear in the stable from where the cow came."—W.

matter how many the milkers and cows are, the same, and often scant supply of water has to do service for all throughout the milking. It is natural that bacteria in this way will accumulate in the water, and that the washing will do more harm than good. The practice which some persons have of dipping their fingers into the milk during the milking, in order to give them the desired degree of moisture, is nothing short of horrid.

Milking with Wet Hands.—The milking ought in no case to be done with wet hands—a custom so common that we even sometimes hear it asserted that it is impossible to milk with dry hands. This is, however, not only possible, but far more, an absolute necessity. Milking with wet hands cannot be a clean operation, a Danish author says, and correctly; for even if the teats are wiped dry and cleaned in the most careful manner they are not so clean but that the hands of the milker, if wet, may be soiled by touching them.

Manner of Milking.—The milking is with us usually done in the way that two fingers, or at best the whole hand, is made to press along the teats, and the milk is thus driven out of them. This method is, however, to be rejected. The strong pulling on the teats is not agreeable to the cows, and may even give rise to cracking and diseases of the udder. The milk is not formed in the teats, and the elaboration of the milk is not therefore forwarded by stretching them. Only by a deliberate and quiet pressure of the milk out of the teats and an irritation of the lower part of the udder can a complete clean-milking be obtained, and at the same time the secretion of milk will be promoted. The method of milking common with us ought to be rejected for the further reason that it contributes greatly to the infection of the milk. As the fingers rub down along the teats they loosen and pull into the milk all the dirt which was not removed by the washing of the udder. The hands of the milker furthermore often come in contact with the milk by the strong pulling of the teats, and dirt adhering to the hand may thus be washed into the milk-pail. If dairy products of the highest quality are wanted, this method of milking must therefore be done away with, and the milking performed in a way similar to the following given by a Danish writer:

"Take hold of the udder with the whole hand, so that the small finger will be held just so low that the stream of milk coming from the teat cannot wet the finger or the lower part of the hand. The hand is then lifted, opening it at the same time so that it takes hold of the teat very loosely, with a quick but soft pressure, and is then lowered so far that the teat is stretched just to its natural length. At the same time as the hand is brought downward, begin to press the teat from above downward, and end with squeezing the milk out with an increasing pressure of the whole hand. This pressure, with a soft push into the udder, is a splendid means of emptying the udder. The movements must not be violent, however, but soft and at the same time as energetic as possible. Finally, when only a little milk remains in the udder, the milking is continued in the same manner, only with the difference that the hand is entirely loosened from the teat every time it is carried up toward the udder, and the lower part of the udder is held by the thumb on one side and the other fingers on the other side; the udder is then given a couple of soft pushes, and the milk pressed out in the manner given."

The picture in the text, taken from *Ugeskrift for Land-*

mänd for 1890, from which the above quotation is taken, shows the proper position of the hand in milking. The milk ought to be pressed out of the udder in regular uninterrupted streams, so that it may be exposed to infection for as short a time as possible, this being especially threaten-

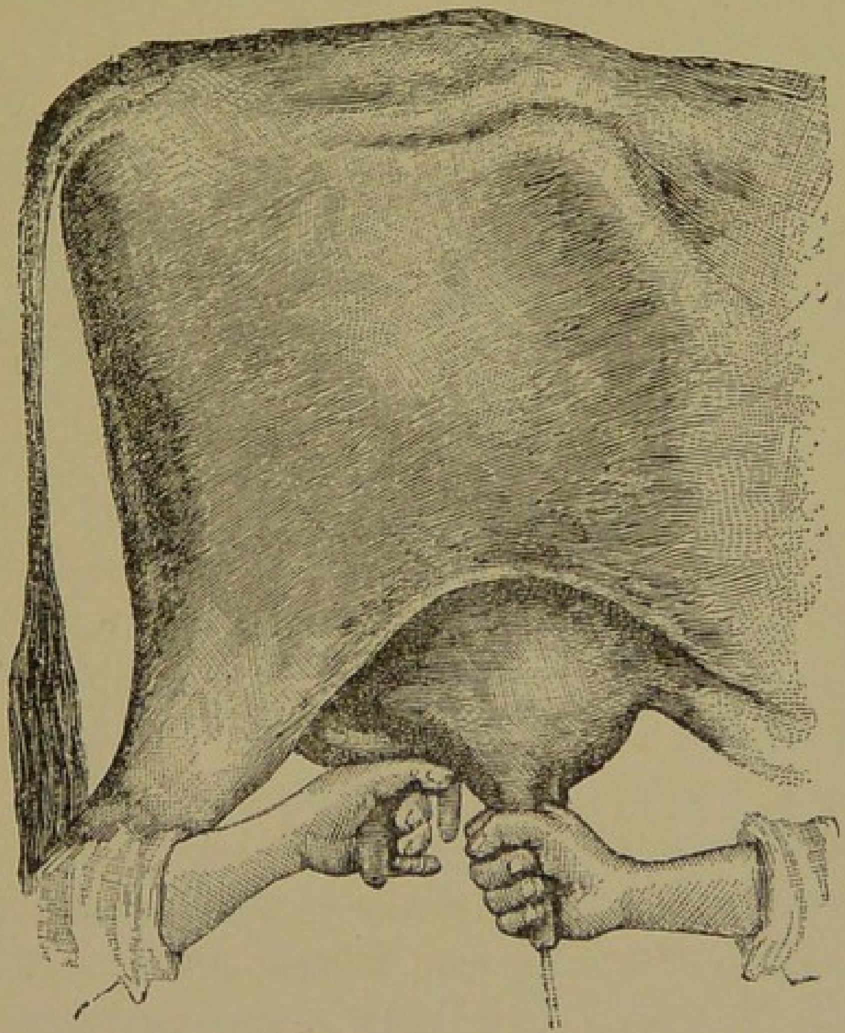

FIG. 19.—PROPER POSITION OF HANDS IN MILKING.

ing when a fluid comes in contact with the air on a large surface.

The milker must always be quiet and deliberate in his movements in the stable, and on approaching a cow ought to speak gently to her. If the cow is disturbed by knocks and pushes, as is often the case, she becomes impatient and nervous during the milking. She moves from place to place, shakes herself, and lifts her feet, movements which set legions of infectious germs in motion in the immediate neighborhood of the milk. If the cow is restless during the milking the milk-pail may also easily be kicked over, and dirt and filthiness of all kinds may be thrown into the milk. Quiet and deliberate manners in the milker are therefore an advantage even in regard to the preservation of the original qualities of the milk to the largest extent possible.

Usually the teats are moist after the milking is over on account of the irritation of the skin, splash, etc. If this moisture remains, something like a membrane is formed around the teat; colonies of bacteria quickly develop in this moist and warm membranous covering. The teats ought, therefore, to be wiped off after the milking is finished.

Abnormal Milk.—The milker should closely observe the appearance of the milk during the milking, to see whether it is normal when drawn. If it has an unusual appearance it should by no means be mixed with the rest of the milk. We sometimes find that the milk from sick cows is bloody, filled with cheesy particles, or otherwise abnormally changed. When milkers meet with such milk they often quietly mix it in with the rest of the milk if its abnormal qualities are not very strongly marked. In this way large quantities of milk may be infected, and if the temperature is favorable for bacterial development, accidents may take place. If the milk, on the other hand, looks very bad they usually pour it out on the stable-floor. This method is of course objectionable. At many places this milk is fed to swine in the hope that these omnivorous animals are not so particular and so receptive of contagion. It is doubtless a fact that one of the reasons for the wide distribution of tuberculosis may be sought here.* All abnormal milk ought to be removed from the stable and destroyed as soon as possible.

Milk from Tuberculous Cows.—The most common form of diseased milk with us, which is abnormal when drawn from the udder, is that from tuberculous cows. Such milk should not be used without being freed from its infectious qualities, above all where tuberculosis of the udder is present. In the first stages of tuberculosis it is very hard to prove whether the milk has an abnormal composition or not without delicate bacteriological examinations; it still has the color and appearance of ordinary milk, and the number of tubercle bacilli in the same is comparatively small. But as the disease develops, the abnormal condition of the milk can more easily be discovered with the naked eye. Even when the disease is in its earlier stages the milk assumes a somewhat yellowish color. Later on it grows thinner and less viscous, and a large number of slimy, cheese-like lumps may be discovered in the same. The color finally turns entirely yellowish brown.

We are often able, even in the earlier stages of tuberculosis, to tell the abnormal condition of the milk from the fact that such milk does not show an amphoteric reaction, but is alkaline—a feature which is of course the more characteristic the farther the disease has progressed.†

* Bang states (Bull. 4, Copenhagen experiment station, 1885, 22) that at a Danish creamery where centrifuge slime was fed to swine, all of these proved tuberculous, and warns against the use of slime for this purpose without its being previously boiled or heated toward the temperature of boiling water. The prevalence of tuberculosis among swine in certain parts of Germany has been attributed to this system of feeding. (See Fühling's *Landw. Zeitschrift*, 1893, p. 779; 1894, p. 400; *Milch Zeitung*, 1893, p. 672).—W.

† *Amphoteric Reaction of Milk.*—When drawn from the udder

According to Bang, tuberculous milk coagulates at 75°–85° C. In regard to tuberculosis in cows, it may further be mentioned that not all glands in the udder are necessarily attacked by the disease at one time. The milk in the sound glands has in such cases been very rich in fat, and reminded one of cream in its appearance.*

milk will as a rule turn red litmus paper blue and blue litmus paper red, i.e., give both an acid and an alkaline reaction. This double reaction is explained by the presence of normal and acid alkaline phosphates and carbonates in the milk (Soxhlet). On standing even for a short time, normal cows' milk has always an acid reaction.—W.

* The subject of bovine tuberculosis has been much discussed of late among dairymen in all parts of the world, and its importance has hardly been overestimated. The complete eradication of the much-dreaded disease in our country is one of the great dairy problems of the age. Fortunately we have in the *Tuberculin* test a ready and but rarely-failing means of discovering the disease even when it is in its early stages. Breeders of dairy stock are now beginning to sell their stock on a guarantee of freedom from tuberculosis, as shown by the test, and dairy-farmers in buying new stock should insist on such a guarantee—in justice to themselves as well as to their customers.

Dairymen suspecting tubereulous animals in their herds should not fail to isolate suspicious cases at once, and to call in a skilled and careful veterinarian to make the test. For a preliminary examination of the cows the following schedule of manner of procedure adopted by Danish veterinarians may be of service (see Woodhead, "Bacteria and their Products," 1891, 225).

a. "First of all the submaxillary glands are examined; these are easily felt, and any change is readily made out.

b. "The glands at the root of the neck and those in front of the haunch bones are always carefully examined. The glands in the flank should be equal in size—about the size of the middle finger, and not hard. Mere enlargement, however, even when considerable, is not looked upon as of great importance if it is perfectly equal on both sides.

c. "The animal is made to cough by means of pressure on the

Milk from Inflamed Udders.—Another form of diseased milk which is also abnormal when drawn is that produced

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windpipe, and the lungs are carefully examined during and after the coughing. The condition of the skin over the flanks is carefully observed; it should in a healthy animal be 'loose,' like that of a dog, soft and pliable; any adhesion, hardness, or harshness should be carefully noted.

d. "The udder is carefully examined for inequality of size or for any induration. It is a somewhat curious fact that tuberculosis disease usually affects the hind quarters of the udder, which becomes hard and knotty, but not painful; while in acute inflammation of the udder the anterior quarters are quite as much affected as the posterior; the pain is usually very acute, and the process is accompanied by much more marked febrile symptoms.

e. "Then the glands above the udder, high up between the quarters, are most carefully examined. In cases of tubercular disease of the udder these glands are invariably affected, are unequal in size, and the large one, corresponding to the affected quarter, is usually considerably indurated.

f. "Careful auscultation is carried out at least once a month, the fore foot of the side that is being examined being always well advanced. The normal expiration-sound lasts half as long as the normal inspiration, and if this rhythm is deviated from in any way, a further and thorough examination of the lungs should always be made.

g. "The examination is continued still further if the slightest suspicion of tubercular disease is aroused by the above investigation. . . . In case of suspicion the milk from that animal should not be put into the milk-supply, but is either thrown out or, after being most thoroughly disinfected by prolonged boiling, is given to the pigs."

Prof. Nocard, of Alfort Agricultural College, France, who has made a special study of this subject, in a recent publication gives the following directions for manner of procedure in case of the appearance of tuberculosis in a herd (*L'Industrie Laitière*, **19** (1894), p. 144):

"The diagnosing power of tuberculin is at the present time admitted by all authorities. By its application it is easy to prevent the by cows suffering from inflammation of the udder—a disease which is not transferable from cows to man, as tuber-

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spread of tuberculosis in cattle. In all cases where tuberculosis has been found or is suspected, all animals in the herd should be injected with tuberculin ; and those giving the characteristic reaction must at once be separated from the sound ones, and a thorough disinfection of the stable must take place. It is not necessary to sacrifice the diseased cows immediately; their milk may be utilized AFTER HAVING BEEN BOILED, and they may be prepared for the butcher, so that the owner may realize as much as possible on them. The disease having been taken in its beginning—at least in case of the greater number of animals—they fatten easily, and the loss resulting from sacrificing them prematurely will thus be reduced to a minimum. Delivered to the butcher at the proper time their lesions will be insignificant. [Tubercle bacilli very rarely appear in the flesh of animals, and even if such should be the case the bacteria, according to the consensus of authorities on the subject, are easily killed by simply boiling.—W.]

"The essential point to be observed in all cases is to remove the diseased animals from the healthy ones, and to exclude them mercilessly from reproduction. If the young animals escape infection the renewal of the herd will not be endangered, and the void will be filled in the courae of a couple of years. When I have applied tuberculin injections I have always assured the owners that the young stock which proved healthy would remain so in the future provided they were separated from the diseased animals; and experience has always confirmed the correctness of this prevision.

"It is only necessary to go over a herd once with the test, if the directions given have been strictly followed ; no new animals should be introduced into the herd before having been subjected to the tuberculin test.

"Thanks to this simple method, the owners of the animals can with little expense and without relying on governmental aid, free themselves from the heavy tribute annually paid to tuberculosis.

"Everybody knows, but it is well to repeat it, how dangerous culosis, but, to make up for it, is the more contagious for cows. As in case of tuberculosis it is caused by bacteria, and has frequently been the cause of large losses. We may here only recall the great damage which it caused in Holstein, 1873–78, where, e.g., at the estate "Stendorf" the whole herd of 200 milch-cows was attacked. As an example of the extremely contagious nature of the inflammation of the udder, the following may be cited: During the epidemic mentioned, the dairyman at Stendorf was once called to a remote farm where inflammation of the udder had never yet appeared, in order to assist in a hard parturition case of a cow. Six days after his visit the first case of inflammation of the udder was observed at the latter place, and before long six of the nine cows on the farm were attacked. The dairyman had doubtless brought the bacterium causing the inflammation to this farm. Milk from cows attacked by this disease may be recog-

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tuberculosis is to human life. In banishing the disease from the cow stables we banish one of the causes of its spreading among the human race."

The following experiment-station publications have been issued on the subject of tuberculosis in American cattle:

Ala., b. 67; Ark., b. 57 and 63; Conn. (Storrs), b. 19, reports 1898 and 1899; Me., b. 13 (S. S.), reports 1890 and 1898; Mass. (Hatch), b. 8, 27; Mich., b. 184; N. H., b. 78; N. J., b. 101; N. Y. (Cornell), b. 65 and 82; N. D., b. 14; Ohio, b. 108; Penna., b. 21; S. C., b. 50; Texas, b. 40; Utah, b. 41; Vt., b. 42; Va., b. 26, 32, and 39; Wis., b. 40, 78, and 84; Canada (Ottawa), b. 20.

See also Report on Tuberculosis in Ontario (Bryce), Toronto, 1894; *Veterinary Magazine*, 1894, pp. 12 and 527; Annual Reports of Bureau of Animal Industry, U. S. Dept. of Agriculture.—W.

nized among other ways by its appearance, it being thick, slimy, and mixed with lumps.*

"**Diseased Milk.**"—It is fortunately still rather seldom in this as well as other northern countries to find the milk which is in any way abnormal when drawn from the udder. Creameries troubled with "diseased milk" are, however, often mentioned in our agricultural literature, and creamerymen usually account for the poor quality of the butter produced by this reason. Milk which is abnormal when drawn may occasionally appear also on our farms, but generally the diseases of the milk met with in our creameries and dairies have arisen because the milk has been subjected to a careless treatment after having been drawn. Many dairymen try to hide their own faults and carelessness by speaking of diseased milk, in the same way as persons who do not understand their business generally lay the poor results obtained to faults in the material or the tools.

Light in Cow-stables.—If the preceding directions of strict order and cleanliness during the milking process and in all manipulations on the farm are to be followed, it is absolutely necessary to have sufficient light in the stables, especially during milking-time. Most of our stables leave, however, much to be wished for in this respect. This is true not only of the previously mentioned dark, prison-like cow-stables so often met with at our smaller farms, but also of many farms run in a rational manner. It is of great importance to have sufficient light in the cow-stable, not only for the reason that the larger number of bacteria, and

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* See Bang, "The Causes of Inflammation of the Udder in Cows," 14th Report, Copenhagen Experiment Station, 1889, 38 pp.

those most injurious to the dairy business, thrive best in darkness, as we shall refer to later on, but it is impossible to clean the cows properly and to conduct the milking properly in a dusky stable. The cow-stable must be liberally supplied with clean windows, and in winter-time it must be so arranged that the stable shall be sufficiently lighted morning and evening. If we step into one of our common cow-stables on a winter evening at milking-time, we shall often be surprised to note how the milkers have to grope around in darkness while they perform their important work and handle a material so delicate and easily contaminated as is milk. Under such conditions it is not strange if part of the milk goes outside the milk-pail instead of into it, and that the cows are not always clean when the milking begins. It is therefore an absolutely necessary condition for the production of milk that will keep well that the light in the cow-stables be improved; every milker ought, furthermore, to be supplied with his own bright shining lantern.

Air and Bacteria.—As already mentioned, the impure air in the stable is one of the main causes of bacterial infection of the milk before it leaves the stable. There is no difficulty in proving this bacteriologically. The fact is apparent from the experiments above given made in the stable and in the open air, concerning the bacterial infection from the udder and its surroundings (p. 28). Hesse states in his account of the quantitative determination of the micro-organisms of the air, that he found not less than 120 bacteria and molds in a liter (quart) of air in a common cow-stable, while the same quantity of air in a dusty schoolroom, from where the pupils were just hurrying out, contained only 80 such micro-organisms. It has been found by scientific investigations that bacteria do not multiply in the air; they lack there the moisture so essential for their development. The air can therefore be filled with bacteria only by the drying and subsequent reduction to a powder-like dust of fluids and other media where these organisms are found, the dust being later on set in motion by currents of the air. The bacteria of the air are thus closely connected with the dust, and appear most numerous in air where a good deal of dust is set in motion. When the air is not stirred, both bacteria and the dust will of course sink to the ground or the floor. It has been found that the air in a closed living-house, when left undisturbed will become free from bacteria, in one to two hours.

During the hot season the outside air contains most bacteria, while during snowy winters it contains very few such in our climate. In the atmosphere of cities considerably more bacteria are usually found than in the air in the country. On high mountains and out on the sea far from land, or deep down into the earth, the air seems to be sterile.

Importance of Pure Air.—It is evident that the air in a cow-stable must be highly infected with bacteria a large portion of the day, it being usually in strong motion and an enormous number of them being scattered at feeding-time. As the bacteria obey the law of gravitation they are of course, as we have seen, most numerous in the lower layers of the air, i.e., just where the milking takes place. The bacterial content of the atmosphere in a stable varies, however, greatly at different times of the day, as I have often had an opportunity of proving in my investigations. While a sterilized gelatine plate placed in the stable immediately after the feeding within two minutes became seeded with innumerable bacteria, a similar plate placed at exactly the same spot two hours after the feeding and the cleaning in the stable was done, did not become greatly infected with bacteria during ten minutes' exposure. This shows plainly that it is possible to considerably decrease the infection of the milk through the air of the stable. It is only necessary for this purpose that chores which contaminate the air be done with the greatest care, and not performed at the time of or shortly before milking.

Time of Feeding. On many farms it is the custom to feed the cows directly before or during milking. The intention is to direct the attention of the cow away from the milking, or to induce her to stand quiet during the process. It is, however, apparent that it is not natural for a cow to eat while she is being milked, from the fact that she stops eating when the calf begins sucking her, and that she never grazes in the pasture while the milking takes place. I do not believe that feeding immediately before or during the milking tends to keep the cow quiet. But even if the method should bring this about, it is nevertheless to be rejected. Feeding directly before or during the milking leads largely to a contamination of the milk, especially when the cows are fed coarse fodders.* Masses of dust with accompanying bacteria are set in motion during the feeding. Hesse states that the air in the stable in his experiments contained so many bacteria and especially molds when the feeding took place that it was impossible to count them. In an instance where very rusty chaff and straw was fed in a stable I found the air

* See also Weigmann and Zirn, On the source of bacteria in milk, *Milch-Zeitung*, 22, (1893) 569; *Exp. Sta. Record*, V, p. 431, and *Molkerei-Ztg.*, 8, p. 371.—W.

almost filled with such micro-organisms. As might be predicted, it was easy to trace large quantities of them in the milk produced on this farm, where the milking and the feeding took place at the same time. The feeding in many places is also performed in a manner most favorable to the spreading of the dust, e.g., by being thrown down from the hay-mow through a chute.*

We then see that the quality of the milk will be greatly lowered by exposure to the dust stirred up when the fodder is brought into the stable and fed to the cows. The most typical bacteria in this dust seem to be *Bacillus subtilis* and non-peptonizing forms resembling it. The reason why these organisms are so common in the milk may doubtless be traced to this origin.

It ought furthermore to be remembered that cows like to take a quiet siesta after their meals, during which digestion may be allowed to go on undisturbed. It is therefore of much importance that some time—at least 1½ hours—go by after the feeding before the milking takes place. In this way the animals will be more at ease, and the danger from infection will be decreased.

Regular Cleaning of the Stable.—A vicious practice followed on many farms, which is perhaps more fatal than the unfortunate arrangement of feeding just mentioned, is that the manure is cleaned out during or immediately before the milking. It is not difficult to see that in cleaning out the stable a mass of small particles of dung will

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* Some feeds, such as turnips, cabbage, silage, etc., may furthermore be fed safely after milking, while if fed before or during milking they will give their peculiar flavors to the milk. Complaints of certain feeds tainting the milk have doubtless in many cases come from an injudicious method of feeding.—W.

be spread around in the air and fall down on the cows, on the clothes and hands of the milkers, in the milk-pails, etc. The fact that many of the worst enemies of the milk are included among the bacteria adhering to these particles makes the matter still worse. Within a short time some of them produce putrefactive fermentations in the milk, while others do not show their injurious effects until later on—viz., in the products of the milk. During their presence in the milk bacteria of the latter kind lie in a torpor-like inactivity, from which they do not awake until they find conditions more favorable to their growth ; they then obtain power to conquer other bacteria found in the same medium, and soon give rise to their special fermentations. It ought to be remembered that the longer the manure remains in the warm cow-stable, the richer it will be in bacteria, and above all in spores of bacteria, and therefore the sooner it is removed the better. On some well-conducted farms I have seen this rule observed so carefully that the manure has been carried away as soon as it falls to the floor, an arrangement which can be carried out cheaper than many persons think. If the principle taught cannot be so scrupulously followed, it is necessary to prevent as far as possible the infection emanating from this source by other precautions. The manure should be removed from the stable several times during the day, and it must be arranged so that a sufficiently long time will elapse between this operation and the milking.

Dangers of Infection from Fermenting Foods.—Another quite common condition on our farms which is deleterious to the quality of the milk is that fermenting or spoilt cattle-foods, etc., are kept in the stable or in its immediate vicinity.* The milk may easily be infected with very injurious bacteria from such hotbeds of fermentation.

Ventilation in the Stable.—As regards the air in the stable, it is of the greatest importance to avoid as much as possible everything that may tend to make it impure; the air must be kept fresh and pure by means of an effectual and well-arranged system of ventilation. The stable ought to be aired after each milking, and the cleaning of stable and feeding should not begin till after the milking.

In order that the ventilation be effective it is, however, essential that the air outside of the barn be purer than that in it, which in many places is not the case. Generally the surroundings of the cow-stable are not given the attention and careful inspection which they deserve.

The fear that the animals be exposed to draught must not prevent the airing of the stable, for draught can very well be avoided if the ventilation be arranged in a proper manner. The ventilation-valves of the stable ought always to be open except when the temperature sinks be-

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* The general use of silage as a food for dairy cows among American farmers makes this a most important point to us, which we cannot afford to overlook. In building a silo mere convenience in handling the silage is too often thought of, to the exclusion of considering the influence of the presence of a fermented cattle-food on the milk and its keeping quality. The silo is often built in a corner of the barn, and arranged so as to open directly to the stable, filling the stable air at all times with a strong silage odor. Silage, and especially corn silage, is one of the great adjuncts to modern American dairy-farming, but it is essential that it be fed judiciously, in connection with some dry coarse fodders, hay, corn fodder, etc., and that the feeding take place after, and not directly before or during milking.—W.

low 50°. Stables as a rule are kept too warm; the high temperature is not only not beneficial to the cows, but on the other hand is highly favorable to bacteria, the development of which takes place with far more intensity at 59°-68° than at 50°. By a proper system of ventilation air containing fewer bacteria will get into the stable, and the multiplication of the bacteria present will at the same time be delayed and decreased.*

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* To show more plainly that the demands made as regards the order of work in the stable are not impossible, the author gives a schedule for the day's work which is in conformity with the principles laid down. The schedule is not applicable to our American conditions, and is given here mainly as a matter of curiosity to show the amount of work and what length of day's work the European farm-laborer is asked to perform.

"4 A.M. Feeding. Cleaning out stable.

5 A.M. Cows watered. Stable aired.

5.30 A.M. The udders of the cows are cleaned and the milking begins.

7-8.30 A.M. Stable closed.

8.30 A.M. Feeding. Cows cleaned and brushed.

10-11.30 A.M. Stable closed.

11.30 A.M. Cows watered.

12 noon. The udders of the cows washed and the milking begins.

1.30 P.M. Feeding. Cleaning out stable; cows let out and stable aired.

2.30-4 P.M. Stable closed; bulls let out.

4 P.M. Feeding. Cows cleaned and brushed.

5.30 P.M. Cows watered; stalls carefully cleaned and stable aired.

6 P.M. The udders cleaned and the milking begins.

7.30 P.M. Distributing night-feed.

8 P.M. Stable closed for the night.

In making the schedule of work given, I have followed these main principles:

Delay in Removing Milk from Stable.—No matter how carefully the precautions given concerning the treatment of the milk are observed, the milk is always threatened with infection from many sources as long as it is in the stable. The fact that milk when drawn from the udder has a temperature highly favorable to the development of the bacteria, and that it is a splendid nutritive medium for the large majority of bacteria, makes the matter worse. It is plain therefore that the milk ought to be removed from the warm stable as soon as possible. On most farms in our country an entirely different practice is followed. When a cow has been milked or the milk-pail is full, the milk is poured into a large transportation-can, at the opening of which a strainer is placed. As this does not allow the milk to run through very quickly, and the opening of the can is usually comparatively small, the milk must be poured slowly from the pail. The milk is usually left in the can until the whole herd has been milked, and it is then removed from the warm, foul air in the stable. This manner of procedure is very deleterious to the quality

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1. The manure is to be cleaned out 1½ hours before milking-time.
2. The stable is aired every time it is cleaned.
3. The cows are watered before every milking.
4. The feeding takes place at least 1½ hours before milking.
5. The cows have a rest of 1½ hours three times a day, during which time the stable is closed.
6. The cows are cleaned twice a day; their udders and hind parts are washed before every milking.
7. The cows are allowed to exercise during the warmest time of the day.

If the feeding takes place even five times a day, the demands made in this respect may be satisfied. If the number of feeds is smaller, it is of course still easier to observe these principles."

of the milk. It is exposed to air filled with all kinds of contagious organisms, and is left to remain in the stable an hour or still longer; this is so much the worse since the transportation-can is often not perfectly clean. I am fully convinced that diseases of milk with us are most frequently caused by irrational methods of procedure like those mentioned. Fortunately it is very easy to change this method so that it becomes, if not perfect, at any rate far better. First of all, the milk must be removed from the stable as soon as possible. Further, the milk ought not to be strained in the stable, but in a separate room near by, where the air is pure and fresh, and where cleanliness is observed in the most scrupulous manner. Such a room ought to be found in connection with every cow stable. It must not be placed in the neighborhood of the manure-pile, and is to be provided with large windows, but may otherwise be built very plainly. It is a good plan to keep the basin for washing of hands in this room, so that this operation may be performed after each cow has been milked.*

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* Another reason why the setting or separation of milk should not be delayed more than necessary is that delay will cause a diminished yield of butter from the milk, making the skim-milk richer in fat. This has been shown by a number of experimenters:

(1) *For creaming by gravity processes:* by Fjord, 14th Report of Dairy Experiments, 1881, p. 24; Henry, Wis. Experiment Station Report II. p. 21; Wing. Cornell Experiment Station Bulletin No. 29; Babcock, Wis. Experiment Station Report VIII., p. 82; Hills, Vermont Experiment Station Report f. 1890, p. 100; Robertson, Canada Experimental Farms, 1891, p 89: Dean, Ontario Agricultural College Report 1891, p. 181 ; 1892, p. 219.

(2) *For centrifugal creaming:* by Fjord (loc. cit.) and by Adametz and Wilckens (Ldw. Jahrb. **21** (1892), p. 131; Exp. Sta. Rec. 3, p.

Straining the Milk.—As soon as the milk is brought into this room it ought to be strained through a fine strainer. By straining the milk in a room with fresh and pure air, a strong infection of bacteria is not only avoided, but the advantage is also gained that the milk is aired in the best manner. The animal odor of milk as drawn from the udder, which is so unpleasant to many, will not disappear to an appreciable extent if the straining takes place in the stable where the air is foul; the odor may, on the contrary, often increase by the milk being kept there for any length of time. In the fresh air of the milk-room the animal odor would, however, largely disappear.

The straining of the milk may cause germs of infection to be spread in the milk instead of removing them from the same—if, e.g., the strainer-cloth is not changed often enough, or if the wire strainer is not frequently cleaned. In such cases it will easily happen that the finest dust-like impurities remaining on the strainer are pressed downward by the milk running through, and that the bacteria found on the larger impurities are washed off. Actual trials have convinced me that this may happen and largely contribute to the infection of the milk. I spread some coarse soil strongly impregnated with bacteria on a fine strainer cloth and poured newly-separated milk containing only a small number of bacteria over the same. The

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652). The latter investigators, as it would seem, erroneously ascribe the diminished yield of butter in case of delayed separation to the *transportation*, instead of to the *delay in separation* incident to the same. Fjord showed that in the ice-setting system transportation gave even somewhat better results than mere delay for the same length of time. Delay caused a greater decrease with the ice-setting system of cream-raising than with the separator.—W.

bacteria in the milk were previously studied and found to be different from the characteristic forms in the layer of soil. After the straining the milk showed an entirely different appearance under the microscope than before. It now teemed with the same kinds of bacteria as those found in the soil. In a sample taken after the straining had continued for some time their number had, however, greatly decreased, and soon the strained milk contained the same kinds of bacteria as the unstrained milk, which plainly showed that the soil particles had lost their high bacterial content. By a bacteriological analysis of the layer of soil this proved to be the case, as this now contained only a very small number of bacteria. The strained milk was therefore far richer in bacteria than before the straining, and the keeping qualities of the milk were decreased by the straining process. We thus see that by carelessness in straining germs of infection may be scattered in the milk. The large impurities are removed from the milk in the straining, but the most dangerous components of these, the fermentation-starters themselves, are washed into the strained milk.

It is therefore very important to change the strainer cloth often during the straining; or, if a metal strainer is used, the operation should be changed occasionally by allowing steam or hot water to pass through the strainer in the opposite direction. The more unclean the milk the more frequently the changing and cleaning process should take place.

In my straining experiments it was also shown that the more violently the milk dropped on the strainer, the more the strained milk was mixed with fine soil-particles and cowhairs. The kind of strainer used also played an important part in regard to the quality of the milk strained. Milk of highest purity was not obtained by straining the milk through a good linen strainer-cloth, or by applying a fine wire-gauze strainer, but by placing the linen cloth on the wire-gauze strainer and allowing the milk to pass through them both. By changing the former as often as need be, the washing-down of bacteria from the filth remaining on the strainer will be limited as much as possible.

Hauling the Milk.—When the milk is strained it should as quickly as possible be removed to the dairy or creamery for further treatment. If the greatest care has been taken in cleaning the cans, in milking and other manipulations in the stable, the milk in the cans will be only slightly infected by bacteria. If the milk is left for a longer time in wholly or partly closed transportation-cans and allowed to retain its warm temperature, the fruits of all preceding efforts will be destroyed. The bacteria in the milk will in such case begin to multiply rapidly, and the milk will soon be as highly infected as if no precautions whatever had been taken in the stable. It is not yet possible at this stage to tell by test or smell that the bacteria have begun to start injurious fermentations in the milk; but the results will be felt in the manufacture of the milk.

If the creamery is near by the farm the milk ought at once to be hauled rapidly there, while in the opposite case it is necessary to take proper steps before the transportation to check the growth of the bacteria. The best means at our service for this purpose is to cool the milk.

Cooling the Milk.—If the cooling is conducted in the right way a strong current is started in the milk-can, so that the last traces of animal odor may disappear,* provided only that the can has not too small an opening. The cooling has, however, still more important results. If the temperature of the milk is lowered sufficiently, the development of bacteria will be completely stopped. The low temperature places these organisms in a torpid condition, during which they are unable to multiply or to bring about fermentations. A proper cooling of the milk will therefore greatly increase its keeping quality. By lowering the temperature to 45° F. (7° C.), satisfactory results may be obtained; but it is safest in all cases to cool to a temperature of 39° F. (4° C.).

If the milk is to be hauled to a creamery not too far away, where it will be immediately cooled further or separated, it is not necessary to cool below 50° F. (10° C.). At this temperature the activity of the bacteria is generally stopped, and the small increase that may happen during the short interval will not cause any damage worth mentioning, especially if the milk is protected from being heated during the transportation. Even a cooling to about 54° F. (12° C.) has often proved of great advantage.

The matter will, however, stand differently if the milk has to be hauled far, and if it is not protected from heating during the transportation. The cooling must then be

* It has been claimed that a simple aeration of the milk will have a beneficial effect on its keeping quality but this is erroneous, as shown by Cooke (Vermont Experiment Station Report 1892, p. 127) and Wing (Cornell Experiment Station Bulletin No. 39; Powell Aerator). Aeration *with* cooling, on the other hand, will increase the keeping quality of the milk; see Wing, *loc. cit;* Plumb (Purdue Experiment Station Bulletin No. 44); Hills (Vermont Experiment Station Bulletin No. 27); Armsby, Waters, and Caldwell (Pennsylvania Experiment Station Bulletin No. 20).—W.

considerably stronger. The most important point in the cooling of the milk is, however, that it should take place as quickly as possible. The object of the cooling is only partly reached if the temperature of the milk is not rapidly lowered to the degree which has been found preferable under the conditions of transportation present.

Coolers.—Several kinds of apparatus for the rapid cooling of milk are sold.* Lawrence's cooler is best known (Fig. 20). It seems to me, however, it exposes the milk

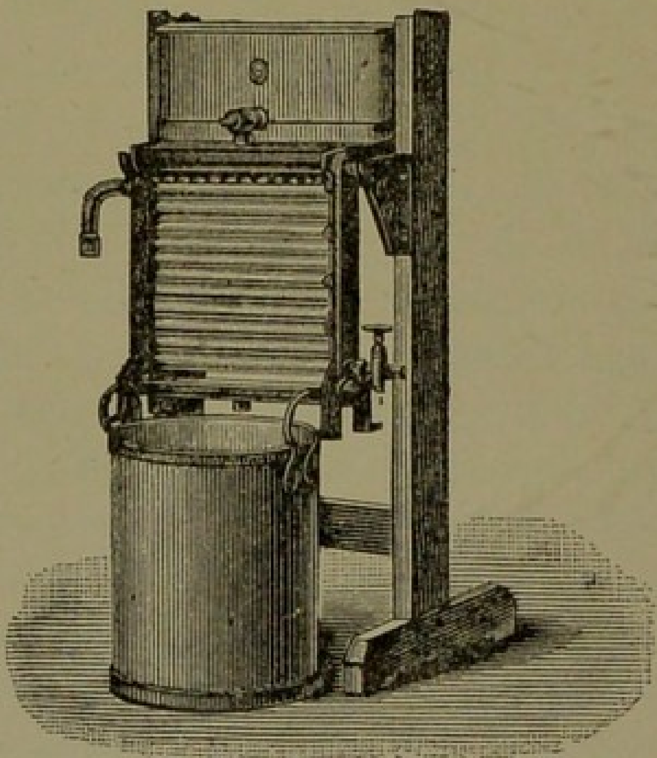

FIG. 20.—LAWRENCE COOLER.

too much to infection from the air, etc. In this respect Pfeiff's cooler (Fig. 21) offers greater safety, but it has the

* The following coolers and aerators are the main ones on the American market: "Star Milk and Cream Cooler," "Champion Milk Cooler and Aerator," "Howard's Patent Milk Cooler," "Powell Aerator." Dealers in dairy supplies will doubtless be glad to quote prices and give any other information desired concerning these and other kinds offered for sale.

disadvantage of being difficult to keep clean. The milk is cooled in tank *A* by means of crushed ice placed in the outside tank *B*. As shown in the figure the milk is run through pipes and between cooled tin surfaces, and runs into the transportation-can at the other end. Other coolers will be mentioned later on under "Pasteurization of Milk."

It must be emphasized that the cooling in no way may take place in the stable, although it is stated in some text-books on dairying that this may very well be done.

We must not forget, however, that the bacteria are not

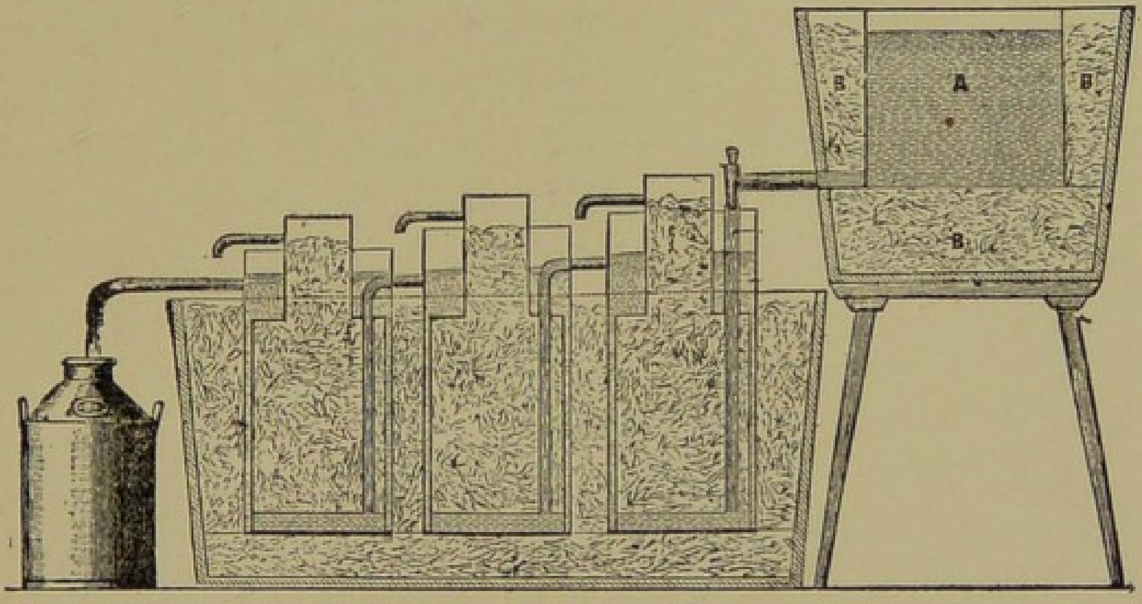

FIG. 21.—PFEIFF'S COOLER.

killed by a simple cooling of the milk. When they again come under favorable conditions they at once begin their activities. This fact every dairy and creamery man must always keep in mind during the continued treatment of the milk. If the milk is subjected to a process of manufacture it must of course have the temperature most suited for the different manipulations, but when left to itself the milk should always be kept as cool as the conditions will permit.

When to Cool the Milk.—Among our farmers and milk-dealers there is a general belief that cooling is necessary only during the hot season—an opinion to which I most emphatically take exception. It is possible during the cold season to haul the milk even to a somewhat distant creamery without previous cooling and keep it sweet; but the development of the bacteria will not be sufficiently checked by this method. The results do not appear at once, but are felt later on, as the products made from the milk will not keep well.

A quick and efficient cooling of the milk is a strong remedy to regulate and counteract the development of the bacteria found in it. It is my opinion that high-grade dairy products can only be made on farms where sufficient quantities of ice are used in the handling of the milk. Fortunately for our country, nature has arranged matters so that ice, the most effective and practical means of cooling the milk, is offered in sufficient quantities and at a low cost to our dairymen.

The Value of Ice to the Dairyman.—In this very condition lies, in my opinion, the secret of the fact that we in this country, far away from the markets of the world, can compete successfully in dairying with other countries more fortunately situated as regards location and many other conditions. For instance, the ice in Denmark is both expensive and poor, and cannot every year be obtained in anything like sufficient quantities. Our conditions are entirely different. Our numerous lakes and streams yield ice in abundance. The hauling of it does not come high, and the quality of the ice leaves nothing to be wished for. Crystal-clear lake ice, more than two feet thick, of such purity that it leaves practically no sediment on melting, is obtained here every winter. In Denmark, and still more in France and Ireland, which three countries, besides Sweden, are our only competitors in the English market, the dairymen are generally forced to cool the milk with water only—a method which doubtless is better than no cooling whatever, but which does not form any certain remedy against bacterial development. I have often had occasion to observe at Danish coöperative creameries that the milk even on arrival at the creamery has been somewhat sour or at least has been slightly off flavor, and that the butter when packed in the tubs has been soft and insipid—all a result of deficient cooling. More than once I have witnessed that the dairyman even on large Danish estates has been entirely at his wit's end for lack of means of cooling in the dairy. The Danes are fully aware of the importance of keeping the dairy products at a low temperature, but the only practical means which would make this possible—the ice—is often not to be had at a reasonable price. If we consider that ice-famines may as a consequence arise even at the large, financially strong proprietary creameries, it is evident that co operative creameries cannot require their patrons to cool their milk immediately after the milking. The milk, which usually is hauled to the creamery only once a day, is at best cooled with water, but is oftener exposed to a very doubtful "air-cooling." The result is, of course, that a perceptible fermentation may often be discovered in the milk on its arrival at the creamery. And from a second-grade raw material no one can make high-grade products. One of the main reasons for the rather low price of Danish butter during certain seasons of the year must be sought in these conditions.

Our dairymen and milkmen may draw many useful lessons from these facts. Ice can in our climate easily be kept packed in sawdust. Small milk producers who cannot make use of large quantities may join with one another in hauling and keeping the ice.

Mixing Evening and Morning Milk.—In this connection I will mention a mistake often made, viz., to mix the warm morning milk with the cold evening milk before the hauling. The whole quantity may be spoiled by this practice, as a temperature especially adapted to the growth of certain bacteria may under these conditions arise. If the comparatively warm, mixed milk be hauled a good distance to the creamery in the heat of the sun, it is not strange that it is changed on the arrival there, or at least contains a large number of bacteria the injurious effects of which it is hardly possible to overcome in the manufacture of the products.*

The milk ought of course to be protected against heating during the transportation, a rule which is often violated. If it has to be transported a long distance, the milk ought to be cooled during the hauling, or ought otherwise to be pasteurized before shipping. (See under *Pasteurization of Milk.*)

Care of Milk-pails.—A very common and strong infection of the milk which takes place both in the stable and the dairy is the one caused by carelessly-cleaned milk pails and cans. Even the first vessel which holds the milk when drawn from the udder, the milk-pail, usually leaves much to be wished for as far as cleanliness is concerned. At many farms in the old countries wooden pails

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* The churning of the milk which often takes place in hauling long distances is easily avoided by filling the cans completely.

are still used for milking. Such pails are, however, entirely unfit for this purpose, since all kinds of bacteria very easily lodge in them. By daily steaming, etc., it is certainly possible to prevent bacterial growth from gaining ground, but wooden vessels can hardly stand daily steamings; they will soon begin to leak. In case this cumbrous cleaning process is not carried on most carefully, irregularities will soon appear in the milk or its products pointing to a strong bacterial infection. It is therefore essential to use tin pails, which may easily be kept free from dirt with its accompanying bacteria.

Even on well-kept farms the practice of leaving the milk-pails in the pasture is often met with in summertime.* Instead of bringing them home to the dairy to be cleaned, they are rinsed in the pasture in some stream or lake and are then turned upside down on a fence-post to dry in the air. By this practice the pails are withdrawn from the careful supervision which the farmer himself or his superintendent may give to them when kept at the farm, and the pails are not thoroughly scoured and cleaned during the whole summer. In corners of milk-pails cleaned in the manner given and kept in the pasture I have found a slimy creamlike substance resembling coagulated milk. When the substance was shown to the dairymaid she was greatly surprised and could not understand how so much milk could remain in the pail. By closer inspection this whole whitish mass proved to be nothing but molds and bacteria. They had presumably daily fed on insignificant milk-remnants and strongly multiplied in the summer heat.

* On dairy farms in northern Europe, during the summer months, the cows are usually milked in the pasture or in an enclosure of the same.—W.

At other farms the milk-pails are kept in the cow stable. The inadvisability of this method ought to be easily seen by everybody. The air in the stable is seldom so pure that the pails will not be highly infected there. Their cleaning will furthermore always be more or less deficient under these conditions. It is not sufficient that the milk-pails are rinsed and scrubbed each time they have been used; they must first be rinsed in cold water and then scrubbed with a brush and boiling hot water. By cleaning first with cold water, the milk remaining is removed from the corners and joints; if water above 70° C. is first used, some of the albuminoids of the milk are coagulated and will remain in the corners, from where they later can be removed with difficulty; such coagulated albuminoid substances are of course splendid nutritive substrata for the bacteria.

The Use of Soda in Cleaning Milk-vessels.—In many places it is the custom to use boiling water to which soda has been added, for cleaning the milk-pails. The use of such a caustic is, however, not to be recommended; it only neutralizes or hides the acid that may be there, for that particular time, but does not expel the causes of the appearance of this acid. Rinsing with water containing soda may, on the contrary, have injurious effects, as even after last treatment with ordinary water some lye may remain in the corners of the pails and make these remains a still better nutritive medium than the moisture remaining after rinsing with ordinary water. Soda should therefore not be used indiscriminately for cleaning dairy utensils, but only in case of vessels in which sour whey, etc., has been kept. In using water containing soda the last traces of the soda must be removed by repeated rinsings with common water.

It is a very good plan to dip the milk-pail in boiling-hot water at the end of each cleaning. This will make the pails dry almost instantaneously, even in the joints, and a large number of bacteria but little tenacious of life (like, e.g., the one causing the milk and butter disease at Duelund mentioned before, see p. 20) will be destroyed. It is also advisable to steam the pails once a week, especially in winter.

The milk-cans used for hauling ought to be treated in the same manner after each use, with the difference that steaming ought to be obligatory in their cleaning. Steaming is the strongest weapon against bacterial growth in the cans and should be applied far more than is now the case. By the word cleanliness we do not understand the same now as in former days. In it is included all that heretofore was included under the term and a new point has been added—freedom from bacteria: cleanliness now also includes sterility. Absolute sterility can of course never be reached in a business like practical dairying, but it is nevertheless the duty of every dairyman to try to reach a certain degree of sterility in the milk cans and pails which may be easily obtained in any modern creamery by means of steaming.

Steaming Milk-vessels.—A good method of arranging the steaming is, e.g., to conduct one or two steam-pipes under the floor or under a low table near the sink by an arrangement like that shown in the accompanying illustration (Fig. 22).

When the milk-can has been scrubbed clean, it is turned upside down over the steam-pipe and steam is turned on. In this way all cans may be easily and rapidly steamed and practically sterilized. If absolute sterilization is wanted, it can be obtained more easily by repeating the steaming a couple of times with short intervals than by one uninterrupted long steaming. When the milk-cans have been steamed, they are left upside down, unless cov-

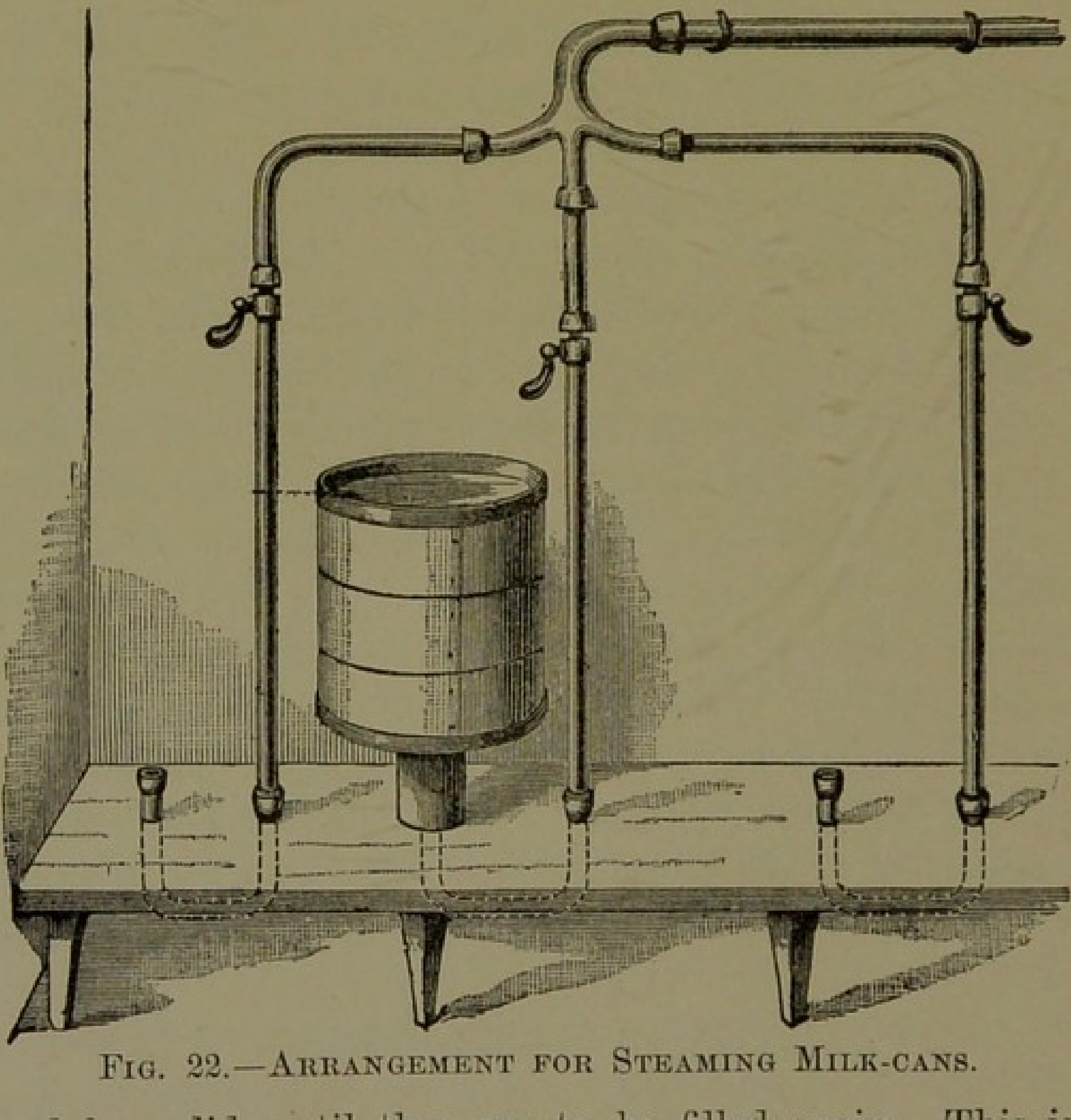

FIG. 22.—ARRANGEMENT FOR STEAMING MILK-CANS.

ered by a lid, until they are to be filled again. This is to prevent the introduction of bacteria into the cans, the bacteria being, as before mentioned, subject to the law of gravitation.

The steaming of the milk-cans can usually take place only at creameries, as the proper facilities are lacking on the farms. If the steaming is done by means of a number of pipes according to the plan shown in the illustration, the operation spoken of will not take long.

As the patrons of a creamery take back their skimmed milk immediately after the separation it is not usually practical to steam the cans in the creamery. In that way one of the most effective means of securing good milk is not taken advantage of, however. To get his milk-cans steamed every patron should bring some extra cans along, and they may then in turn be left in the creamery to be thoroughly cleaned and steamed.

This does not imply, however, that the cans are not also to be cleaned at the farm as well as the conditions will permit. The Swedish writer K. F. Lundin gives in his book, "The Main Conditions for Furnishing Good Milk to the Creameries," a sad but true picture of how bad matters generally stand in this respect. Although intended for Swedish conditions, his description may equally well be applied to our country. He says among other things:

"Almost daily the author while on duty has had occasion to noticc how milk-cans are left at railway depots, at roadsides and crossroads, with closed covers, often in the full heat of the sun the whole day until evening, although the farms often do not lie more than a stone's throw from the place, and the cans might easily be brought over and cleaned. Such a practice cannot be called anything but unpardonable carelessness and gross negligence. The results are soon felt. It is almost impossible, even by the most careful cleaning, to remove the foul smell which arises in the cans when thus kept covered in the heat of the sun. The milk remaining in the can from the creamery has soured and dried solid on account of the heat, for which reason the cleaning is made greatly more difficult and perhaps not with the best of intentions thoroughly effected in the hurry, since people often do not remember to clean the cans till the very moment when again they are to be used. There is no time to more than just rinse the can and rush around its inside with an old dish-rag which is sometimes dirtier than the can itself, having often before been used for the same purpose. This is not exaggerated, but is often met with in practice, I am sorry to say. The farmer himself may be ignorant of the manner in which the cans are taken care of, but he has careless servants and does not exercise sufficient supervision over them. When the milk is poured into such vessels one cannot be surprised if it is damaged and comes to the creamery in a diseased condition.

"At many creameries we have also had occasion to see that there are patrons whose milk is sour and bad-flavored on its arrival at the creamery. It ought not to be harder for these than for the rest to keep the milk sweet. The whole fault lies in the lack of cleanliness. Therefore the best way to remedy the evil is mercilessly to send back such milk.

"If the milk-cans are examined more closely and the hand brought around in them, we shall in some cases find a greasy, yellowish and putrid substance, an evident proof of the manner in which the cans are kept clean."

Annual Cleaning of Stable.—Besides the careful cleaning explained in the preceding, which must take place daily on the farm, a thorough cleaning combined with disinfection should be made at least once a year. In this process the whole stable must first be emptied and all remnants of fodders, manure, litter, etc., be carried away.

The whole stable is then to be scraped clean and swept, all hooks and corners, all joints in walls and floor; the ceiling is freed from dust and cobwebs by means of a stiff broom. The sweepings are at once to be removed from the vicinity of the stable and either burned (this is essential if any contagious disease has appeared in the herd during the year) or else ploughed under in the field. They ought never to be left uncovered near the stable, e.g., on the compost heap outside the same, for in this case the same filthiness filled with bacterial life may again enter the stable or else be introduced to the living-houses, etc.

The ceiling, floor, and walls in the stable having been scraped clean, both they and the tools ought to be carefully scoured and finally rinsed with boiling-hot water; small pools of water possibly remaining in recesses must be well wiped up.

If a mow for keeping coarse fodders, etc., is found in the stable it should also be emptied and cleaned every spring.

Whitewashing the Stable.—If no contagious diseases have appeared among the cattle in the stable since the last general cleaning, disinfection of the stable is not absolutely necessary. After the cleaning, the inside of the stable should be at once whitewashed. To prepare *milk of lime* 100 parts (by weight) of quick-lime are mixed with 60 parts of water, and a quart of the powder-like slaked lime is then mixed with 5 quarts of water. The milk of lime is well stirred before being applied. Walls and ceilings, pillars, etc., are brushed with lime-water, an effort being made to have it soak into cracks and corners as much as possible. By this whitewash, which is very cheap, several advantages are gained: the stable becomes lighter and more cheerful, the woodwork is preserved, and, what is still more important, the development of micro-organisms is checked for some time, as the lime-water acts as a weak antiseptic. To become very effective the whitewash ought, however, to be repeated during the summer.

Disinfection of Stable.—In case contagious diseases have appeared in the stable since the last thorough cleaning took place, or if the milk in spite of all precautions has still proved strongly infected in the stable, the liming ought to be preceded by a disinfection of the stable. This may be effected in various ways. I shall here describe a method in use at an estate in Germany which is reported to have given good results.

After having scrubbed, cleaned and aired the stable, as directed, all doors, wickets, windows, flues, etc., are shut. If straw or hay is found in the mow it must be removed. The less leaky the doors, etc., are the better. Several earthenware plates with chloride of lime are now placed in the stable and crude muriatic acid poured over them. Chlorin gas is then generated, which will kill the bacteria. It must be remembered that this gas is injurious also to man, especially for the respiratory organs, for which reason one must leave the stable as quickly as possible after the addition of the acid; the stable is now kept shut up for twenty-four hours and then thoroughly aired. If the stable is well closed an application of *one pound of chloride of lime* and *three pounds of crude acid* may suffice for every 5000 cubic feet. After airing, all woodwork, as window-sills, mangers, beams, etc., are carefully scrubbed and washed with boiling-hot water.

Sulphurous acid, which is generated by burning sulphur in a suitable dish, has also been used for disinfection of stables; it acts only in the presence of moisture. Recent investigations have shown, however, that the disinfecting power of this agent is small even if it is allowed to act for a long time.

It is to be remembered that disinfection with chlorin is generally more effective than an application of any disinfecting fluid, since the gas will be able to penetrate into all the small cracks and crevices.

The disinfection described is best made in the spring, soon after the cows are let out on pasture. The woodwork will then soon dry, and the whole summer may be taken for the perfect airing of the stable—an operation which must not be neglected even if no disinfection is made. If the stable is provided with a wooden floor, some floor-planks should be taken up, so as to facilitate the drying and cleaning of the space under the floor. The stable-loft must also be aired in summer-time.

Another good way to fight the bacterial growth generally so luxuriant in stables is to wash all woodwork with warm *coal-tar* in the spring after the cleaning and airing. If the floor in the stable is made of bowlders (which in general must be considered unsuitable, however), all filthiness between the stones must be carefully removed, the interstices thoroughly soaked with a solution of *chloride of lime* (one pound to six quarts of water), and the floor leveled with new sand. If the stable is supplied with earthen floor (which, also, for many reasons cannot be recommended), five to six inches of the upper layer ought to be carted off, the underlying dirt wet with the chloride-of-lime solution mentioned, and new dirt filled in.

If this disinfection is made during the spring, all kinds of carbolic-acid preparations may be used instead of the chloride of lime; but disinfection with carbolic acid must not be made later during the summer, since it will take a long time before the strong carbolic-acid smell is gone, and as the milk very quickly will take up all kinds of odors and be tainted by it. A suitable carbolic-acid solution may be obtained by dissolving soda in water and milk of lime, adding some crude carbolic acid to the solution. This mixture has proved effective in disinfections after all kinds of epidemic diseases.

In my opinion the safest method is to disinfect the stable, even when infectious diseases have not appeared there. This method will doubtless tend to increase the keeping quality of the milk and its products. In this connection I will mention that the milk epidemic at the Duelund estate in Denmark (see page 20) did not disappear until after a thorough disinfection of both stable and dairy.

In the January number of the *Annales de l'Institut Pasteur*, 1891, appearing after the above chapter was written, Prof. Duclaux gives a full account of some experiments which confirm the main principles for the treatment of milk laid down in the preceding pages.

"It seems to me," Duclaux says,* "that instead of going farther in this direction [sterilization of the milk by heat], it would be well to turn around and ask if it were not better to avoid that the heating become necessary, i.e., prevent all injurious bacteria from entering into the milk. In an address which I made during the World's Fair, on June 7, in Trocadero Hall, I said that milk from a well-kept cow stable, milked very rapidly into a carefully-cleaned pail, by a milker who washed well his hands and the teats of the cow, does not sour more rapidly than

* *Loc. cit.*, vol. 5, p. 59.

milk drawn without care and to which soda was added in order to hide its lack of cleanliness. This thought arose in me through the strong power of resistance which I have noticed in milk which was milked with extra precautions in my presence. It was taken up by one of my hearers—Dr. Smester*—who applied it in Normandy. He is now sending milk to Paris which has not been heated or received any chemical preservatives, but which still keeps for a long time, even in hot weather. It seems to me that we ought to improve in this direction,—at least when the question is of milk intended for rapid consumption,—and that we ought not to try to multiply and further perfect the pasteurization apparatus. It is true that an improvement of these will bring about a perfect neatness on the farms and among the farmers, and that an industrial tool is created sooner than traditional habits are changed. But a change would soon occur among the producers, if only the consumers demand the same. When the latter really want clean milk they will get it. As matters now stand it is always safest to boil the milk before using, if the consumer is not fully certain of the cleanliness and general health of the animals producing it; but the question of the keeping quality of the milk will nevertheless have taken a great step toward its solution when it is correctly understood on farms and in dairies what *cleanliness* really means."

* Dr. Smester is continuing his experiments with a view of applying them on a large scale.

CHAPTER III.

THE COMMON FORMS OF BACTERIA FOUND IN COWS' MILK.

The milk when drawn from a healthy udder being sterile (see p. 23), the kinds of micro-organisms found in the same are dependent on the forms of bacteria found in its surroundings. For this reason we generally find different kinds of bacteria in different places, and can often form an opinion concerning the company it has kept from a mere microscopic examination of the milk. I shall here only recall a couple of instances described in the preceding. The presence of *bacillus subtilis* in the milk shows plainly that in some way or other it has been exposed to fodder dust, etc., while the presence of peptonizing, putrefactive bacteria in large numbers indicates that the milk has been in too intimate contact with manure particles and other filthiness. Still more certain pointers as regards the causes of the infection of the milk, are obtained by microscopic examinations of the non-bacterial impurities, as described in the preceding chapter (see p. 31).

Different forms of bacteria are usually found in the milk during the different seasons, for the reason that the surroundings of the milk during its production and handling are not the same during different periods of the year. As is natural, the greatest differences are found between samples of milk taken when the cows were kept in the barn and when they were on pasture. According to my observations, these two kinds of milk differ from one another not only in the fact that the milk produced while on pasture contains a much smaller number of bacteria, but also because the organisms found in it are by no means as dangerous for the keeping quality of the milk as those infecting the milk originating in the stable. This is especially striking if the pasture milk is compared with milk from a dark and dirty cow-stable where the cows are standing on manure.

In view of the conditions mentioned, we cannot here enumerate all or even the most common micro-organisms found in the milk.* We shall only consider the varieties which, according to my investigations, are the most dangerous enemies to the keeping qualities of our milk. There may, of course, be a large number of other bacteria which in certain regions, where I have not had an opportunity to examine the milk, play a still more injurious part than those here mentioned.

My investigational material has come mainly from middle Savolak, or from the regions around Helsingfors and Tammerfors. A large number of samples examined,

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* For a detailed enumeration of the different forms of bacteria found in cows' milk, see Kramer, "Bakteriologie d. Landwirtschaft," 1892; Freudenreich, "Bakteriologie der Milchwirtschaft," 1893, pp. 36–53; Conn, "The Fermentations of Milk," 1893, pp. 17–63; Adametz, "Normal and Abnormal Bacteria in Milk," *Oest. Monatschr. f. Thierheilkunde*, **15**, pp. 1–36; *Centralbl. f. Bact.*, **8**, 109; Schuppan, "Bakterien in Bezieh. z. Milchwirtschaft," *Centralbl. f. Bact.*, **13**, 527; Löffler, "Ueber Bacterien in d. Milch.," *Berl. klin. Wochenschr.* 1887; Hueppe, "Untersuch. ueber die Zersetzungen d. Milch durch Mikro-organismen," *Mitt. Kais. Ges. Amtes*, **2**, 309, and Conn, Classification of Dairy Bacteria, Storrs Experiment Station, Rep. 1899, pp. 13–68 (with bibliography); see also the more general works on bacteriology, given on pp. 12–13.—W.

especially of sour milk, buttermilk, and sour cream, came from different regions of our country. Samples of sweet milk have generally been examined at once after they came into my possession.

FIGS. 23, 24.

Other samples, taken on travels in the different districts, were usually not examined at once, no facilities being available. These samples were kept in thin, short, previously sterilized glass tubes, drawn out to fine points in both ends, and at once melted together. The illustration (Fig. 23) shows such a tube in natural size. In using it the outer wall of the tube which is introduced in the milk is sterilized over an alcohol flame, the points are broken off rapidly with a pair of recently ignited nippers, the milk is sucked in, and the ends again melted together. A careful record was kept of the outward appearance, color, taste, and odor of each sample of milk, and of conditions in the dairy and barn on the farms where the milk was produced. In cases where samples of tuberculous and other contagious or abnormal milk were taken I used a sterilized glass tube of a somewhat different shape than the one just described, since it was undesirable in such cases to get any of the milk into the mouth in filling it. The latter kind of sampling tubes are of about double length, and supplied with two reservoirs for the milk, of which the one only served as a safety bulb in sampling (Fig. 24).

The examination of the samples taken and kept in this way cannot of course give any information of the number of bacteria in the original fluid, as quantitative bacteriological analyses, as shown in the Introduction, must be made immediately after the sampling. The method used will, however, throw a clear light on the question of the varieties of bacteria found in the different samples. It is possible that some kinds of bacteria may become less active, or even succumb, if the sample is kept too long; but all control analyses which I have made have failed to show any appreciable decrease in the number of the living kinds of bacteria, even after a lapse of three months. A long confinement in the glass tube appears, on the other hand, to cause the destruction of some forms of bacteria, while lactic-acid bacteria have shown strong ability to multiply even after having been kept for fourteen months in the manner described; their ability to develop lactic-acid fermentation in milk was, however, considerably weakened.

Number of Bacteria in Milk.—The number of bacteria in cows' milk depends of course on the treatment to which the milk has been subjected since drawn from the udder. This explains the different data given in the literature on the subject. Cnopf in Munich counted the number of bacteria in recently drawn milk. He found no less than 60,000 to 100,000 bacteria in one cubic centimeter. Freudenreich in Rütti, Switzerland, on the other hand, found only 9300 per cc. in milk on its arrival in the laboratory. Jensen in Copenhagen says he is inclined to think that the number of bacteria in the milk cans immediately after all the cows have been milked is many times larger under ordinary Danish conditions than given by Cnopf.

The results found by me in case of different samples of milk have also varied greatly, according to the age of the sample when the bacterial content is determined, as well as the origin of the milk analyzed.

Samples taken *in a pasture* on a fresh, somewhat damp summer morning showed the following average results as regards their bacterial content:

	Immediately after Milking.	$\frac{1}{2}$ hour.	2 hours.
Number of bacteria in one cubic centimeter,	10	88	1530

The numbers in this table are surprisingly small as compared with those previously given, but the samples were taken under particularly favorable conditions. The milking took place away from any dwelling-house, in a pasture surrounded by woods, during complete calm, and the cows were still damp after the moisture and the fog of the night air. The infection under these conditions would naturally be very small. During the two hours given in the table the milk stood in the hauling can in the pasture and during the transportation to the dairy.

Entirely different data are obtained in examining *milk produced in a barn.* The infection is there very pronounced, even within the first half-hour after the milking is done.

In making some quantitative bacteriological analyses of the milk produced on a certain farm I obtained samples of milk from a stable where only the heavy milkers had yet been taken in from the summer pasture. The stable was therefore not filled with cows, and ordinary winter conditions had not yet appeared there. This explains why this milk also contained comparatively few bacteria.

	Immediately after Milking.	½ hour.	1½ hours.
Number of bacteria per cubic centimeter	106	980	3655

The milk was kept in the hauling-can in the stable during the 1½ hours after the milking. The mouth of the can was covered by a clean, thin linen cloth thrown loosely over it, which did not exclude the air, but to a large extent prevented possible new infection from bacteria in the air.*

It was found in these experiments that immediately after the milking a very varying number of bacteria was found in the different layers of the milk. I was of the opinion that since the milk in the pail is under constant

* Sedgwick and Batchelder (*Boston Med. and Surg. Journal*, Jan. 14, 1892) in studying the Boston milk supply made the following experiments: "Milk was drawn from a clean and well-kept Holstein cow in an unusually decent stable. The normal milk of this cow had already been repeatedly proved to be sterile. Milk drawn by hand from this cow with great care into sterilized bottles, and planted quickly, yielded as an average of several trials 530 bacteria per cubic centimeter. When, however, the milkman used the ordinary milk-pail of flaring form, seated himself with more or less disturbance of the bedding, and vigorously shook the udder over the pail during the usual process of milking, we found that the numbers were very much higher, namely, an average of 30,500 per cubic centimeter at the end of the milking. When such milk is found upon the tables of country families a few hours later it naturally shows still more bacteria, doubtless because those with which it was seeded have had time to multiply, The average of fifteen such samples from the tables of families in Jamaica Plain, Cambridge, and Auburndale was 69,143 per cubic centimeter. In these cases, moreover, the conditions of the cows and of the stables were exceptionally good, while the milkmen were much more than ordinarily clean and careful." See also Leufven, Influence of milking on the bacterial content of milk, *Centralbl. f. Bakt.*, II, 1895, p. 824.—W.

stirring during the milking that the bacterial content would be about even in the whole of the can. But control experiments showed in a very striking manner that *the number of bacteria was largest on the surface of the milk.* All samples taken from the depth of the mess of milk, by means of sterilized, so-called Pasteur pipettes showed very few bacteria,—on an average 20.3 per cc.,—while all samples taken from the surface contained over 200 per cc. If I should venture an explanation of this phenomenon, I would say that it still more confirms the observations made in the preceding, that one of the main sources of the infection of the milk is the lower part of the stomach and the udder region of the cow, from which filthiness with accompanying bacteria all the time is falling down during the milking.

Milk from stables where winter conditions have entered has usually shown a higher bacteria content. Bacteriological analyses of such milk half an hour after the close of the milking have given the following data for the content per cubic centimeter: 4100; 2450; 1890; 14,670; 830; 3030; 5450; 21,700; and 1030.

I have made bacteriological analyses of several *samples of milk supplied to creameries,* the samples being taken under different conditions. The results naturally differed greatly. Milk from a well-conducted farm was examined after standing for one hour in the warm stable and then hauled to the creamery near by. The milk contained on an average 4500 bacteria per cubic centimeter. Milk from a filthy stable where the cows were standing in manure, on a warm day, transported by rail to the city where I took the sample, seven hours after the milking, contained 25,000 bacteria per cc. After having been kept for an hour in the rather warm laboratory the sample was found to contain considerably over 100,000 organisms per cubic centimeter. From a filthy and dark cow stable, spoken of more in detail in Chapter V, a sample of milk came which three-fourths of an hour after milking showed not less than about 670,000 bacteria per cc. The bacterial content of three samples of milk taken on three consecutive days from this stable, did not vary much, the analyses showing the following average figures per cc.: 730,000, 560,000, and 780,000. The most infected milk ever analyzed by me was from a milk store in Wiesbaden (Germany). Its age and the treatment to which it had been subjected could not be ascertained. It was sold as fresh new milk, did not taste sour, but had a decided "off" flavor; on analysis it was found to contain an immense number of bacteria, according to a low estimate several tens of millions per cubic centimeter. Any exact figures in this analysis could not be obtained by the methods then at my disposal.*

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* The influence of the *season* on the bacterial content of milk is illustrated by the data furnished by Dr. Russell as given on p. 92, foot-note. See also Schmelck, Exp. Sta. Record VI., p. 342.

The *weather* doubtless also greatly influences the number of bacteria found in milk. Dr. Russell has kindly furnished me with the following illustration: The milk of one of the patrons at the Wisconsin University Creamery was examined in May 1894, on two succeeding days, the sampling being done at the same time both days; it contained 1,150,000 and 48,000 bacteria per cubic centimeter, on an average, during the two days. The first day was very warm, while the second was cold and rainy.

The milk contained seven to ten different species of bacteria: slimy organisms were isolated in large numbers; hay bacillus was quite numerous, and pitted liquefiers very numerous in the sample.—W.

Increase in Bacterial Content of Milk.—The increase of the bacteria in milk depends of course both on the temperature and on the kinds appearing in the milk. The influence of the former factor is shown by the following investigations:

Cnopf and Escherich in Munich found 60,000–100,000 bacteria per cc. in a sample of milk recently drawn under precautions of great cleanliness. This milk was kept in a cool cellar at a temperature of 12°.5 C. (56°.5 F.). After two hours the number of bacteria was 4 times larger than at the beginning, after four hours 8 times larger, after five hours 26 times larger, and after six hours 435 times larger. [Another portion of the same milk was kept at 35° C. in an incubator; the bacteria contained in it had multiplied 23 times after two hours and 215 times after four hours, 1830 times after five hours and 3800 times after six hours. The development of bacteria in milk kept on ice was so small during this time that it could hardly be ascertained, but in the course of some days it reached as high figures as in the other samples.*—W.]

From the laboratory at Rütti the following table is furnished concerning the number of bacteria per cc. in milk of Nov. 14, 1889. On the arrival at the laboratory there was found 9300 bacteria per cc. in the milk.

INCREASE IN BACTERIAL CONTENT.

	When kept at 15° C.	When kept at 25° C.	When kept at 35° C.
3 hours later.....	1.06 times	2 times	4 times
6 hours later.....	2.5 "	18.5 "	1,290 "
9 hours later.....	5.0 "	107.5 "	3,794 "
24 hours later....	163 "	62,097. "	5,376 "

* *Centralb. f. Bakteriologie*, 6, 554.

The following instructive facts are shown from these figures:* 1. At 15° C. (59° F.) there was no increase during the first three hours, and during the first six hours only an insignificant one. 2. At 25° C. (77° F.) the increase was insignificant during the first three hours, but the number of bacteria then increased rapidly at the temperature so favorable to the growth of the bacteria. 3. At 35° C. (95° F.) the development was rather rapid from the start, but the increase in the bacterial content was still after twenty-four hours not so large as at the last-mentioned lower and evidently more favorable temperature.

If a still lower temperature than 59° F. (15° C.) be used for keeping the milk the bacterial growth is nearly completely checked. If the temperature of the milk is lowered to 45° F. (7° C.) immediately after the milking, the bacterial content according to my results is practically unchanged after twenty-four hours, and even after a still longer time from what it was at the beginning of the cooling. I have, however, observed in isolated cases that even at this temperature a considerable increase has taken place; this increase always stopped entirely when the bacteria were subjected to this temperature for 5–6 hours. The bacteria able to multiply even at 45° F. (7° C.) thus appear to be slowly paralyzed under the influence of this temperature. Even when the milk has had a temperature of 43° F. (6° C.), an increase of the bacteria has twice been found: in the one instance the increase, strange to say, took place a long time after the temperature of the milk had been lowered to this point. The tenacious organisms

* See also results obtained by Miquel, *Ann. Microgr.* 1889, Dec. No.; and by Baumann (Inaug. Dissert. Univ. Königsberg, 1893, pp. 16,17).—W.

which thrived so well at this low temperature were not, however, of a kind that would exert any influence on the quality of the milk. With the temperature of the milk at 39° F. (4° C.) I have never, no matter how long it was kept, been able to observe any increase in the bacteria content; this has always remained unchanged from the moment the temperature sank to 39° F. (4° C.).

It may finally be mentioned that Cnopf * analyzed milk samples which contained from 200,000 to 6,000,000 bacteria per cubic centimeter 5–6 hours after the milking (average over 1,000,000 per cc.).†

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* *Centralbl. f. Bact.* **6**, 553.

† The determinations of the bacterial content of market milk or of milk peddled in cities have as a rule given exceedingly high figures, owing to the comparatively long interval between the milking and the sampling. The following results have been obtained in the main investigations in this line:

Clauss (Inaug. Dissert. Würzberg, 1890; *Chem. Centralbl.* 1890, 518) found from 222,000 to 2.3 million bacteria per cubic centimeter in eight samples of Würzburg market milk taken during winter time; average 1–2 million per cc.

Hohenkamp (*Arch. f. Hyg.*, **14**, 260) found from 1.9 to 7.2 millions in the market milk of the same city during the summer.

Bujwid (*vide* Knochenstiern) in 1890 found on an average 4 million germs in sixteen samples of Warsaw milk.

Freudenreich (*vide* Knochenstiern) found 10,000 to 20,000 bacteria per cc. of Rütti milk.

v. Geuns (*Arch. f. Hyg.*, **3**, 479) found fresh milk sold in Amsteram to contain 2.5 millions, and when ten hours old 10.5 millions.

Cunningham (*Arch. f. Hyg.*, **12**) found 3400 to 300,000 bacteria per cc. of Calcutta milk taken during summer 1891.

Renk (*Centralbl. f. Bact.*, **10**, 193) found 6–30.7 million per cc. in Halle milk.

Uhl (*Zeitschr. f. Hyg.*, **12**, 475) found from 83,100 to 170 millions av. 22.9 millions, in thirty samples of Giessen market milk, taken

Comparing the data just given concerning the number of bacteria found in milk, it will be seen that milk under certain conditions may contain very few bacteria and under other conditions immense numbers of these organisms. That the latter is always the case with milk coming from filthy stables is apparent from the data given, and it is equally apparent that cleanliness and neatness in the handling of the milk may cause a considerable decrease in its bacterial content.*

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during May 1892, and from 10,500 to 13.6 millions, av. 2.9 millions, in the same kind of milk sampled during June 1892.

Knochenstiern (Inaug. Dissert. Univ. Dorpat, 1893) obtained the following results in his investigations of the Dorpat milk supply:

40 samples of milk sold by milkmen:

36,000–83 millions; av. 10.2 millions

25 samples of milk from village dairies:

90,000–103 " " 12 "

35 samples of milk sold on market-place:

137,000–287 " " 25 "

40 samples of milk sold in milk stores:

11,600–257 " " 30 "

Gernhardt (Inaug. Dissert. Univ. Jurjew, 1893) found similar results for Dorpat milk.

See also Baumann (Inaug. Dissert. Univ. Königsberg, 1893, pp. 16, 17).—W.

* The number of bacteria in American milk has been studied by but few investigators. Sedgwick and Batchelder examined the milk supply of Boston bacteriologically (*Boston Med. and Surg. Jour.*, 1892, Jan. 14); the average number of bacteria found in fifty-seven samples in the spring of 1890 was 2,355,500 per cubic centimeter. Sixteen samples obtained from groceries contained 4,577,000 per cc. Ten samples collected from "well-to-do families upon the Back Bay" showed an average of 1,438,000 per cc. The lowest number found in Boston milk supplied in the ordinary way was 30,600 per cc.

Dr. Russell (private communication) determined the bacteria content of morning milk as delivered to customers in Madison, Wis.:

Kinds, not Numbers, of Bacteria of Most Importance.—It must be remembered, however, that in the infection of milk with bacteria, as in every other infection, the main importance does not lie in the large or small number of bacteria, but in their qualities and nature. It is a common observation that a large number of different kinds of bacteria are found in the milk by the first examination in the stable, but in later examinations of the same milk the number of different kinds will be found considerably reduced. The struggle for existence thus seems to be as pronounced in the microscopic as in the macroscopic world. The milk is infected from different sources by different kinds of bacteria, and each of them begins to hunt for sustenance in the new nutritive medium, and seeks to gain superiority over the others. The struggle is for life and for the greatest power, for even among these pygmies of the living world the old maxim holds good, that he who has the power appropriates for himself all the good things of life. The organisms, for one reason or another gaining the upper hand, increase so rapidly that the others at best can only just save their lives, and are unable to exert their vital functions on a large scale. They remain helplessly in the minority as long as the conditions are favorable for their more favored conquerors. We thus find that only a few forms of bacteria have been able to increase in preponderating numbers in samples of milk that have been

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from 35,000 to 275,000 was found per cc. on an average during April (1894), and from 380,000 to 2,000,000 per cc. during May and June. See also foot-note on p. 87; Conn. Exp. Sta. Bull. 4; Rep. 6, p. 43; 7, p. 69, and Wis. Exp. Sta. Rep. 11, pp. 150–165.

Pammel (*Iowa Experiment Station Bulletin* No. 21, p. 801) found 571,900 bacteria in milk "just before the curd was ready to cut for cheese"; another sample contained 165,000 bacteria per cc.—W.

kept for about one day. Among the determining causes for the superiority of these few forms three circumstances may especially be pointed out:

1. The milk is a better nutritive medium for these organisms than for their competitors. Although milk in general may be considered an excellent growing place for bacteria, certain kinds seem to be especially adapted to development in this substratum.

2. The temperature present is more favorable for the conquering kinds than for the others. Experience shows that a difference in temperature of 2°–4° F. may have a decided influence on the development of bacteria, a fact which is apparent in a striking manner in the manufacture of the different kinds of cheese.

3. If the milk has become largely infected with a certain kind of bacteria, this is very apt to keep the superiority, even if the milk generally speaking is not a very good nutritive medium for it. Such "mass-infections" of a certain bacteria frequently occur in the handling of the milk on the farm. Accidents seem to play an important part in this matter. In several cow stables it seems to be the rule that such mass-infection takes place. This was, e.g., the case in a stable where, as mentioned in the preceding chapter (see p. 53), unclean straw and rusty chaff were used day after day.

Fortunately, however, it is always not the case that the conquering species are injurious to the quality of the milk. I have seen examples where milk which was normal both to taste and smell, as well as to consistency in general, contained an immense number of bacteria which did not then interfere with the quality of the milk. Among the species found in such milk I have observed bacteria, which later on exerted a more or less injurious influence on the butter or the cheese made from the milk.

Some bacteria may furthermore appear in the milk which do not in themselves have the power to change appreciably its quality, but which prepare favorable conditions for other, injurious bacteria. As a transition group between these organisms and those directly destructive of the milk, some species may be included that are able both to change the quality of the milk to a considerable extent and to prepare a good field for other bacteria, which in their turn produce other kinds of fermentations.

CLASSIFICATION OF BACTERIA FOUND IN MILK.

In trying to classify the common forms of bacteria found in milk, I have separated them into the following four groups:

I. Indifferent bacteria.
II. Bacteria indifferent in milk, but active in the milk products.
III. Indirectly injurious bacteria.
IV. Injurious bacteria.

I. Indifferent Bacteria.—The species belonging to this group are of course of small interest in studying the problem of the bacteriology of the dairy, and will therefore not be described in detail here. In deciding certain questions, as, e.g., whether a certain sample of milk has been infected by bacteria in the air or by such originating in manure particles, the indifferent bacterial impurities may be of some importance. They seem, however, to show such a different appearance in different localities that only after specific investigations of the local bacteriological conditions can there often be any question of applying them as deciding factors.

II. Bacteria Indifferent in Milk but Active in its Products.—The species belonging to the second group which I have met with will be described in later chapters. On account of the many difficulties met with in the examination of these bacteria, I have unfortunately only to a small extent been able to throw any light on their nature and qualities.

III. Indirectly Injurious Bacteria which Produce Favorable Conditions for Bacteria Injurious to the Milk.—The third group includes first of all several bacteria causing *alkaline* reaction in the milk. These bacteria may play also a certain part in the dairy industry of Finland. On a farm in Karelen, which I visited a couple of years ago, I found the housewife almost in despair. She said that the milk had not soured properly during the whole summer, and as a result inferior butter was made during this time, while previously she had always prided herself on making a mildly acid, first-class butter. Her supply of butter on hand also showed that she had every reason to be dissatisfied. The butter was mottled, insipid, and had a repugnant taste. During the early part of the summer the milk had soured, although it took a long time for it to do so; now the souring did not seem to be forthcoming at all. The milk stood in the pans for days, the cream rose, but did not thicken. It did not taste sour, and had no appreciable after-taste. Tested with litmus-paper the milk showed a distinct alkaline reaction. I was not able to investigate this interesting material bacteriologically, as the samples taken in sterilized-glass tubes were accidentally lost. It may be added that since I could not arrange any disinfection of the dairy and milk vessels at the place, being far off in the wilderness, I had to advise her to seek a remedy entirely opposite to what I should have advised under different conditions—viz., to infect in every way possible the dairy, milk-pails, pans, churn, the cows' udders, etc., with sour milk from a neighboring farm, where the milk soured in the regular way. This "mass-infection" had the desired effect, according to what I learned on a journey in the same region during last summer.

A case of similar nature was observed during the same summer on an estate in Savolaks. It proved impossible to obtain ordinary sour milk at this place. The milk was left to sour in the usual way on the pantry-shelf, where it had always gone through the regular lactic fermentation during previous summers, and had formed good sour milk. During this whole summer the sour milk had been of a rather loose consistency and mostly of an insipid taste. When kept for some time it assumed an obnoxious, rotten taste. The milk soon showed smaller and smaller tendency to coagulate, while the bad taste appeared earlier. The cream rose rather rapidly to the surface and had a tough consistency (in this respect different from the example mentioned above), but the skim-milk was not viscous and had a characteristic greenish-blue color. The milk did not keep this appearance long, however. The surface of the cream turned grayish brown, and swelled in places on account of gas generation. At the same time a disagreeable smell and taste was noticed, for which reason the milk had to be removed from the larder. During several weeks it was impossible to prepare satisfactory sour milk on this farm, although the pans were finally placed in another room and the vessels were carefully cleaned. At last they began to inoculate the milk with ordinary sour buttermilk, and after a considerable time succeeded in this manner in making common sour milk. Not till late in the fall did the milk again turn sour in the ordinary way, without any separate inoculation being necessary.

The greenish-blue skim-milk in the first unsuccessful sour milk gave a very distinct alkaline reaction and contained a large number of bacteria, among which a short, staff-like bacillus was especially noticeable. By pure cultures of this bacteria it was learned that it was in the main similar to the blue-milk bacillus (*Bacillus cyanogenus*) common in Germany, and more particularly similar to the form of it first investigated by Hueppe, and claimed by him to be the typical and regular cause of blue milk. This has been studied again of late by Scholl, and duly characterized as a variety (or species) distinctly different from the forms described by Löffler and others. It does not peptonize gelatine, but produces in the same a fine green coloring-matter resembling chlorophyll; the other kinds of bacteria produce a brownish coloration in gelatine. Neither the bacterium isolated by me nor the blue-milk bacteria found in Germany caused coagulation or fermentation of acid when inoculated in sterile milk; it was sometimes observed that the milk was for a while viscous and thick-flowing. This, however, seemed soon to disappear. The milk turned alkaline if it previously was weakly acid or neutral. I have been unable to observe any blue coloration of the surface of the milk; the lower layers of the milk seemed, however, to assume a greenish-blue coloration.

Small *micrococci* appeared in the same milk, and these also produced a distinct alkaline reaction in it. The cultures in milk of this bacterium had a disagreeable odor, resembling that of ammonia. A mold, *Oidium lactis*, was also observed in large numbers in the milk. This is another micro-organism which produces alkaline reaction in the milk. The three latter organisms were by far the more numerous in the sample of milk mentioned. Lactic-acid bacteria were also found, but they had been largely supplanted. In two calculations of the number of bacteria in one cubic centimeter the ratio of lactic-acid bacteria to bacteria producing the bluish-green color in the milk was about as 1: 40,000. Unfortunately I was unable to obtain exact data as to this ratio by proper control experiments. The micrococcus mentioned was greatly in the minority, both in the cream and in the lower layers of the milk.

By an analysis of this milk made since the change in the cream-layer spoken of had occurred, I was surprised to find the relation between the different species of bacteria greatly changed, as could readily be seen by the microscope. The *micrococci* had gained the upper hand in the cream layer, and the bacteria resembling the blue-milk bacillus had been forced to the lower layers of the milk, where they lived a very feeble life, as was proved by later examinations. Being *aerobic* bacteria, this might be inferred. The lactic-acid bacteria were in a very small minority during the whole experiment, both in the milk itself and in the cream layer. It is plain that the bacteria resembling the blue-milk bacillus produced favorable conditions for the micrococci which can only multiply in a distinctly alkaline substratum. When the milk once had this reaction due to the activity of the bacteria mentioned, they could develop, which they did to such an extent as to put their benefactors to flight. The cream then obtained the disagreeable taste and smell before mentioned as the last stage in the changes of the milk.

According to my experience the moulds *Oidium lactis* spoken of, under which name several species seem to hide, often makes the substratum more favorable for various bacteria—a fact to which I have referred in an earlier publication.*

To the third group (*indirectly injurious bacteria*) some bacteria causing acidity in the milk may also be referred. They more properly belong to the fourth group, however, and will be treated there. Although the bacteria in general require an alkaline or neutral reaction in the substratum, some are found demanding an acid reaction. These are, first of all, the *butyric-acid bacteria.* They thrive only in a strongly acid medium, and are therefore most frequently found in sour milk, where they struggle for a living with the lactic-acid bacteria. These latter are thus their forerunners, which produce a favorable nutritive medium for the butyric-acid bacteria, and are then forced out of the way by these. Although the butyric-acid bacteria at first are only in an exceedingly small minority among the micro-organisms of the milk, they multiply rapidly as soon as the substratum grows too acid for the lactic-acid bacteria, and begin to make their presence felt

* "Saprofyta mikro-organismer i komjölk, I," Helsingfors, 1890, p. 80; see also Lang and Freudenreich, "*Oidium lactis* in Milk," *Ldw. Jahrb. Schw.* 7, p. 229.

by starting the bad-smelling *butyric fermentation* ("rancidity"). These two processes—the lactic and butyric fermentation—seem to be coherent to such an extent that a German author (Wigand) recently even asserted that the butyric fermentation is simply a continuation of the lactic-acid fermentation ("*ein weiteres Stadium der Milchsäure-gährung*").

IV. Bacteria Injurious to the Milk.—Bacteria of very different kinds and of highly-varying characteristics belong to this group. In order more readily to obtain a general view of them, we will separate them into the following subdivisions:

1. Bacteria producing acidity in the milk.
    - *a.* Bacteria producing lactic fermentation.
    - *b.* Bacteria producing butyric fermentation.
    - *c.* Bacteria producing volatile acids in the milk.
2. Bacteria producing no acidity in the milk.
    - *a.* Bacteria causing coagulation of the casein.
    - *b.* Bacteria causing coagulation of the casein and subsequent peptonization of the coagulum.
    - *c.* Bacteria bringing the casein into fermentation without coagulating it.

We shall below briefly mention the main bacteria included under the preceding divisions.

1*a*. *Lactic Fermentation.*—There are many kinds of bacteria producing lactic fermentation. Most of them belong to the bacteria proper, while others belong to the yeasts. The lactic-acid bacteria will be described more fully under the "Ripening of the Cream."

Besides the lactic-acid bacteria proper, a number of other bacteria may be included under this division which only incidentally produce fermentation. Certain infectious bacteria, as the *Mastitis bacterium* and some color-producing bacteria, as the *Bacillus prodigiosus*, belong here. The latter has not, to my knowledge, been found in our country.*

1*b*. *Butyric Fermentation.*—The form of the many butyric-acid bacteria which I have met with in this country has in the main proved similar to the one first isolated and described by Hueppe. It is aerobic, and produces a slight coagulation of the casein, which, however, later on is peptonized. It may therefore also be referred to one of the following groups. If sterilized milk be inoculated with such butyric-acid bacilli, a clear liquid layer of a grayish color will be found after keeping the cultures for a couple of days at about 86° F. (30° C.). Under this layer a lumpy casein coagulum is found, which sinks deeper as the clear liquid increases. The coagulum gradually disappears, and after some time will be entirely peptonized. Milk changed in this way has a very bitter taste.

1*c*. *Bacteria Producing Volatile Acids.* — Among the bacteria producing volatile acids in the milk may be mentioned first the *actino*-bacteria forms, which are rather frequent in milk. They all appear with a translucent, sack-formed cover, in which the fine, long, immovable bacteria are entirely wrapped up, and in which the division of the bacteria seems to take place. Some hours after the sterilized milk has been inoculated with such bacteria the sample will be changed both in appearance and consistency. It assumes a brown to grayish color and becomes rather viscous. No appreciable coagulation will be found. Gradually the milk will be changed to a translucent, grayish-

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* The same is true in case of America (Russell).—W.

colored, somewhat viscous fluid, which would hardly remind one of milk. It is further characteristic for the culture of these bacteria in milk that a lively generation of gas often takes place in the substratum. Carbonic acid seems to be the main gas generated. I have also observed a smell suggesting sulphuretted hydrogen. The presence of small quantities of alcohol and acetic acid may further be shown by distillation of the milk.

Among the organisms belonging to this family I have only observed two varieties in Finnish milk—the one very thin and long, the other thicker and shorter. Neither seem to shun daylight particularly; they are both killed by a single rapid heating of the substratum to 158° F. (70° C.). They seem to be found almost regularly in stringy milk;* they doubtless play a part in the formation of this milk, although they also seem to be assisted by others, e.g., of a lactic-acid bacterium appearing as streptococcus; the latter does not produce volatile acids, as is the case with other lactic-acid bacteria.

2*a*. *Bacteria Causing Coagulation of the Casein.*—Three different varieties found in Finnish milk are included in this subdivision. Of this number only one, however, calls for special mention, since the other two seem to be comparatively rare. The third one is very common, and in my investigations has been found to appear in particularly large numbers in milk which had come in contact with manure-particles, etc. It is a short *bacillus* (1.5 × .5 μ), often thinner in the middle and with rounded ends. Its power of locomotion is very pronounced. Thread-formed runners from the small colonies are no-

* See "Saprophytic Micro-organisms in Cows' Milk," p. 27.

ticed on gelatine-plate cultures. The colonies soon sink in the dissolved gelatine; they generally appear surrounded by a more or less fluorescent zone. In gelatine "stick" cultures of this kind the gelatine is dissolved in a funnel shape, and the surface then first flucresces strongly, and later is covered by a greenish film. On agar-agar a greenish-white deposit is formed. Even in beef-broth a green coloration is observed. This bacterium causes no acidity in milk, but produces a complete precipitate of casein by alkaline reaction (seldom by neutral reaction); a more or less pronounced disagreeable rotten smell, furthermore, appears in the substratum. In many respects this bacterium seems to resemble Flügge's *Bacillus fluorescens liquefaciens.* As mentioned above it is often met with in manure particles, especially if these are very moist. I have also found it in stagnant water. Sunlight and even daylight seems to kill the organism within a short time.

2b. Bacteria Coagulating Casein and Subsequently Peptonizing the Coagulum.—This subdivision has not, according to my experience, many representatives in our country. The bacteria spoken of above as resembling the blue-milk bacillus belong here. Another representative of this subdivision was found last winter in a sample of milk from Helsingfors. The casein in this milk did not coagulate, but the whole milk assumed a jelly-like consistency, became fibrous and coherent, and turned a grayish and afterwards a brownish color. Later on this jelly-like mass gradually dissolved. The bacteria causing these changes were isolated and found to be a long, staff-like bacillus which often appeared in coherent chains. Inoculated in sterilized milk it produced a strong alkaline reaction, and otherwise changed the milk as stated above.

Quite frequently the so-called *potato bacillus—Bacillus mesentericus vulgatus*—is found in Finnish milk. This may easily be recognized by its active power of locomotion, its short, thick staff-shape, its strong peptonizing power, and its great inclination to build spores. I have also found represented in our Finnish milk the Duclaux *Tyrothrix* family, some species of which resemble in several respects the potato bacilli. The organisms belonging to this subdivision generally have spores possessing great tenacity of life; they easily withstand boiling temperatures. For this reason their presence in milk is very injurious. According to Duclaux, the bacteria of this subdivision produce two substances: the one which he identifies with rennet precipitates casein, while the other again peptonizes it.

This subdivision seems to be more numerous in milk produced in southern countries than in our northern milk. My investigations of South German and French milk would show this; and also the constant appearance of milk diseases, as red milk, blue milk, etc., which are caused by infection of bacteria belonging to this subdivision, in samples of milk examined.*

2c. *Bacteria bringing Casein into Fermentation without Coagulating It.*—The final result of the activity in milk of bacteria belonging to this subdivision is the same as that of the families belonging to the last two subdivisions, viz., a solution of the casein through decomposition. These subdivisions together form the group of bacteria called *putrefactive bacteria* by older bacteriologists

* For a description of bacteria belonging to this subdivision see Scholl, "Die Milch," 1891, p. 42; Conn, "The Fermentations of Milk," 1892, p. 48; Freudenreich, "Bakteriologie d. Milchwirtschaft," 1893, p. 45, etc.

—a term also used in the following pages for the sake of brevity. All these bacteria decompose albuminoid substances and produce an unpleasant smell; the final products in the substrata are carbonic acid, ammonia, and water. In the dairy they generally have an injurious influence; some play a part in the ripening of certain kinds of cheese, however. They are of the greatest importance and value to the agriculturist in other domains, since they split up the complicated albuminoids of the manure into such substances as may serve as nutrients for cultivated plants. These bacteria are therefore especially numerous in solid and liquid manure, and their presence in milk shows that this has been contaminated with these substances.

This applies especially to the bacteria included in the third subdivision. The more macroscopic impurities coming from the manure, the greater is the probability that these bacteria will appear in large numbers. The most common of them belong to the family *Proteus* (Hauser), and are characterized by a rapid power of locomotion; they are often supplied with cilia, and generally somewhat curved, staff-like bacteria. They seem to attack the casein of the milk directly without precipitating it, and dissolve it under decomposition. Although they do not develop spores, they are very tenacious of life. They can stand both prolonged drought and a cold of $-4°$ to $-22°$ F. ($20° - 30°$ C.). The fermentation produced by these bacteria in milk gives it sometimes a bad and insipid, sometimes a bitter, taste. If the cream from such milk is allowed to grow old it will yield a rotten odor, and air-bubbles will form both in the inner portion and on the surface of the skim-milk.

All the milk bacteria enumerated in the preceding are aerobic, i.e., they form first of all in the presence of air. But anaerobic bacteria (i.e , such as cannot live in an atmosphere containing oxygen) may also be found in milk. The examination of these is unfortunately attended by great difficulties. I have found a butyric-acid fermentation produced by anaerobic bacilli in two samples of milk, and in several other samples have found numerous anaerobic bacteria causing putrefactive fermentations. By an ordinary aerobic quantitative analysis only a very few colonies appeared in these samples; this was contrary to the results of a preceding microscopic examination which showed that the milk was filled with numerous bacteria. The explanation of the apparent contradiction was of course that the bacteria found in the milk were largely anaerobic, and could not thus develop in cultures to which the air had free access.

Other Micro-organisms in Milk.—The short enumeration of the injurious bacteria of milk given in the preceding only includes the bacteria proper. Other micro-organisms resembling the bacteria are also found in milk, that may influence its quality. Among these the *yeast-fungi* may be mentioned. They demand in the main the same conditions of life as the bacteria, are somewhat larger than these, and oval-shaped. They multiply through budding (Fig. 12), i.e., in the manner that cell-buds project from one or both ends of the round cell. This gradually grows until the new cell reaches the size of the mother-cell, when it either breaks off from the latter by a cross-wall, or at once begins to form new buds.

The yeasts appear comparatively seldom in milk, and only a very few forms are able to cause fermentations in this medium, and thus injure its quality. I have examined the relation of a large number of different yeasts in this respect, and found that only two of them may be considered as enemies of the quality of the milk. These produce lactic-acid fermentations, and also form alcohol in it in smaller or larger quantities. In "Saprophytic Micro-organisms in Cows' Milk," pp. 34–36, I have characterized more fully these two organisms, which I have named *Saccharomyces lactis* and *S. acidi lactici*.

The latter yeast has several times been found by me in Finnish milk, both in milk from the Kuopio and the Joensum region, and in samples coming from Borgaa.

Besides bacteria and yeasts, *molds* often appear in milk. We see mentioned in many text-books that the milk has a special mold, *Oidium lactis*. As a matter of fact, however, we very often find organisms in the milk which long have had this name in bacterial science; they are especially found in milk left to sour in wooden pans. Every sample of sour milk of this kind which I have met with has been strongly infected by *oidium lactis*. The fact seems to be, however, that several different moulds hide themselves under this name, and that *oidium lactis* only signifies a certain stage of development with different moulds—a stage when they all have about the same appearance. They appear to the naked eye as a fine, white, velvet down on the milk; under the microscope they appear like ramified threads separated by numerous cross walls. We shall in a later chapter return to the action of these moulds in the milk.

CHAPTER IV.

CLEANLINESS IN BUTTER AND CHEESE FACTORIES.

THE sources of infection of the milk while kept in the stable and during the transportation to the factory have been described in the preceding. We shall now consider the dangers of infection threatening the milk during its further treatment in the factory. The necessary cleanliness and care in receiving, weighing, and straining or keeping the milk in the vats are as a rule observed in the modern dairy industry. It may be in order, however, to call attention to some points in which this principle is occasionally violated.

Admittance to Factory.—To begin with, the butter or cheese maker ought to take charge of the milk at the door of the factory, or at least at the door of the separator or milk-room. Farm hands or drivers should not be admitted into the creamery direct from the work in the barn. Yet we find that in nearly all creameries in our country, and not seldom in foreign countries, they are at liberty to visit any room in the factory. I have seen milk-drivers pour the milk into the separator-vat, change skim-milk cans, etc. It is not difficult to prove that dusty drivers carry legions of the infectious organisms of the milk with them into the factory, and in their movements clouds of dust charged with fermentation spores are set in motion.

Clothes of Factory hands.—That the factory hands themselves must keep clean in the most scrupulous manner is a principle agreed to by everybody in theory, but not always duly followed in practice. It is not fastidiousness to insist that factory hands should appear dressed in a white, easily washable costume, for only in this case can we feel certain that they go at their work in a neat way, and that their clothes may not be the cause of infecting the milk or its products. Furthermore, it cannot be considered unreasonable to require that persons working with milk or milk products to wear a white cap, as it is well known how easily hairs, etc., may loosen from one's head. The small coquettish caps placed on the back of the head, which are seen in some model dairies at expositions, do not accomplish the object sought.*

It is often objected that it is impracticable for factory hands to wear white costumes, as these soil so quickly, for which reason gray or blue-striped clothes are recommended. In my opinion this objection shows in the most striking manner that white clothes alone ought to be used in butter and cheese factories, for any dirt on them is noticeable. The first condition for keeping absolutely clean is, of course, that filthiness may be observed and immediately removed, thus preventing its spreading.

Changing Clothes.—A question which sometimes agitates the owners of factories is how often the factory-hands ought to change clothes. As a reasonable rule in this respect it is often stated that every factory-man ought to appear with clean washed clothes at least every Sunday morning. According to my experience from both Danish and Finnish factories, it is, however, impossible to keep the

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* In European creameries all lighter work and the making of the butter are usually done by women.—W.

clothes properly clean for a whole week, no matter how careful a person may be. The only sensible rule in regard to the changing of wearing apparel is that clothes ought to be replaced by clean ones as soon as they become slightly soiled. It is in my opinion necessary that factory hands should have clean clothes every day and every hour in the week, and not only at the beginning of the week.

A great difference may, as a rule, be observed between men and women working in creameries in regard to outward appearance. We often find that the men are negligent as to cleanliness in wearing apparel, etc., a condition which not seldom has led to sad results as regards the butter and cheese product. It is of course true that the fact that neatness in outward appearance is observed is no guarantee for cleanliness in general; but, on the other hand, it is always difficult, almost impossible, for a person negligent about his looks to observe cleanliness in other directions. It does not involve so much expense for factory-hands always to appear in white and clean aprons, sleeves, and caps, for while laundry expenses are increased, the rest of the clothes are protected by their use.

Necessity of Clean Hands.—The attention of dairy and factory workers may furthermore be called to the necessity of keeping their hands carefully clean, as these very often come in contact with the milk, cream, and especially the butter. I found the following custom prevailing at a margarine factory in France: Before beginning work in which the men came in near contact with the milk or its products they had to present themselves before the superintendent, who then strictly examined them as to cleanliness, especially their hands.

Through the bacteriological investigations of Mittmann and others it has been proved that the frequently appearing black dirt under the finger nails contains a large number of different kinds of bacteria. The heat and moisture found there are very favorable to the growth of microorganisms; they are highly fit to become brooding places for all kinds of bacteria. Bremer has even shown the presence of tubercle bacilli in the dirt under finger nails, and putrefactive bacteria may easily be found in it.

The Cause of the "Factory Odor."—Leaving the factory-workers and turning our attention to the factory itself, it must first of all be stated that in most of them (in almost all older ones) the atmosphere met with is far from pure and sweet. It is heavy and moist, mixed with a characteristic odor which reminds one partly of sourness, partly of musty, rotting wood. This specific creamery (and cheese factory) odor is a nuisance in most factories. If we look around at the floors, ceilings, walls, and utensils we are not in most cases at a loss to ascertain the cause of this condition. Fermentation hotbeds without number may usually be found, and large colonies of moulds may be seen, as well as thick dirt-spots on walls and ceiling, and bad-smelling pools on the floor; in many cases the drain-gutter also spreads an offensive odor. Where such bad conditions are not present, there are others, more hidden ones, giving rise to the foul atmosphere. It is only necessary to examine the corners of the rooms, cracks in the floor and wall, crooks and crevices of staircases and thresholds, and the explanation of the bad condition of affairs will doubtless be found there.

The Use of Water in the Creamery.—A characteristic feature of modern creameries is the superfluity of water used in them; it is, e.g., considered proper at any time to deluge the floor. Many and great advantages are obtained by an abundant application of water, but the same advantages may, as we shall see, be reached in another way. The main object of this liberal use of water in creameries is to remove all kinds of fermentable fluids found on the floor and elsewhere. By this means the fermentation-germs are removed, and under otherwise proper conditions the end sought will also be reached. The other method for removing spilt fermentative fluids formerly followed by dairymen also led to good results, especially where the conditions in the creamery were somewhat primitive, and where the floor was not perfect. As soon as some milk, whey, etc., was spilt on the floor it was carefully wiped up, and the place was rinsed with a small quantity of pure water which was then also wiped up. This method of procedure is directly opposite to the first-mentioned one, and according to this method the creamery ought to be kept as dry as possible. Excellent results are doubtless obtained by a careful observation of this rule. On account of the lack of fermentative fluids bacteria cannot infest the factory, and the air in the whole building is fresh and sweet.

As already stated, this method was much thought of during the early days of rational dairying. Martens thus writes in 1869 in his book on the dairy-farms of Schleswig-Holstein: "The drier the milk-cellar is kept in every nook and corner, the highest cleanliness being at the same time observed, the better the milk will be protected from souring. Any one considering this too insignificant a matter to deserve attention can never hope to make high-grade butter." It cannot be doubted that this method of fighting the bacteria "on the dry way," as it were, is good, and it certainly would be a great advantage if it were introduced as far as practicable also in our modern creameries. It has been objected that the steaming so often applied in the latter makes it difficult to follow this method; but this difficulty may be obviated by removing the steaming to a separate building, or at least to a separate room in the creamery. The separator-room ought occasionally to be rinsed and even steamed, but also here an effort ought to be made to keep the floors and air dry; in the other creamery-rooms the floors should be kept dry in the daily work. The impropriety of putting the wash-room in between the creamery-rooms, as is the case in many creameries, is evident from what has been said, as well as for other reasons.

If the rule is observed that the steaming and rinsing are to take place in a separate room, there is no reason why the floors and the air even in our modern creameries may not be kept dry. The other difficulties connected with this method are easily overcome; the same scrupulous care and neatness which formerly existed in the creameries is necessary. Strict cleanliness can very well be observed in this way, without the use of large quantities of water. In addition, regular and when necessary special scrubbings and washings of floor, walls, and ceiling must, however, also be made.

The method now commonly adopted in our creameries, viz., to remove dirt, milk, etc., from the floor through a liberal rinsing with water, offers this advantage, that it places less demands on the creamery-hands than the other method. This assertion is, however, in my opinion, founded on a misunderstanding, which is very deleterious to the quality of the dairy products. It says that the creamery-man may be relieved from paying attention to the condition of cleanliness in detail; he has to see to it that the rinsing be made thoroughly, and the rest will then take care of itself. The first man in the creamery concentrates all his efforts on the making of the butter, the running of the separators, etc., and the cleaning up and even the supervision of the same is left to his helpers, while he himself ought to care for and look after everything, and this first of all as far as the conditions of cleanliness are concerned. An abundant use of water in creameries places great demands on the condition of the creamery-rooms, as will be seen from what follows.

We often find larger or smaller cracks in the creamery floors; these places are splendid culture-beds for all kinds of bacteria. I have amused myself by examining bacteriologically the fluid which stood in such cracks in the cement floor of a creamery. An astounding sight met my eye. The large number of species of bacteria and the immense number in which most of them were found approached the incredible. No better object-lesson can be found than such a fluid, if it is desired to illustrate especially, to what an extent an object may be filled with bacteria. The fluid will, of course, contain micro-organisms in proportion to the quantity of milk remains contained in it. From what has been said it follows that the creamery floor, above all in a creamery where large quantities of water are used for washing, must be tight and even, without cracks and crevices.

The Factory Floor.—These conditions are not filled by the cement floors generally used in our creameries. It is easily cracked by bruises, and holes and crevices are thus formed in them. I have often observed in creameries, especially in frame buildings, that the layer of cement has loosened along the walls and the crack thus formed has been filled with a dark, moist mass, containing filth of all kinds, and of course bacteria without number. Cement floors are furthermore eaten up by lactic acid (sour milk). On account of all this they cannot be recommended in creameries where large quantities of water are used for rinsing. The same holds true in regard to floors of *limestone slabs;* the slabs have rarely a sufficiently smooth surface, and they often cannot be laid close up to each other. The custom to lay these slabs as closely as possible up to one another in loose sand, which is practised in many places—especially in foreign countries—hoping that the interstices soon will be filled with sand and dirt, must of course be absolutely condemned, for infection hotbeds are thereby created all over the floor. It is a better practice to imbed these slabs in cement so that the interstices become filled therewith. I have, however, observed in several creameries where such floors are found that the cement between the slabs is soon eaten up and gives way to large gaping cracks, that gradually fill up with a sticky, filthy mass. *Wooden floors* are still more to be rejected. Through the abundant washing they are kept constantly moist and are apt to soften and swell, after a while allowing water mixed with milk to run through into the ground, where a luxurious and injurious mould and bacteria growth is produced in the dark, giving off bad odors and forming a constantly threatening source of infection for the milk.

The only creamery-floor which in my experience fills the demands just given, and thus allows of a flooding of the floor, are those made of a genuine, natural *asphalt.* Such a floor is firm, impervious to water, will not crack, is not attacked by acids, does not spread any odor, can stand changes in temperature well, is not cold to walk on, and may be easily kept clean. To all these advantages may also be added that asphalt floors are easily laid and also very easily and rapidly repaired. It will not be necessary to interrupt the regular work in the creamery when such a floor is to be laid. If we begin laying the floor at noon immediately after the day's work is done, even the largest floor may be entirely done before the milk comes in the next morning.

The only disadvantages of asphalt floors in creameries is that asphalt is dissolved by oils which may drop from the machinery, and that it becomes soft and pliable under cans filled with hot water. These disadvantages may, however, easily be avoided by a little care. Dripping of oil ought in general to be out of the question with dairy machinery, and the softening of the asphalt through the effect of hot cans may easily be avoided by placing these on a wooden stand.

It is important that the creamery floor be laid at an even slant so that water may drain off as completely as possible. In this respect the asphalt floors are also very serviceable; gutters may be easily made in them, and what I consider very important, the asphalt may be laid from the floor up on the wall at least two feet, so that the lower part of the latter may be impervious to water. By this arrangement the part of the wall most liable to become soiled may easily be kept clean through rinsing and washing. The wall around the exit-hole in the wash-room should also be dressed with asphalt.

In planning and building creameries the number of corners and crooks that cannot be easily cleaned must be diminished as far as possible. Dark hiding-places under staircases, etc., floor-drains which cannot be cleaned in their whole length, and similar places where infection might start up, ought not to be found. By painstaking care in the planning and building of the factory we may easily succeed in securing these conditions for keeping its atmosphere pure and sweet.

If a tight, smooth, somewhat slanting, acid-proof floor built as directed has been secured, as abundant quantities of water as may be wished for can safely be used in keeping it clean. But how many creameries in our country fulfil such conditions? Many creameries have still wooden floors, or, worse still (in, fortunately, but few creameries), there is only a wooden floor under and around the churn while the rest of the creamery has to do with a dirt floor. The innumerable chances of infection to which the delicate dairy products are here exposed may be easily imagined. One might believe that the picture drawn applied to a past era, when dairying was still in its infancy; but such is unfortunately not the case. I have even found a separator put in a creamery with such a floor. Otherwise well-equipped creameries also often leave much to be wished for as regards the material and the grading of the floor.

When the main creamery work is done, about 1 P.M. every day, all machinery and vessels as well as the floors are of course cleaned. The floor is not washed until all other cleaning is finished, when it is washed with plenty of water and swept up with a broom. Here and there, however, some water remains in holes, cracks, etc., and if we enter the creamery an hour later we shall find the air exceedingly moist, and perhaps pools of water still left on the floors. These pools are often filled with bacteria, especially if the washing was done carelessly so that milk remained in them. To avoid this inconvenience the creamery floor should be frequently washed with *boiling-hot water*, and the washing of the floor at the close of the daily creamery work should be followed by a similar treatment. The floor will then dry more rapidly, and there will be no standing pools of water—at least not to such an extent as by the method now followed.

The great humidity of the air in modern creameries in connection with the heat usually incommoding them in summer-time produce conditions particularly favorable to bacteria and moulds. In many creameries we observe various kinds of colored mould vegetation on walls and under the ceiling. Even if spores and bacteria from these colonies do not often get into the milk they will easily infect vessels and apparatus with which the milk comes in direct contact.

Creamery Walls and Ceilings.—It is often difficult to keep ceiling and walls properly free from these growths. If the creamery has stone walls they are usually plastered and kalsomined, and cannot therefore be washed; this is, however, decidedly a weak point. In model creameries made of brick I have seen some rooms dressed with white tiles, which of course did splendid service. The walls could be washed and scrubbed as often as desired. Such tile walls may, however, prove too expensive in first cost. Two other methods of dressing the walls are cheaper, and have given satisfaction. If the walls are plastered with cement, smoothed, and several times finished with water-glass, a waterproof wall is obtained that will stand rinsing and careful washing. Such a wall is not so good from the standpoint of cleanliness, however, as it is grayish, which in my opinion is a serious drawback, since dirt cannot at once be observed on it. Walls satisfactory also in this respect may be obtained by painting the cemented and smoothed wall with white oil paint; this, however, will come a little higher than applying a dressing of water-glass. Wooden walls may also be made very neat by being painted white, and are then easily cleaned. The ceiling in the creamery-rooms must likewise be kept free from dirt and bacterial growth; they had therefore better be dressed in the same way as the walls.

Airing of Apparatus.—All woodwork in the creamery should be well painted. As often as practicable all loose wooden utensils ought to be carried outside into the open air and sunshine, to be dried and ventilated. In some creameries many utensils are unnecessarily massive and clumsy, making it difficult to carry them outside. The creamery-hands therefore soon grow tired of handling them and leave off the airing process, the result of which will soon be seen, however. I have often in Finnish creameries met with large working tables which have had colonies of molds and bacteria on the outside; having never had a chance to dry properly in the open air they were soon attacked by bacteria. In many creameries large and heavy boxes for cooling the butter are now being introduced; the small cooling boxes previously used were, in my opinion, considerably better, for the reason given. Water-soaked and rotting wood ought never to be found in butter or cheese factories. I suppose it is from such wood that the peculiar factory odor largely arises.

Ventilation of Factories.—In order to avoid the heat in the factories in summer-time the sun is usually shut out by blinds or curtains at the closed windows. The heat is certainly diminished in this way, but at the same time the creamery loses the disinfecting influence of sunshine and daylight; the darkness produced is favorable to the bacteria and the ventilation is checked. Awnings are in some ways preferable, as the windows may then be kept open and a draught created. Many creameries are not ventilate during the day, but only during the cool evening and night. This method cannot, however, be recommended, since the air purified by sunshine and daylight is especially wanted. By ventilating only during the night a moist atmosphere is let into the creamery, producing a wet coating on walls and ceiling. A certain coolness is obtained in this way, but it is bought altogether too dearly. A cool atmosphere may be produced in the creamery, e.g., in the same way as in breweries—by means of refrigeration machines producing cold and dry air. An apparatus which I have seen used in a small brewery, and which ought to be adapted to creameries, is the *Luftkühl-apparat*, patent *Honerla.* It is simple and easily worked; by means of a fan the air is forced into a funnel-shaped iron vessel where the cooling material (ice) is kept. The lower part of the vessel is divided into several compartments by shelves, between which the melted water runs down and the air rises up toward the ice. The air is thus comparatively cold when it reaches the ice, and a too rapid melting is avoided. If the ice be mixed with one-tenth part of salt, the cooling becomes still more effective. The apparatus is comparatively cheap (about $125).

As the creamery-rooms may be kept properly cool by the use of this or similar apparatus, it is not necessary to ventilate less on account of the heat. The admission of large quantities of pure fresh air into the creamery-rooms is one of the best means of working against the spreading of factory odor. All rooms ought to have ventilators, preferably both at the floor and the ceiling, and should be supplied with large windows which may be opened.

The effort to keep the air in the cheese or butter factories pure may be made very difficult and sometimes even impossible by an irrational arrangement of the various rooms in the factory. We find in many places that, e.g., the cheese-room is directly adjoining the churning or separator-room, although it is plain that the very bacteria active in the ripening of the cheese are the worst enemies to the keeping quality of the milk and butter, and may easily infect the adjoining rooms. We often see even the engine-room, with its atmosphere filled with soot and odor of oil, directly joining the separator-room; and frequently we find the room of the creamery-man opening into the milk-room. Bad arrangements of the rooms may plainly be fatal to the products made there, and, like a secret disease, all the time prevent the business from paying.

The Surroundings of the Factory.—In connection with the question of the necessity of fresh air stands the rule that every factory ought to have neat surroundings, a rule against which nearly every factory in our country sins in one way or another. In order to obtain purer air in the factory through ventilation it is, however, essential that the air outside be purer than that inside. In spite of this but little care is in most cases taken of the many conditions which may infect the air in the vicinity of the factory. A few examples will illustrate the truth of this statement.

Drainage.—What is the usual manner by which the wash and drain water when once outside of the creamery wall is prevented from stagnating and spreading bad odors? In numerous instances no effort whatever is made to prevent it. In the worst cases slop-water is allowed simply to run under the floor and from there spread odors and infectious bacteria by the million. At other factories, again, it is left to stagnate just outside of the building and even dry off there, which of course causes the soil to be mixed with enormous masses of bacteria; when the wind sets the air in motion immense quantities of infectious matter gain access to the factory through windows, ventilators, and doors. This immigration of bacteria from the outside may also take place in other ways. According to my observations, many bacteria especially injurious to the quality of the milk usually thrive in such stagnating factory slop-water. I have found species of *tyrothrix* in such water, and also other of the putrefactive bacteria enumerated in the preceding chapter.

The proper drainage of the slop-water is therefore of the greatest importance. Sub-earth sewers are in most cases to be rejected, since it is almost impossible to keep them properly clean. Only in cases where they can be properly cleaned by steam ought they, in my opinion, to be tolerated. Open sewers seem better, being more easily cleaned and watched. In the Danish bill concerning Co-operative and Proprietary Creameries (1888) it is specified that "the slop-water is to be conducted from the creamery by paved or cemented gutters or glazed tile with a sufficient fall, to water-proof brick cisterns situated at least 100 feet away from the creamery building, its well, and other buildings, provided they are occupied." "The cisterns must be cleaned and disinfected according to the further directions of the inspection committee" (Sanitary Commission).

Location of Factories.—We see the proof of how poorly is understood the importance of the proper removal of drainage water for the successful conduct of the creamery business; in creameries being situated so as to make it impossible to get rid of the slop-water without great expense. At such places as these no creamery should of course ever have been built. It is evidently absolutely impossible to keep the air pure and fresh in a creamery located near a barn yard or a hog pen. It is not so generally understood as we *a priori* should suppose, however; for here and there we find creameries whose location testifies to the ignorance of the owner in regard to this simple point. In the Danish bill just mentioned the distance required between the creamery and hog-pen is at least 50 feet. Another mistake often made in locating a creamery is to place it at a lower point than the barn and manure-pile. On a dairy farm in our country I found, e.g., that the liquid manure drained off alongside the creamery, the ventilation of which was largely from the side where the drainage went.

Even at factories where such glaring mistakes as those mentioned cannot be found, there is often one thing or another to criticise concerning the location. We thus often see the factories erected close up to the highway, from which dust clouds during the summer are scattered by teams and wagons. That a serious infection of the milk may arise from road dust is plain from the fact given by Maggiora that one gram of road dust ($\frac{1}{28}$ of an ounce) at Turin usually contains not less than 78 millions of bacteria. By investigations in our country I have never obtained as high figures, but my analyses have also shown that road dust contains immense quantities of bacteria, and I have found among these such as may injure the keeping quality of the milk. If a factory is located too near the roadside it is furthermore impossible to undertake the very necessary airing of utensils—a disadvantage which is by no means of small importance.

It is, however, absolutely necessary to be able to reach the factory with teams. To avoid infection through dust the road up to the factory should be paved, and during hot days sprinkled and swept. It is greatly to be recommended to plant trees and keep a lawn around the factory. Close up to the factory there must not be tall trees, however, as they will throw too much shadow, and prevent the light from properly purifying the factory air. Large groups of shrubs keep the ground moist, and if near the wall will produce rot and moldiness. A small, neat, ornamental garden with old linden trees and some groups of flowers and shrubs here and there has this further advantage, that they not only increase the feeling of well-being of the factory hands, but also to a great extent sharpen their eye and sense for neatness and good looks.

It is very difficult to keep a factory clean for any length of time in a dirty and poorly kept location: even if it is nice-looking and neat when built, so that it forms a real oasis of cleanliness among the disorder of the surroundings, it will pretty soon be impossible for the factory-hands to keep it so. Their eye for neatness and cleanliness will be gradually dulled, the fight against filth become more and more hopeless every week, and finally they meet and become accustomed to slovenliness in the factory itself.

The Farm Dairy.—On many farms the dairy house is also used for other purposes than those for which it is intended. I need hardly mention the mistake of using it for the storage of all kinds of food articles, as is the custom at many smaller farms; these fill the air with the smell of food, which is easily communicated to the milk; with the articles of food, molds, dust, etc., are furthermore often brought into the dairy.

A mistake of similar nature, which we are surprised to find also at many large places and which cannot be too strongly condemned, is that the washing takes place in the dairy. The dairy stands vacant for several hours every day, but if it is used for washing and steaming of clothes during the interval it cannot be properly dried out and aired before the dairy work again begins. And what is still worse, by using the dairy for this purpose a great deal of dirt and infectious material is brought into the dairy. There can be no doubt that typhoid and other disease bacteria have in this manner found their way into the milk.* It must therefore be pronounced a gross mistake in the dairyman if he permits the use of the dairy for this purpose.

Disinfection of Factories.—In spite of all care and precautions the bacteria will sometimes get the upper hand in some butter and cheese factories. In well-conducted factories this ought never to happen, but many of them are so arranged and equipped that it is impossible to observe the rules of cleanliness in all respects in them. At such places where the bacterial growth cannot, then, be checked by ordinary means, it is necessary to fight the bacteria directly by arranging a disinfection of the factory or parts of it. We note in this connection that in dairy practice disinfection is often confounded with deodorization. It is not sufficient to destroy the odors which putre-

* See Welply, "Creameries and Infectious Diseases" (abstr. in Exp. Sta. Record VI., p. 481).

factive and other fermentative processes produce in the creamery, but the bacteria themselves must be killed or their development and reproduction must be checked. Disinfection must therefore be considered far more important than deodorization; the latter cannot, however, be neglected in the dairy practice, for dairy products, especially milk, are extremely sensitive to all odors.

On account of this sensitiveness a good many disinfectants, as carbolic acid, chloride of lime, etc., cannot be used for factory disinfection. Nor is it advisable to make use of poisons, as corrosive sublimate, in the disinfection of a butter or cheese factory, although these are very effective.

Lime is used at several factories as a disinfectant, especially in case of acidity in milk utensils, etc. The disinfecting quality of this substance is, however, comparatively small. Liborius concludes from lengthy investigations that lime-water checks the development of micro-organisms, but cannot destroy them completely. Migula recommends to disinfect the yard outside the factory, floors, etc., by a repeated sprinkling of a freshly prepared solution of slaked lime.

Chloride of Lime is applied in breweries for this purpose, but both on account of its strong odor and its cost it will not be found adapted to creameries. *Vitriol of zinc* is, on the other hand, a very suitable disinfectant; it is reported to kill bacteria, and is also cheap. Other vitriols, as *copperas* and *blue vitriol*, may also advantageously be used, since they not only destroy bacteria, but prevent the rise of bad odors in the creamery. On account of its poisonous character blue vitriol must be applied with care; copperas is cheap. Alexander Müller recommends a preparation made at Meyer & Riemann's chemical factory in Hamburg for application in creameries, containing

Sol. iron sulfate	63%
Iron oxide	17%
Chem. combined water	20%

This powder is mixed with about 20 parts of water in a wooden pail, the mixture stirred and used after standing for a while, until the precipitate does not color the water yellow or until the water no longer gives a distinct taste of ink. After having been well washed the floor is sprinkled with the mixture by means of a broom, and then rinsed with pure water. If the sewer-pipes and sewer-boxes are not deodorized through the action of the disinfecting fluid, some of the vitriol is sprinkled in them in solid form. In applying this chemical it may be noted that clothes or wooden materials with which it comes in contact will be colored brown from the iron in the liquid.

Chlorin Gas may be applied for deodorization as well as for disinfection; potassium permanganate is, however, to be preferred, and does splendid service. If substances possessing bad odor or taste are dipped into a weak solution of permanganate they will be freed from these undesirable qualities. The substance is entirely harmless, but is unfortunately comparatively expensive.

Water for Factory Purposes.—As is apparent from the preceding, water plays an important part in the management of the dairy business, and it may therefore be in order to further explain the conditions which influence its quality.

If sufficient quantities of spring-water or good well-water are at hand it is comparatively easy to keep the creamery clean. But, especially during the spring floods, many of our factories have to be satisfied with an impure water, rich in micro-organisms which may directly contribute to the infection of the factory.

As we have seen before, water is generally an excellent nutritive medium for a large number of bacteria, which thrive the better in it the more it is polluted with organic substances and the less it is exposed to the air. We often see brick-laid wells covered so that ventilation is rendered entirely impossible. I have heard complaints of the quality of the water at every factory where I found this was the case. In the Danish bill for Co-operative and Proprietary Creameries previously mentioned it is stipulated that the wells of the creameries should be located in such a way as to prevent impure water from flowing into them. New creameries are to be located only where plenty of good water may be obtained.

The solid particles and impurities found in the wells seem to affect the bacteria content of the water. It has been proved by special investigations that bacteria in wells multiply best in the immediate neighborhood of solid matters, even if these are as unfit for nutrients as stones. A properly-kept well ought therefore to be free from all unnecessary solid substances. It is further of importance that the well be not long left unused. The best way to keep the water pure in a well is of course to empty it as often as possible. Heraeus says on this point: The best well may, if used only a little or not at all, yield water with thousands of bacteria capable of reproduction in every cubic centimeter, and the poorest well may be so improved by continual pumping that its water will contain but few bacteria.

The bacteria content of well-water depends to a large extent on its origin. If it comes directly from the surface it will, especially during the hot season, be very rich in bacteria, since surface-water generally goes through fields, roads, and other places rich in bacterial life. In a good many of our factories this danger of surface-water leaking into the well has not been realized. Such water may in several creameries run directly into the well or down through the leaky woodwork; this explains why many creamery-men complain that they cannot use the well-water after a heavy rain.

Even if the surface-water does not run into the well, the water may contain bacteria in large number, according to the stratum of the earth from which it is derived.

The earth acts on the whole as a filter, retaining the bacteria. We therefore find the largest number of such organisms in its upper layers. In the surface layer of sandy soil (in Berlin) Frankel found 45,000–350,000 bacteria per cubic centimeter, while Reimers in the surface layer of a clayey soil (in Jena) found 160,000–2,500,000 per cubic centimeter; both investigators ascertained that the largest quantity was not found directly on the surface, but a little below the same—a fact which is perhaps explained by the fatal action of the light on the surface bacteria. From maximum at a few inches below the surface the bacteria content of the soil decreases rapidly as we go down. Frankel found only 200–2000 bacteria in soil three feet deep, and four and a half feet below the surface the soil was generally free from bacteria. In Jena absolute sterility of the soil does not appear until at a depth of six feet. These facts corroborate the observation made by both investigators mentioned, that the deep water proper is always free from bacteria. Frankel's investigations show that this is the case even where the water is derived from strata of the earth under highly polluted places. Artesian well-water is therefore as a rule sterile.

The water in a creamery well ought of course preferably to come from deep-soil layers. By digging a deep well another advantage is secured from the fact that the deeper the layer from which the water comes the colder it naturally is, and, as is well known, a low temperature will check the bacteria to a large extent. In comparing the rapidity in the development of the same kind of bacteria from the upper strata of soil and from lower strata Reimers found that the latter showed a considerably slower development (*Wachsthumsverlangsamung*) than the former —a relation which appeared the sharper the deeper the well.

In case of doubt whether the water available in a creamery is fit for use, it will not do to make only a chemical examination, but it must also be analyzed bacteriologically. The difficulty with the latter examination is, that the sample must be analyzed as soon as taken. It cannot therefore be sent away for bacteriological examination, but the bacteriologist himself must take the sample and begin the analysis at once. If the bacteria in the sample get time to increase before the examination is made, it will not be possible to find the original bacterial content of the same. Owing to the fight between the different kinds of bacteria mentioned in the preceding chapter, the true relation between the different forms can then, furthermore, not be ascertained—a point which is of course important in judging the applicability of the water. Heraeus fixes as a standard for good drinking and well-water that it must not contain more than 500 bacteria capable of development per cubic centimeter. Plagge and Proskauer consider the upper limit 300 per cubic centimeter, while others place the standard still lower.

The milk and its products often come into most intimate contact with water in the factory. Small portions of water will remain in every can, in the churn, in vats, on the worker, etc., so that the milk throughout its handling and manufacturing may be infected by bacteria found in the water. It will not therefore be surprising that we have dwelt at length on the importance of the quality of the water in the factory and the care of the well.

Purification of Water.—It would of course be preferable to entirely remove the bacteria from the water to be used in the factory, but this would be too expensive. Breyer's "micro-membrane filter" is recommended by several parties for use in factories and is said to deliver sufficient water. The water is in this apparatus filtered through specially prepared asbestos disks. Chamberland's filtering apparatus also performs this cleaning process very well, but the capacity of the apparatus is generally much too small to be adapted to factory use. At all events it is so expensive to remove bacteria from the water by such apparatus that it will hardly be generally adopted in factories.

It is, however, the duty of every factory-man to keep the water in the factory as pure and free from bacteria as possible. He must first of all see to it that the well fulfils fair demands in regard to the conditions mentioned, and that the water is always used as soon as pumped. By standing in the warm factory a far greater number of bacteria may develop in the same than was originally found in it. In some cases it will prove of advantage to free the water from coarse impurities by means of a sand or animal-charcoal filter. A simple and practical water-filter has been constructed by Paasch in Horsens, Denmark. In an iron cylinder about three feet high and one foot wide were placed six different layers, viz., small pebbles, gravel, sand, charcoal, rusty bits of iron, etc.; the layers were separated from one another by means of perforated false bottoms. The apparatus is very easily cleaned and kept in order.

The water used for rinsing vessels in which milk or its products are to be handled ought in one way or another to be made germ-free. If allowed to evaporate in or on the utensils it leaves on them not only all visible impurities it may happen to contain, but also substances invisible to the naked eyes, as bacteria. The special treatment necessary for preventing infection by the water may, in my experience, be of two kinds. The more common way in dairy work is to *sterilize the water* through boiling before using it; where boiled water cannot be used, *melted ice-water* with pieces of ice still floating in the same is often applied.

Sterilization of Water.—Both these methods may be recommended for factory purposes. The boiling is done by heating water with steam in clean tin cans after finishing the other work of the day; the cans are then covered so that dust cannot get into them, and the water is cooled as rapidly as possible. The majority of the bacteria and spores found in it will be killed by this treatment, and the development and multiplication of the few surviving ones will be checked.

Use of Ice-water.—The method of applying ice-water in dairy work must be spoken of a little more at length. Many investigators have proved that ice may contain a large number of bacteria. Frankel found ice from the river Spree to contain between 20 and 6000 bacteria per cubic centimeter. Ice from rivers and lakes close by cities and factories will contain a large number of bacteria; conditions, as whether the ice sampled was formed near by the shore or out in the open lake, at the surface or farther down, will also cause great variability in the results found by analysis.

Bacteria in Ice.—Although we may find a considerable number of bacteria in ice under certain conditions, it is, however, a fact that every time water freezes its bacterial content is considerably diminished. Frankel's investigations show this plainly. Water from the river Spree containing 6000 bacteria per cubic centimeter froze at 10°–18° F. After two days one cubic centimeter contained only 1200 bacteria, and after nine days only 14. In another sample 3300 bacteria were found per cubic centimeter at the beginning of the experiment and after three days' freezing only 20 bacteria in the same volume. A third sample, which was highly infected with bacteria, containing not less than 500,000 bacteria per cubic centimeter, showed only 36,000 per cubic centimeter after six days' freezing. The freezing is therefore a powerful means against the development of the bacteria in the water.* It is in reality of no great importance that absolute sterility cannot be obtained in the water in this way, as the bacterial content by this method will be extremely small, provided the water is not highly infected before the freezing.

In the bacteriological analysis of ice which I have made I have obtained greatly varying results, according to

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* See foot-note on p. 134.

the origin of the ice. In examining thick lake ice in the centre of a large block of ice the analyses proved it to be entirely free from bacteria. On the surface of this block, which was exposed to infection during the cutting, hauling, etc., an appreciable quantity was, on the other hand, found ranging from 20 to 400 per cubic centimeter. Only one inch deep no bacteria was usually found; sometimes, however, a couple of bacteria colonies appeared on the gelatine plates in the bacteriological analyses. The block of ice was taken from the lake in March and hauled to an ice-house; the analyses were made in the following August. Even porous, soft ice has proved very poor in bacteria, sometimes entirely sterile, if it did not come from the surface layer. This was found to be the case in ice taken from a lake where no city or factory was situated. The results of analyses made of ice from the harbor of Helsingfors were different. They showed that the water must have been very rich in bacteria before the freezing, for about two months after the harbor was frozen over, the ice contained between 260 and 3500 bacteria per cubic centimeter. The material for these analyses was taken by myself from the ice in the harbor. No ice free from bacteria was found in this place.*

* Russell (*Med. News*, Aug. 17, 1889) gives bacteriological analyses of ice from Mendota Lake (near Madison, Wis.). No factory is found on the shores of this lake, but it receives a good share of the sewage from about 15,000 people. The number of bacteria per cubic centimeter of ice varied greatly, viz., in 62 trials from 14 to 1249, the average number being 270. The bacteria content of the lake water varied from 3 to 3167, the average being 684 per cc. About 60 per cent of the bacteria were thus lost by the freezing. Prudden (*Med. Record*, **31**, 344; see loc. cit.) claims that 90 per cent are destroyed by freezing; while Frankel (*Zeit. f. Hyg.*, **1**, 308) has

My investigations concerning the bacteria of ice have also proved another fact, which still more confirms my opinion that recently melted ice-water is to be preferred even to very pure well-water in the dairy work. The investigations showed that in case of bacteria remaining in the ice for a long time their virulence, i.e., their power to develop their specific qualities, was greatly diminished. Their multiplication took place very slowly, and where the bacteria were made up of fermentation-starters, the fermentation developed considerably more slowly and less intensely than was usually the case. I also observed that some of the ice-water bacteria which did not show any fermentative power on the first inoculation cultures, after having later reached their normal conditions again possessed this power. The investigations were made both with lactic-acid bacteria and putrefactive bacteria. The former, which caused a complete fermentation in milk before the freezing by being kept for twenty-four hours in an incubator at 86° F. (30° C.), were unable to produce even something like a similar characteristic fermentation in several days after having been inclosed in ice for two weeks. The phenomenon is analogous to that which Reimers (see p. 130) observed concerning the bacteria from the deep layers of the earth, and also to that shown by me

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shown that "while in some cases the loss may reach as high as 90 per cent, it is ordinarily much less."

Comparative analyses of white and of transparent ice, made by Russell (*loc. cit.*), show, as the average of 153 determinations, that the latter kind contained a smaller number of bacteria than the former ("snow-ice"); but in several cases a larger number of bacteria per cc. was found in clear transparent ice than was found in any sample of snow-ice.—W.

in 1888 concerning the behavior of the lactic acid bacteria after repeated inoculations in sugar-free gelatine.*

Putrefactive bacteria appearing in the ice also showed a considerably diminished peptonizing power. By inoculating for a long time slightly virulent bacteria of this kind successively on new fermentable mediums I have again been able to awaken their fermentative power and gradually return the normal virulence to the organisms.

Uses of Purified Water in Factories. In some cases boiled water had better be applied in creamery and dairy work, and in other cases recently melted ice-water had better be applied, as will be apparent from the following examples:

The last rinsing of milk vessels ought always to be made with boiling-hot water. By this we gain both that the vessel dries more rapidly and that the water in evaporating does not leave behind living bacteria. The same is true in rinsing the churn, butter-worker, and all other utensils coming in direct contact with milk, cream, or butter.

Before the cream is poured into the churn the walls of the latter ought to be given the temperature proper for churning by the application of recently-melted ice-water. When the butter, as is often the case, especially in making "Paris butter," is to be washed in the churn we ought generally to use water of comparatively low temperature, according to the experience gained at several creameries. 40° F. (4° C.) is considered the best temperature at many places. Water containing pieces of ice is well adapted to this purpose; the pieces of ice ought not, of course, to go into the churn.

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* "See Saprofyta mikro-organismer i komjölk," pp. 36–42.

CHAPTER V.

MILK FOR CITY CONSUMPTION.

It does not come within the range of this work to treat this subject exhaustively. I cannot refrain, however, from referring to certain phases of it, since we may then learn the manner in which milk is usually kept when intended for direct consumption, and will have an opportunity to explain the causes of some difficulties which city people meet in their efforts to keep milk sweet. The treatment of the milk before it comes to the household plays, of course, an important part as regards the question of its keeping quality, as may be inferred from the preceding. I want to impress on housekeepers, first of all, that they must not buy milk blindly: they themselves should investigate the conditions on the farm where the milk used in their household is produced. This is easily done where the milk is obtained from a farm in the town where they reside; but even if the milk comes from the country they should not neglect to inform themselves concerning the conditions of cleanliness in the stable. This is above all necessary to insure one's self against the spreading of contagion through the milk, a danger which has not been treated in this book, but which cannot be disregarded. Such an investigation is the only way in which a housewife can protect herself against obtaining unclean milk. If the milk-producers were under the special supervision of the consumers it would act highly beneficially and educationally for the whole milk business; with their naturally higher sense of cleanliness the housekeepers would be able to call the attention of the milkman to many conditions deleterious to the cleanliness of the milk that may not have come under his observation.

Their influence is especially necessary for starting a reform regarding stables situated in small towns; according to my observations these are generally almost below criticism, as far as cleanliness is concerned. My investigations of the milk from different city stables have further verified this fact.

On approaching such a stable we find stinking manure and other filthiness outside the door, and the air in the stable and around it as a result becomes intolerable, especially on warm days. The stable air is often so bitter and sharp that it makes the eyes of the visitors smart, and when the door is closed complete Egyptian darkness reigns. This darkness has a bad influence on the keeping quality and palatability of the milk, as is plain to every one who has studied the preceding chapters. Still more shocking than the accommodations are the animals in such a stable. They are usually dirty and unbrushed from horns to tail, and manure particles may be seen all over their bodies We readily see how these conditions will influence the milk produced by the cows.

The filthy condition of many of these stables arises first of all, I suppose, from the fact that they usually are very narrow, dark, and poorly arranged, but other factors also contribute to the result; litter is expensive in cities and towns, and the cows are fed large quantities of concentrated feeds, brewers' grains, distillers' slump, etc., which produce a very soft and stinking manure.* It is expensive to preserve cleanliness under such conditions; but, on the other hand, such farms pay better than those in the country, and their owners ought therefore to be willing to go to somewhat greater expense. It is deplorable, however, that in most cases they do not even pretend to keep their cows clean.

We saw before (see page 87) that a milk examined half an hour after milking on three consecutive days contained the following number of bacteria per cubic centimeter: 730,000, 560,000, and 780,000. This milk came from a village cow-stable of the kind just described; its taste was, strange to say, very good, and it gave the impression of being unusually rich, But it very soon spoiled; although kept on a window-sill at a temperature of about 45° F., it coagulated slightly and turned "off flavor" after only ten hours. The examination spoken of took place in April. Analyses of milk from similar farms gave also bad results, although the bacteria content was not as large as in the case mentioned.

The explanation that such milk can be used in households in spite of all it has gone through lies in the fact that it is rapidly consumed. It is delivered to the customers as soon as it is milked, and often consumed a couple of hours afterwards.

* Soxhlet states (*Münch. med. Woch.*, 1891, No. 19) that feeding stuffs causing frequent evacuations of a thin dung favor the contamination of the milk, since they make it more difficult to keep the cows clean; to these belong sour distillers' slump, root leaves, diffusion chips, etc. The potato bacillus present in distillers' slump furthermore makes the milk liable to abnormal fermentations; hay-dust contaminates the milk in a similar way. See also Auerbach, *Berl. klin. Wochenschr.*, 1893, No. 14.—W.

Coming now to the milk furnished by farms in the country, we find of course better conditions in many respects. We have here two different kinds of stables—primitive and comparatively modern ones. The former remind one in the main of the village stables just described, although they are a good deal better. The building of the stable, the lack of windows, and some other conditions are similar in the two cases, but the cows in poor country stables are generally much cleaner than those in town stables. Litter is more plentiful in the country, and the feeding of the cows is seldom so intense as in the city. This superiority of old country stables is, however, only relative; if we compare them with the modern stables in the country the judgment would be entirely different.

I have only had occasion to analyze milk from such farms a few times. As already stated, a sample of milk produced in such a stable was very strongly infected with bacteria five hours after milking.

We meet with better conditions and better results in examining the country farms equipped and conducted in a modern manner. Conditions are also here found, however, which need improvement, as may be inferred from the description in Chapter II.

The milk furnished to city households is not consumed until after a shorter or longer transportation. As the milk becomes more or less contaminated in every stable, it must be strained and cooled immediately after the milking. If the milk is properly cooled before the transportation it will not be necessary to cool it during the same, provided the distance is not too great: it need then only be protected from being warmed which may be effected by placing the milk-cans in double-walled boxes, the walls of which have been packed with dry shavings, saw-dust, or similar material.

The milk should of course be delivered to the consumers as soon as possible after having been drawn; but in many cases it is impossible to so arrange matters as to bring it directly into their hands, and it is left at some "milk-depot" in the city.

Milk-depots.—Fortunately the milk-depots in our larger cities, thanks to the vigilance of our health officers, have of late improved in many ways. Some features, however, need further examination and subsequent change. A milk-depot ought to be as neat, light, and clean as a creamery, and should have many of the facilities of the latter at its disposal. The salesroom should be arranged so that the customers never need come near the milk-room. The milk is to be cooled to prevent any bacterial development worth mentioning from taking place in the same. The temperature of the milk ought never to exceed 45° F. Sour and sweet milk must not be kept in the same room; nor should cheese or other articles of food be kept together with sweet milk. If some milk is spilled it should immediately be wiped up. As regards the floor, the same holds true in the main as already stated concerning creamery-floors. Neatness must be everywhere. The supply of ice should not be scant or even entirely lacking, as unfortunately is no unfrequent occurrence in many milk-depots.

Care of Milk in the Household.—When the milk has reached a city household it seems to be a general supposition that it requires no further care. It is argued that if it is good it will keep; if it is poor and sours soon we change milkmen. This reasoning is, however, unjust to both parties concerned. It is fortunate that the milk in cities is consumed so soon, for otherwise the injurious results of this careless treatment would oftener show themselves.

Milk kept in the dark in covered and unventilated cupboards often does not sour, but assumes an insipid, sickening, or bitter taste, and shows distinct signs of putrefactive fermentations on standing for a longer time. This led me to investigate why especially putrefactive bacteria gain the upper hand in such milk; and I found that the conditions of light are first of all the causes of it.

Although bacteria, generally speaking, develop best in the dark, we observe in some a greater dislike to light than in others. Bacteria of milk may be separated in two distinct groups, according to their behavior in this respect.

1. Those that can stand daylight without injury.

2. Those that develop only with difficulty in daylight. The lactic-acid bacteria belong to the former group, and the great majority of the putrefactive bacteria and the butyric-acid bacteria to the latter.

If the milk-room is airy and well ventilated as well as light and clean, we can conclude with a great deal of certainty, provided the milk has been properly handled at the farm, first, that a comparatively small number of bacteria is found in it, and second, that putrefactive bacteria are in the minority. The lactic acid bacteria, which are practically everywhere, will then thrive best, and keep the putrefactive bacteria in check—at least as long as the nutritive conditions are favorable.

Sometimes a slight acidity in the milk can also be discovered by chemical reactions: this has arisen partly through the lactic-acid bacteria, which owing to their unusual powers of resistance can if only in a small degree, develop their specific qualities, and partly because bacteria forming other acids in the milk have been able to develop. Even some moulds which do not seem to have any special liking for the light play a certain part in these changes of the milk.

Considering what has been said, we cannot be surprised that the putrefactive bacteria gain the upper hand in milk kept in dark, small, city cellars or pantries.

One of the reasons why milk spoils so soon in old and poorly ventilated milk-rooms and depots is, that the infection is allowed to become more intense and thorough with every day, as the rooms are not thoroughly cleaned as often as necessary, and are never disinfected. A mass infection may therefore easily arise by the least motion in the room, and the fermentation in the milk will have a good start. To this must be added that the temperature in such milk stores and rooms is often very high. Whenever possible the milk ought to be kept on ice; but where ice is not available a too high temperature may be avoided by taking simple precautions, as, for instance, by a system of ventilation, by keeping the milk in cold running water, etc.

One side of the question which cannot here be treated fully is, that milk kept under bad conditions may easily become dangerous to human health. I shall here only point out that the conditions favoring the development of the bacteria inimical to the keeping quality of the milk are also favorable to bacteria injurious to human health; in fighting the former we therefore at the same time counteract the latter.

CHAPTER VI.

STERILIZATION OF MILK.

We have seen in the preceding chapters that it is impossible to obtain a product of absolute keeping quality by our common methods of handling the milk. It is well known that the comparatively poor keeping qualities of the milk cause great difficulties in its handling and sale, and efforts were already long ago made to preserve the same so that it could be better kept and more easily handled in the trade.

The simplest and most natural method of preserving the milk has already been mentioned several times, viz., to cool the milk sufficiently. It is hardly practicable in the trade, however, as it is expensive and inconvenient constantly to surround the milk with a cooling medium. This is, nevertheless, the only way to preserve the milk without its losing its original qualities; all other methods cause greater or smaller changes in the chemical composition of the milk, its taste, appearance, etc.

Use of Chemicals.—A method which has long been applied and as long been objected to, is to add all kinds of antiseptics to the milk, *salicylic acid, boracic acid,* etc.; these substances partly kill the bacteria themselves and partly prevent their growth; such milk is often sold as "improved milk," but ought properly to be called simply adulterated milk.

Salicylic acid seems to be the more common chemical used for preserving milk. It has, however, serious disadvantages. Not more than 75 centigrams per liter (about 10 grains per quart) can be applied before its characteristic taste appears too strongly. By the application of this quantity the coagulation of the milk is retarded, but its acidity increases. It is besides notable that the antiseptic influence of the salicylic acid appears best if the milk is kept at the temperature of 68° – 77° F.; at 77° – 104° F., e.g., it can hardly be observed. Bersch states that by an addition of .1 to .2 gram of salicylic acid to one liter of recently-drawn milk it may be kept sweet for six days longer than it would if it had not been treated in this way. As regards the injurious effect of salicylic acid on human health, Kolbe claimed to have proved that this acid is excreted very rapidly from the full-grown animal body, for which reason no injurious accumulation is to be feared in consuming an article of food preserved with it; but the application of salicylic acid for the preservation of milk is at the present time condemned from a hygienic point of view. For this reason its use is, e.g., in France entirely prohibited as a preservative of food products.

Borax and *boracic acid* also are often used for preserving milk. As early as 1883, however, Forster warned against the application of these substances for the object mentioned, as even in small doses they exert an injurious influence on human digestive organs. Many other scientists, as Bersch and Duclaux, express themselves in the same direction.

The addition to the milk of one or the other substance must always be considered an adulteration in case the consumer is not informed thereof; for such substances change the natural condition of the milk and hide its true quality.*

Condensed Milk.—Another method of preserving milk, to which great hopes were attached in the past, is to prepare condensed milk in hermetically-sealed tin cans. About twenty years ago a large number of expensive and magnificent factories were erected for this purpose in various countries, but only comparatively few were able to operate for a long time. The products did not, as anticipated, prove of such quality that it could find a good market anywhere, for which reason they are now used only in cases where other milk cannot possibly be obtained, as for instance on

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* The indiscriminate use of preservatives in food articles ought to be prohibited by law; this is especially urgent in case of such articles as milk and other dairy products, which in a large measure enter into the nutrition of children and convalescents. Most European countries long ago prohibited the addition of salicylic and boracic acid, and other antiseptics in food, e.g., Germany, Holland, France, Austria, Spain, Italy, etc. Mr. Hehner, the President of the Society of Public Analysts of England, in the November 1890 meeting of the Society, read a paper on Food Preservatives (see *Analyst*, **15** (1890), p. 221), in which he forcibly sums up the question in the following paragraph:

"We should work for the entire prohibition of all kinds of preservatives. It is time that we went back to natural food. I object to being physicked indiscriminately by persons not qualified to administer medicine whilst I am in health. I object still more when I am ill. I object still more strongly to have my children physicked in their milk or their bread and butter. It is no consolation to me to know that the physic is not immediately fatal or not even violently injurious. The practice is utterly unjustifiable, except from the point of view of a dealer who wants to make an extra profit, who wants to palm off a stale or ill-prepared article upon the public."—W.

long voyages, in mining districts, etc. That this industry at the present is not insignificant, however, is apparent from the fact that according to official statistics not less than 520,000 boxes were exported from Switzerland during 1888, each one containing forty-eight one-pound cans of condensed milk. The value of this export article was calculated to be about half of the value of the export of Swiss cheese from Switzerland.

Two different methods are mainly used for the preparation of condensed milk. In the older one of these, adopted, e.g., in the factories in Cham and Guni of the Anglo-Swiss Company, sugar is added to the milk in the process of manufacture. The main features of the method are as follows: The milk is repeatedly heated to 158° – 176° F. (70° – 80° C.), and evaporated in vacuum-pans; 40 to 50 grams of cane-sugar is then added for every liter (quart) of milk. By this method the milk is sterilized and its water content reduced to only one fourth of the original bulk. The final product is a thick, syrupy mass containing all the nutritive components in the milk. Chemical analysis of this condensed milk shows its composition to be 23 to 26 per cent water, 6 to 11 per cent fat, 8 to 10 per cent casein, 53 to 57 per cent sugar, and 2 to 3 per cent ash.

In the other and later method for condensing milk no sugar is added, and the product does not therefore obtain the exceedingly sweet taste which makes the condensed milk prepared according to the former method objectionable to many persons. This method is applied, for instance, at the factory Schuttendobel near Hartzhofen in the Bavarian Algauer Alps, and is described in the following manner:

As soon as received the milk is cleaned from the dirt contained in it by means of a separator, and is then evaporated in a vacuum-pan till it contains 37% of dry substance. The condensed milk is filled into tin cans by a special measuring and filling apparatus, and these are then soldered and heated in the sterilizer under steam-pressure. This method seems to possess many advantages over the first-mentioned one. The condensed milk is free from milk dirt, has no disagreeable sweet taste, and contains always the same quantities of water; it has therefore always the same consistency.

As already stated, the condensed milk has not found application on the milk markets proper, although its keeping qualities have been all that could be wished for. Its consistency is too different from that of ordinary milk, and its price has been too high. The effort has therefore been made to preserve milk by sterilization without changing its physical properties. This sterilization of the milk may be effected in two different ways: first, *by filtration*, and second, *by heating*.*

Sterilization by Filtration.—Different kinds of mate-

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* I pass by the method of sterilization by means of oxygen or carbonic acid under combined pressure and low temperature (see Freudenreich, *L'Ind. Lait.*, 1894, p. 133) or that proposed by the Frenchman Guérin to keep milk in a frozen condition. By this method the bacteria are certainly prevented from starting fermentations, but the method is not practicable, since the milk undergoes certain changes in freezing which decrease its application. [Notices occasionally appear in the agricultural press concerning the sale of frozen milk in foreign countries. A Danish company for shipping frozen milk and cream to the London market has been in successful operation since 1895 (Fr. Casse Patent), see *Ugeskr. f. Landm.*, 1895, p. 84; *Milch-Ztg.*, 1898, p. 568; *Exp. Sta. Record*, **10**, 493; *Brit. Journ. Bd. of Agr.*, II, p. 451; *Landmandsblade*, vol. **37**, p. 305.—W.

rials have been used for filter for the purpose of sterilizing fluids. Zahn used burnt clay, as did also Tiegel and Klebs. Gypsum was used by Pasteur and others, porcelain by Chamberland, fayence by Gautier, and asbestos cardboard and plastic charcoal by Hesse and Breyer. All these substances easily take up the mechanical materials suspended in a fluid, and thus also the bacteria, on the removal of which the fluid will keep.

As Zahn's experiments in my opinion in a very simple and plain manner illustrate the preservation of milk by filtration, I shall briefly describe his method of procedure. Into a porcelain tube glazed on the outside he fitted tightly a rubber stopper, in which a tube connected with an aspirator was placed. The apparatus was then sterilized. When cold, it was lowered into the milk and the aspirator opened. By means of this simple apparatus, shown in the accompanying illustration, Zahn succeeded in sterilizing the milk. (Fig. 25.)

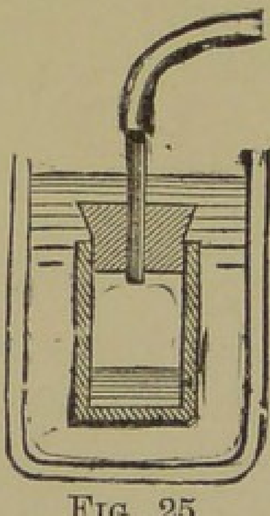
Fig. 25.

Several different kinds of apparatus for sterilizing fluids by filtration are made at the present time; none of these are fully practical, however; the most promising ones are the porcelain filters of Chamberland's mentioned in the preceding, which act continuously and regularly.

It is easy to sterilize milk in this manner, but unfortunately it is changed also in other ways by this method. Duclaux has thus shown through lengthy experiments that not less than nine tenths of the albumen content of the milk remains in the filter. The albuminoids are not really dissolved in the milk, but appear in it in an exceedingly fine, suspended condition. The difference between the milk and the fluid passing the filter is so great that the latter hardly can be called milk. Its most nutritious constituent is gone. By this filtration the sterilization of the milk is therefore obtained at the expense of its nutritive value.

In the experiments which I have made in filtering milk by means of Chamberland's filter the fat globules of the milk have furthermore often caused difficulties, as they will not easily go through the filter at a rather low temperature, and usually clog its inner portion so that the cleaning is very difficult. The same must, of course, also be the case when other methods of filtration are applied. The method of sterilizing the milk through filtration must then, at least in its present phase, be rejected.*

Sterilization of Milk by Heating.—Before entering on this subject it may be proper to state briefly the chemical changes which milk undergoes in heating. These changes are not noticed until the heating rises to about 185° F. (85° C.), when a small separation of albumen may be observed as a white precipitate. Small quantities of casein also seem to separate at the same time. If the temperature is increased above 185°, the albumen will be precipitated more heavily, and the power of coagulation of the casein will be decreased. A. Mayer states that this power is decreased even at 167° F. (75° C.). If, however, the temperature of the milk is slowly raised to 167° F., yes,

* While the apparatus mentioned are of no practical value for sterilization of milk, they serve in an excellent manner as water-filters, and are extensively used as such, especially in larger cities, or where the drinking-water available is not above suspicion.—W.

even to 212° F., then cooled to about 86° F., and good rennet added in larger quantities than usual, distinct symptoms of coagulation will appear, although much slower than ordinarily. Not only are the albuminoids of the milk changed by a stronger heating, but the milk sugar also shows the influence of the heat. If a temperature of 185° to 200° F. acts on the milk for some time or at intervals, it will be easily noticed that it assumes a brown coloration; this occurs through a formation of caramel in the milk, its milk sugar being partly decomposed.

If the heating is carried farther, the symptoms mentioned become still more noticeable, and at the same time the cooked taste, which was only slight by heating to about 167° F., becomes more pronounced. At 266°–300° F. a coagulation of casein takes place, according to Hammarsten, in a manner chemically identical with the coagulation through the addition of rennet.

The sterilization through heating is in practice conducted in two ways: 1, *by boiling under pressure*, and 2, *by ordinary boiling*.

The former method was introduced into practice by Nägeli, who, at the Dairy Exposition in Berlin in 1879, published his experiences with the same. As the foremost spokesman of this method in practice, E. Scherff, in Wendisch Buchholtz (Berlin), has made himself known, and Scherff's milk has of late often been spoken of. According to his method of procedure the newly-drawn-milk is poured into glass bottles, which are stoppered, and then heated under pressure at 248° F. (120° C.) for one to two hours. This method is old, and has long been known in science. The new in Scherff's method, which the inventor has patented in Germany, lies in the peculiar method of closing the bottles.

Scherff's milk will keep beyond question; both bacteria and their spores are killed by this treatment. But even by the application of this method the milk undergoes all kinds of changes, as is natural at such a high temperature, so that its usefulness is greatly impaired. The milk assumes a cooked taste, which often approaches that of burnt milk: and the color is often brownish, showing that a caramel formation has taken place. Munk even found that Scherff's milk had to be mixed with four times the customary quantity of rennet to effect a coagulation, and that this process took place more slowly than usual in spite of this liberal addition of rennet.

The other method of sterilizing milk by heating is to boil it at ordinary pressure. Experiments were made in sterilizing milk by heating to 212° F. for two hours, but this method proved unsatisfactory, as no reliable sterilization was obtained. It has been found that spores of several bacteria will survive this process. The spores of the *hay bacillus*, which, as before mentioned, is often found in milk, are not killed by such a heating continued even for six hours. The spores of the *butyric-acid bacillus* are so tenacious of life that they survive boiling from one to two hours. The same is true for Duclaux's *Tyrothrix tenuis*.

This temperature having proved insufficient, experiments were made by heating the milk to a higher degree. Pasteur found that a single heating to 225°–227° F. is ordinarily sufficient to sterilize the milk. Other investigators again state that it is necessary to heat the milk 230°–239° F. to make certain of complete sterilization. Other difficulties came in with this strong heating, however. The milk assumed a brown color and acquired a burned or boiled taste, which was generally objected to by consumers.

Such milk cannot be used for baby-feeding. It is furthermore very expensive, and difficult to arrange for this heating on a large scale. It can only be done by means of a so-called *autoclave,* or by the application of salt solutions. It therefore proved impossible in many cases to apply high temperatures for the sterilization of milk.

Through Tyndall's and Gay-Lussac's investigations we have learned, however, that sterility may also be obtained in liquids by application of lower heating by the so-called *intermittent sterilization,* which was already spoken of in the Introduction (see p. 15). Hueppe seems to have been the first one to apply this method for sterilization of milk. He stated that it was only necessary to apply a temperature of 167° F. (75° C.) for half an hour for five consecutive days. It has been found, however, that this method is not always reliable. Only where the results obtained can be controlled, as in laboratories by testing in an incubator or similar apparatus, can they be relied on. In my experiments, cultures of certain species of *potato bacilli* in milk have stood such a treatment without appreciably losing their vitality. We know bacteria which develop well at about 158° F.,—a fact sufficient to shake our faith in the reliability of a method of sterilization of the kind mentioned. This also shows the reason why different scientists have come to such different results in their investigations of this subject. One states that milk may be sterilized perfectly by repeated heating to 167° F., and another that a considerably higher temperature must be applied. The difference of results comes, of course, from the fact that different bacteria were found in the samples of milk investigated. Hueppe has later prescribed that the intermittent sterilization of milk takes place best by exposing it to live steam at 212° F. during the first day for an hour, and during each of the following two or three days for twenty to thirty minutes. As already stated, a separation of the albumen of milk takes place at this temperature, its behavior toward rennet is changed, and an almost imperceptible change in some of the milk-sugar takes place.

The intermittent sterilization applied in laboratories has also been introduced in practice for the preservation of milk by the Norwegian Chr. Gerhard Dahl of Drammen, who succeeded so well in this that at the last Paris Exposition he could show milk several years' old prepared at his factory. This milk is said to have been very palatable, although it possessed a distinctly cooked taste, which, however, according to a statement made by a visitor at the Exposition, was no more pronounced than that of ordinary boiled milk.

Dahl describes his method in the following manner in the letters-patent granted in Germany November 14, 1886 (quoted from *Molkerei-Zeitung*):

The method of condensing the milk consists in (1) cooling the newly-drawn milk to 50°–64° F. (10°–15° C.); (2) filling the milk into cans; (3) air-tight stoppering; (4) heating of the cans to about 158° F. (70° C.) for about one and three quarters of an hour; (5) cooling to 104° F. (40° C.) for one and three quarter hours, and then (6) rapid heating of the milk to 158° F. (70° C.); (7) repetition of these three processes—heating, cooling, heating—with about one-half-hour intervals; (8) a final heating for one half-hour to 176°–212° F. (80°–100° C.); and finally (9) cooling to 59° F. (15° C.).

Good results can doubtless, as a rule, be obtained by this or a similar method of procedure. Difficulties of all kinds have, however, arisen also here. First of all, perfectly satisfactory condensing-cans have not been obtained. Those applied by Dahl were of sheet iron, and were made air-tight by soldering the cover on. The weak points of these cans are, that they can only be used once—when the can is once opened the milk will spoil comparatively soon; and they are, rather expensive to be used for so cheap an article as milk. Glass bottles would be far better in many respects, but they are so easily broken during the heating as to greatly increase the expense of the sterilization.

Like Scherff's method, that of Dahl has been modified in many ways without any really practical and reliable method for the preservation of the milk having, to my knowledge, yet been found. The difficulties which have not yet been overcome are partly that the proper preserving cans come too dear, partly that the milk is not completely sterile, or else must be heated so high that it assumes a disagreeable cooked taste, and is changed in quality and appearance. Different apparatus have been constructed, and preserving-cans of the most varying kinds have been invented and improved. [Among German methods which have given satisfactory results in practice may be mentioned that of Neuhaus, Gronwald, and Oehlmann (see Weigmann, "Milchconservirung," 1893, p. 47). In the investigation made by Petri and Massen in regard to milk sterilized by this method they found, however, among the six hundred bottles examined "a large number of bottles" containing living bacteria.*] Patents in large numbers have been granted in different countries, and each inventor has claimed with confidence that the problem has been solved, and that his apparatus and method may be successfully applied anywhere.

The bacteria found in milk during different seasons

* Author's addition to American translation.

and under different conditions vary so greatly that the sterilization of milk on a large scale must always remain a difficult problem. In my opinion we ought to begin with reforms in the cow-stable, and better milk, containing fewer bacteria, than that now generally available, should be supplied. Some milk is difficult to sterilize and other milk is easily made germ-free. Sometimes this may be attained by a single heating of three fourths of an hour; sometimes, again, the operation has to be repeated for three or four days. According to my investigations this depends, without doubt, on the treatment which the milk receives on the farm. The milk from the same farms also shows a certain regularity as regards the difficulties met with in its sterilization.*

As long as the question of the sterilization of the milk by heating for practical purposes is at its present stage we ought, however, in my opinion, to receive with great reserve claims that some experimenters have succeeded in solving the problem.

[Since the preceding account of the sterilization of milk was written (1891), the question has not received any further light. An excellent exposition of the subject is given by H. Weigmann in his small work, already referred to, on "Methods of Preservation of Milk" ("Die Methoden der Milchconservirung," Bremen, 1893, 176 pp.), to which the reader interested in the subject is referred. The book is especially complete as regards descriptions of different kinds of apparatus and methods proposed for the sterilization and pasteurization of milk.†]

* The preparation of absolutely germ-free milk is more easily accomplished the purer and fresher the milk used,—a fact which is of the greatest importance to milk-condensing factories as well as to physicians and persons using sterilized or even pasteurized milk. See Weigmann, "Milchconservirung," 1893, p. 51.—W.

† Author's addition to American translation.

CHAPTER VII.

PASTEURIZATION OF MILK.

One phase, and perhaps the most important one in the sterilization of milk, has not yet been touched upon, viz., that at the same time as the milk has been made to keep it has also been improved from a hygienic point of view. Milk is an exceptionally good nutritive medium for most bacteria; we know that it has been the means, although comparatively seldom, of spreading various dangerous diseases, as tuberculosis, diphtheria, typhoid and scarlet fever. These are all infectious diseases caused by different kinds of bacteria. The bacteria thrive well in milk; once there and with the person consuming the milk liable to contagion, infection and disease will easily be the result.

The pathogenic bacteria existing in milk are fortunately all killed rapidly at a comparatively low temperature. Special investigations have shown that they can hardly stand a heating up to 167°–185° F. (75°–85° C.).* It is therefore not necessary to obtain complete sterility in the milk to guard against infectious bacteria.

As regards the other bacteria in milk, I want to call attention to a point suggested by my heating experiments with milk containing bacteria of different kinds. If the heating was continued to about 167° F. (75° C.) it was shown by subsequent bacteriological examinations that the lactic-acid bacteria proper had disappeared or else were considerably reduced in number, and that even putrefactive bacteria had decreased in number, although not as much as the former. This change in the bacterial content was so striking that it could be observed by a mere microscopic examination, and showed that the pure bacilli forms had entirely gained the upper hand after the heating. I am not in possession of sufficient medical knowledge to state the hygienic importance of the disappearance of the lactic-acid bacteria proper from the milk, or at least their great diminution, and of the decrease in the number of bacteria causing fermentations of the casein; but I can testify on the basis of my investigations that this relation plays an important part in regard to the keeping qualities of the milk, since the lactic-acid fermentation usually precedes the fermentation processes caused by the other bacteria.†

The relative keeping qualities of the milk are thus increased through the disappearance of the lactic-acid bacteria.

A heating of the milk to 165°–185° F. will therefore

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* Bitter found that tubercle bacilli were killed by simple heating for 30 minutes at 154° F.; Forster (*Milchzeitung*, 1894, p. 84) obtained the same result by heating for 10 minutes at 158° F., for 5 minutes at 170° F., and for 1 minute at 203° F. At lower temperatures longer time was required, viz., 1 hour at 140° F. and 4 hours at 131° F. Bang found that a temperature of 176°–185° was required to kill tubercle bacilli; see Part IV., Chapter I.—W.

† Duclaux mentions similar observations in the January number of *Annales de l'Institute Pasteur* for 1891, and ascribes great hygienic importance to the fact that the acid forming bacteria have disappeared in the heated milk, especially in regard to the application of the milk for baby-feeding.

not only protect the consumer from infection of contagious bacteria, but will also appreciably increase the keeping quality of the milk. Such heating has been called *pasteurization*, and is now practised at a large number of creameries. This treatment of the milk is especially necessary at large factories where it is difficult to properly supervise cleanliness, etc., at the farms of the patrons. The details of pasteurization will be treated farther on in this book.

There are, however, two cases in which still greater precautions are necessary for preventing infection from milk, namely, at milk sanatoriums and for baby-feeding. In both cases large quantities of milk are consumed, and if this is infected by malignant bacteria infection may easily arise.

Milk for Sanatoriums.—At milk sanatoriums the effort is of course to supply milk from as healthy cows as possible and to observe all possible neatness and cleanliness in the production and handling of the milk ; besides this an obligatory heating of the milk is practised. This is the case, e.g., at the milk sanatorium in Berlin under the direction of the well-known dairy authority Benno Martiny; all milk is there heated for half an hour to about 176° F. previously to consumption.

Milk for Baby-feeding.—The milk intended for baby-feeding must also undergo a special treatment.* Babies

*In case of milk intended for sanatoriums or for baby-feeding, special care must be taken as regards the system of feeding the cows. Only well-preserved, carefully-selected feed stuffs should be given. Sweet aromatic and well-cured hay or corn fodder is the best coarse fodder for the purpose. Corn silage must be fed only in small quantities, if at all ; always after milking, and not to exceed 10–15 lbs. a day. Oat or barley straw may also be fed ; likewise often consume cows' milk in large quantities, and their systems possess less power of resistance than that of grown people.† But even here it may not be necessary to strive to reach complete sterility, since infectious bacteria do not appear to be very resistant toward heating. If precautions are taken that the milk is always consumed within twenty-four hours at the latest after the heating process, and that it is kept in a cool place during this time, it will not be infectious or undergo any injurious changes.

The same results may be obtained by heating the milk in an ordinary casserole to the boiling point, or even only to about 158° F. It must be remembered, however, that such a heating does not of course protect the milk from

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rutabagas or carrots (in small quantities). Of concentrated feed stuffs, the cereals or the flour-mill refuse-products may safely be fed, but not pea-meal, bean-meal, or any other legumes. Malt-sprouts, linseed-meal, palm-nut meal, cocoanut-meal, etc., may be fed sparingly—all but the first-mentioned not to exceed one pound of each feed a day per head. No fermented or rancid feed should be given (except silage, with the proviso mentioned), and no slump feed, brewers' grains, etc. The milk from fresh cows should not be used for this purpose until the eighth day after calving, and never under any condition unless the cows are perfectly healthy and give milk fully normal according to both taste, smell, and appearance.—W.

† Munk and Uffelmann (in their "Ernährung d. Menschen," 1891, p. 294) state that "the high germ content of cows' milk, especially of fermentative forms, is doubtless largely the cause of its poorer utilization and palatability in baby-feeding. Soxhlet considers the particles of dung very frequently present in cows' milk the main carriers of these bacteria; and he is doubtless right. Experience teaches us at any rate that feeding babies with boiled or especially with sterilized milk gives far better results, and causes a much smaller number of digestive troubles, stomach and intestinal catarrhs, etc., than does feeding with unboiled milk."—W.

renewed infection before it is consumed. To prevent this infection, which is a very important point in case of baby-feeding, the milk must be heated and kept in a sterile and carefully closed vessel. Many different kinds of apparatus and methods have been invented for the treatment of milk for this purpose. I shall here only mention two methods which may be considered typical. The one was invented by Dr. Engli-Sinclair in Switzerland; the other by Dr. Soxhlet in Germany. Both these methods are essentially alike: Engli-Sinclair works with simpler and more primitive apparatus than Soxhlet. Both methods seem to give perfectly reliable results, although the admirers of the Soxhlet method maintain that that alone fulfils the demands for an ideal milk-sterilizing apparatus.†

Methods of "Milk-sterilization."* — The method of Engli-Sinclair is as follows: In an ordinary porcelain-lined iron casserole provided with a cover a sheet-iron stand is placed holding seven bottles; these will hold about 1.6 liters ($1\frac{3}{8}$ quarts), or about as much milk as is required for one meal. The bottles are filled with milk of the best quality, which if necessary is diluted with water; the bottles are at

* There is some confusion in the use of the term sterilization and pasteurization of milk and milk products. *Sterilization*, as we have seen, implies absolute freedom from bacteria and their spores, while *pasteurization* implies freedom from a large majority of the bacteria found in the milk; the former is reached by prolonged heating at the boiling-point or higher temperatures; the latter by heating at temperatures from 165°–185° F. (see p. 159). When the methods to be described in the above were given to the world, it was thought that the product obtained was absolutely germ-free, and the process was therefore called sterilization of milk—a name still applied, although according to our present knowledge it is not strictly correct. The methods are described in the present chapter because the milk thus treated will act like pasteurized milk, as will be apparent from the remarks of the author.—W.

† See Bendix, *Centralbl. f. Bakt.*, 17, p. 139.—W.

once, without being stoppered, lowered into the casserole, which is filled three fourths full of water. The casserole is now put over the fire, and when the water is boiling hard the bottles are hermetically sealed with rubber stoppers and the cover put on the casserole. After half an hour the casserole is taken away from the fire and kept in a cool place. The bottles must cool in the casserole, as otherwise they are liable to break. The same bottles are used for nursing, and a nipple carefully cleaned and boiled each time is substituted for the cork. In this way the different milk portions are completely protected from contamination until the very moment they are to be consumed.

The milk is treated exactly according to the same principles in Soxhlet's method. The superiority of this method consists in the fact that the apparatus may be used by any one, and is more easily kept clean, which is a very important point.* As fresh milk as possible is to be used, and never milk from a single cow—only mixed milk. The dilution of the milk with water should always take place before the boiling. The milk must be boiled for three quarters of an hour. The rubber rings on the bottles should not be removed until the milk is to be used. The covers should also be left on the bottles, and the latter kept in a cool place after the boiling. When the milk is to be used it should be heated to body temperature. It is to be remembered that the cold bottles must not be placed in hot

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* Soxhlet's apparatus with the latest improvements can be obtained from the manufacturer, Metzeler & Co., in Munich, at a price of 13 to 16 marks. A collection of the most necessary pieces may be obtained from the same firm for 10 marks. The apparatus can doubtless be obtained from American dealers in chemical glassware or from wholesale druggists.—W.

water; if they do not break immediately in such a case they will become brittle and readily break in the next boiling. Milk residues in the bottles should not be saved. The cleaning of the bottles is best effected as soon as the milk has been consumed.

Ardent adherents of Soxhlet's method claim that milk treated in this way will keep for three to four days, and advise that large quantities of milk be sterilized at once. This is doubtless an exaggeration. One of the best points in the method is in my opinion the fact that small quantities of milk may be easily and cheaply treated. If such incompletely sterilized milk is saved for a longer time than, e.g., twenty-four hours, risks are doubtless taken. If living bacteria are found in milk they will necessarily soon make their presence known if it is kept longer, and not in a cool place.[1]

Milk treated according to Soxhlet's method seldom becomes absolutely sterile. I have made numerous experiments on this point and have kept milk carefully prepared in a Soxhlet apparatus at a temperature of 90° F. (32° C.) in an incubator; I have practically every time within forty eight hours been able to verify in it a large number of *Bacillus-subtilis* forms and other bacteria. Soxhlet warns against sterilizing such large quantities at one time that the milk has to be kept long before being used. He holds that lactic acid is almost exclusively formed in unboiled milk kept at 95° F. (35° C.); butyric acid formed at the same time does not make up even 4 per cent of the total acidity. Large quantities of butyric acid are, on the other hand, formed in samples of partially sterilized milk—at least 15 per cent, on an average 30 per cent, and often more than 50 per cent of the total acidity. This butyric acid must be considered injurious, and it seems therefore safest to prepare only as much milk as will be used during twelve hours. Soxhlet has also constructed an arrangement for heating milk up to the proper temperature immediately before consumption.

In many larger cities, as, e.g., in Vienna (Dr. Hochsinger), so-called milk-sterilizing stations have been established, where children's milk is prepared on a large scale according to Soxhlet's method and is sold in definite mixtures of milk and water according to the prescription of physicians. If careful supervision is given to the station, so that everything is conducted as it ought to be, this is an excellent idea, since pasteurized milk in this way can be had cheaper than if everybody pasteurize milk for their own use. The Soxhlet apparatus is rather expensive, and the cost is farther increased by the frequent breakage of bottles. The cleaning of the apparatus demands time and care. Engli-Sinclair's method is cheaper, as before mentioned, but may require greater care in execution than that of Soxhlet.†

The methods just explained have gained still more in importance since it has been proved that the indigestible condition of cow's milk does not really arise from its chemical composition, but from its "unavoidable contamination with micro-organisms" which in some way or other cause disturbances in the digestive organs of nursing children.*

I must finally mention that although pasteurization

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* See foot-note of p. 160.

† Of late years, Gaertner's "humanized cow's milk" has come into some prominence; see *Wien. med. Woch.*, 1894, No. 44; *Hyg. Rundsch.*, 1895, p. 178, and recent volumes of the various *Jahresberichte*.—W.

will kill the majority of bacteria, the danger that the milk may occasion sickness is not in all cases entirely removed. Some bacteria are found producing poisonous principles by their living actions, which are not destroyed by the heat applied.*

Fortunately these substances appear very rarely in milk, and seem to originate from bacteria thriving best in dark, filthy, and poorly-ventilated places. Sterilization of the milk does not, therefore, render it unnecessary to observe as great cleanliness and care as possible in the production and handling of the milk.

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* As an example it may be mentioned that a poisonous principle (*tyrotoxicon*) is sometimes found in milk (see "Hygiæa," 1888, p. 695). In the case quoted it had arisen after the milking, in milk kept in a building with poor ventilation, the grounds of which were exposed to contamination from a neighboring slaughter-house. The milk caused a cholera-morbus-like disease in children. Boiling or sterilization did not diminish the injurious effects of the milk. See also Flügge, "On Sterilization of Milk," *Zeitschr. f. Hyg.*, **17** (1894), pp. 272–342.

PART II.

CREAM.

CHAPTER I.

CREAM RAISED BY GRAVITY PROCESSES.

a. **The Old Shallow-setting System.** — In the old shallow-setting system of cream separation the cream is allowed to sour on the milk. This method is still common in our country at the present, the greater portion of our farm butter being made from cream raised in this way. As the method is practised on most farms it is not attractive ; a good many of the faults to be found with it do not, however, really belong to the method itself, but are coincident with it. The farmer's wife has generally to fight the worst conditions imaginable in her dairy, especially in winter-time. During this season the milk is, first of all, of the poorest quality, on account of the scant feeding. It is furthermore usually milked in dark stables, where the cows are standing on manure, with no good litter under them. It is natural that the milk under these conditions should come in intimate contact with dung particles and other filth. The milk-pail also shows variegated colors, testifying to slovenliness; and as it is often used for feeding meal and milk to the calves, it is natural that it never dries out thoroughly. The pail harbors luxuriant bacteria and mold-cultures, as any one can satisfy himself if he places such a pail in a clean room, where the air is fresh: it will not be long before colonies visible to the naked eye may be seen, especially if the wood is kept moist.

Milk subjected to such conditions cannot possibly keep well. If an effort is made to prepare palatable, well-keeping cream by this method by means of ice, in nine cases out of ten we shall not succeed.

The conditions in the dairy, if such a building or room be kept, are also such as to prohibit the production of first-class cream. It is often dark, dirty, and poorly ventilated, and frequently also used for other purposes. The milk is therefore exposed to the most unfavorable conditions during the winter months, and as a result good butter cannot be produced during this time.

During the summer season matters are fortunately different. The quality of the milk is then of the very best, thanks to our good natural pastures. The cows are milked in the open air, although often in muddy inclosures. The udder and hind-quarters of the cows are fairly clean, as the animals often have a chance to stand in some lake or stream, and as they never soil in the pasture as in the stable. The milk-pail also has a better appearance, being thoroughly aired in light and sunshine. The condition of the milk-pans is also very different in summer-time. They are not only well scrubbed, but are often placed outside in the sunshine with the churn and other household utensils. This is in my opinion the great secret and the main reason why farm butter can be first-class and of good keeping quality during the summer-time, in spite of many unfavorable conditions and poor facilities. As previously shown sun rays in a short time kill all bacteria. The putrefactive butyric acid and similar darkness-loving bacteria seem to be easily destroyed by direct sunlight. The lactic-acid bacteria are also sensitive to their action, but according to my experiments are not so easily killed in sunlight as the former. The presence of lactic-acid bacteria in the milk-pans is not, however, as injurious for the milk as that of putrefactive and butyric-acid bacteria—a point which will soon be further explained.

The conditions to which milk is subjected during the separation of the cream are also far more favorable in summer-time. The air in the dairy is better; the small window usually found is insignificant, but it constantly acts as a ventilator, being usually left open; the door is also left open a large share of the day, so that a draft is created. Outside the door of the dairy there is usually a lawn, and dust or dirt from the surrounding regions are not therefore very apt to be brought in from the outside.

Having now considered the conditions present where the old shallow setting system of cream separation is practised, we shall consider in how far the unfavorable conditions for the keeping quality of the products are dependent on the method itself.

For one thing, uncleanliness does not at all belong to the method. The lack of neatness often found among farmers using the system comes from their poverty and lack of knowledge. Give the farmer more education and knowledge and better conditions of life, and it will not be long before the quality of the milk and the whole dairy business on the farms will be revolutionized.

The straining of milk into wooden dishes is also applied in the Holstein method, which is still used in many places abroad. It has been proved beyond a doubt that first-class aromatic products of good keeping quality may be obtained by handling the milk in wooden vessels. These require greater care in cleaning, and are therefore not adapted to creamery use, but they have advantages which tin vessels lack. As is well known, wood is a poor conductor of heat, for which reason wooden dishes are very suitable to the simple conditions present in the dairies of ordinary farms. No special arrangements are necessary to keep the milk in them at something like an even temperature, and comparatively much and good cream is obtained by their use.

The milk is allowed to sour spontaneously in this method, but up to very late there was no rational and systematically conducted ripening, even in the most modern dairy methods—a lack which certainly has not been to the advantage of the products. The modern dairy practices need to be reformed in this respect as well as the old-fashioned method here considered. Even the latter is not incompatible with such a systematic souring, as we shall see later on in this book, where more detailed directions for this souring will be given.

In this system of cream separation the ripening takes place at the same time as the cream-raising. By closer examination this is found to possess both advantages and disadvantages.

If we compare this method with, e.g., the Holstein method, we find that the cream-raising and ripening in the latter demand a very long time, because the milk is creamed under conditions which do not hasten this process and the cream is not ripened until after skimming. In the old shallow setting method these processes go hand in hand, and under favorable conditions occur more rapidly than in the method just mentioned, especially if we consider that the pans used by the farmer hold more milk than the Holstein pans—which is a decided advantage. This method cannot of course be compared with the centrifugal method as far as rapidity in reaching the result goes; but, as my experiments have shown, we can obtain a properly soured cream in a good deal shorter time by this method than is required by the ice method if the milk-room is kept moderately warm and a good starter is added to the milk.

It is often stated that a smaller quantity of butter is obtained by the old shallow setting method than in the modern methods of cream-raising. Repeated direct experiments conducted by me do not bear out this assertion, however. I shall here briefly report an experiment made last summer.

The same quantity of the same milk was treated according to the separator, the ice, and the shallow setting system, care being taken in all cases to observe the directions for the different methods with the greatest possible accuracy. The milk was separated at 86° F., the separator (de Laval) making 7600 revolutions per minute; the separated cream was ripened in the usual way in eighteen hours. In the ice method the milk was left for twenty-eight hours, the temperature of the room being

54° F., and that of the water in the creamer 36°. The cream was ripened in the same way as in the separator method. In the shallow setting method the milk was strained into wooden pans holding about three quarts. It was left for forty-eight hours in a room with a temperature of 54°, to allow the cream to raise and the souring to take place. It was then removed to another room with a temperature of 64° F., where it was kept for twelve hours. When the milk was skimmed the casein was evenly coagulated. The experiment gave the following results:

<table>
<tr><th rowspan="2">System of Cream-raising.</th><th rowspan="2">Milk.</th><th colspan="2">Temperature—</th><th colspan="2">Products.</th><th rowspan="2">Hours required for Cream-raising.</th><th rowspan="2">Hours required for Ripening.</th></tr>
<tr><th>of Room.</th><th>of Milk.</th><th>Cream.</th><th>Butter.</th></tr>
<tr><td></td><td>Lbs.</td><td>° F.</td><td>° F.</td><td>Lbs.</td><td>Lbs.</td><td></td><td></td></tr>
<tr><td>Separator method......</td><td>125.4</td><td>64</td><td>86</td><td>26.6</td><td>6.4</td><td>....</td><td>18</td></tr>
<tr><td>Ice method...........</td><td>125.4</td><td>54</td><td>36</td><td>23.8</td><td>5.5</td><td>28</td><td>18</td></tr>
<tr><td>Shallow setting method</td><td>125.4</td><td>54–64</td><td>59</td><td>17.8</td><td>5.5</td><td colspan="2">60</td></tr>
</table>

As might have been predicted, the yield was largest in the separator method, but similar quantities of butter were obtained in the two other methods from the same quantity of milk.*

* Without doubting the correctness of the figures given in the foregoing experiment, I cannot agree with the author that the old method of cream-raising will in general give as good results, as far as yield of butter goes, as do the modern methods. The per-cent of fat left in the skim-milk obtained by the various processes will, as it seems, show that such cannot be the case. Skim-milk from shallow pans set in the air in my experience contains at least one per cent of fat, and often more; while deep-setting skim-milk cooled by water will contain from .50 to 1 per cent of fat,

The main objection to this method is that the skim-milk sours at the same time as the cream. This is a serious objection from one point of view, but many farmers accustomed to the wholesome and refreshing sour milk obtained in the old method often complain that they cannot get as good, delicious sour milk when this is made from sweet skim-milk. It is doubtless a fact that the two kinds of sour milk taste entirely different. It is also natural that such should be the case, for in one instance the milk is allowed to sour slowly in a relatively shallow layer, while in the other it sours rapidly in deep ripening cans. I have also found that the layer of cream on the milk in the shallow pans has a special influence on the acidity and taste of the underlying skim-milk, evidently because this condition favors the growth and development of special bacteria.

A weak point in this method is the fact that the skim-milk can only be boiled with difficulty. Farmers preferably use their skim-milk as sour milk, however, and only rarely consume boiled milk, so that this point is not very important. Another question on which I dare not express an opinion is, whether it would be right from a hygienic point of view to agitate against the abundant consumption of sour milk by the people. In passing I will add that

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and cooled by ice from .20 to .50 per cent of fat. Fleischmann gives the following number of pounds of milk as required for making one pound of butter: creaming in high pans at 15° C., 33 lbs.; in shallow pans at 15° C., 31 lbs.; in the Gussander method (see second division of the present chapter), 29.5 lbs.; in cold-water setting, the Holstein method, and Schwartz's method, 29 lbs. of milk. The results of Fjord's experiments (17th Dairy Report, 1882) go in the same direction, as do those obtained at the Guelph (Ont.) Agr. College (see Reports 1893, p. 140; 1894, p. 142; 1895, p. 60), as well as at several of our own experiment stations.—W.

a large number of infectious bacteria do not thrive in a substratum containing large quantities of lactic acid.

Bacteria in Shallow-setting Cream.—Proceeding to a statement of the bacteria which my analyses of cream prepared according to the shallow-setting method have shown present, we first note that this cream when left on the skim-milk shows a downy surface, especially when near the ripening stage. This down comes from a growth of the milk-molds (*Oidium lactis*) spoken of before. The part which the molds play may be manifold: by their alkaline reaction they may be the cause of the lactic-acid bacteria thriving and living for a somewhat longer time in the sour cream. These molds also consume the acid in the upper layer of the cream, thus causing a weakening of acid in the lower layers of the milk, through which these become better adapted to the anaerobic bacteria. Investigations made after the first part of the original of this work was written show that if we want to study the anaerobic bacteria of the milk we may conveniently seek them in just such milk-pans overgrown with molds.

These milk fungi furthermore appear to protect the milk from later and possibly more dangerous infection. They grow fast and spread, especially in the upper layers; and if they were not there, more dangerous micro-organisms would most likely take their place.

Excepting the molds mentioned, I have not, in spite of numerous bacteriological analyses, been able to discover any micro-organisms characteristic of this cream. The bacteria found, both those infecting the milk as well as the useful and desirable lactic-acid bacteria, are mainly the same as those found in any other cream allowed to sour spontaneously. A couple of points are, however, to be observed in this connection. Bacterial infections are first of all, as a rule, more numerous in cream which has soured on the milk than in that prepared according to modern methods. Their number will vary greatly. In examining cream from the same milk obtained by the different methods the shallow-setting cream has usually been found richest in bacteria not producing lactic acid, although this was by no means always the case. A very small number of such bacteria were found in the cream if the milk had been strongly infected with lactic-acid bacteria. The quality of the cream was then as good, from a bacteriological point of view, as if it had been prepared according to the ice method, and often better. The explanation is doubtless to be found in the fact that the early-appearing mass-infection (see p. 93) of lactic-acid bacteria hindered the growth of other bacteria. In this way the ripening took place rapidly and at the same time as the raising of the cream, so that if the infection took place at the proper time the cream was sufficiently sour and coagulated just at the end of the separation.

Another point to be noticed is that yeast-fungi taking part in the starting of the lactic-acid fermentation have been found only in the cream and sour milk from small farm-dairies. I have found such yeasts in "stringy" milk from Borgaa and in buttermilk from Savolaks and Karelen.

Very different kinds of lactic-acid bacteria may appear at the same time in the sour milk and cream on neighboring farms. A fact which will be further considered when the question of cream-ripening comes up is that in some farm-dairies I have met with buttermilk containing practically only lactic-acid bacteria. These samples of buttermilk originated on particularly well-conducted farms, where the housewife herself took care of the milk. By accident I learned of one of these farms that it had the reputation of making first-class, well-keeping butter. A separation and ripening of the cream according to this method can therefore be well conducted and give good results.

Having studied the conditions of this method of cream-raising, and learned how bacteria generally appear in the cream, we shall briefly consider its keeping quality. From the point alone just mentioned, that such cream is generally mixed with a great number of non-lactic-acid-producing bacteria, we may conclude that usually it will not keep long; but we have seen that under favorable conditions cream may also be obtained by this method which will contain practically pure cultures of lactic-acid bacteria. How this exceptional condition may become the rule, or at least more general, will be shown in a later chapter. From the description given it will be seen that it has its good points, and that the method hardly deserves the scorn shown it by writers and speakers on dairy topics.

b. **The Modern Systems of Gravity Creaming.**—In the more modern creaming methods neither cream nor skim-milk undergoes any appreciable change during the creaming. The principle both in these methods (the Holstein, Gussander, Swartz, and Cooley methods), as well as in the separator and extractor methods, to be considered in the next chapter, is, that the fermentation bacteria are not allowed to develop to any appreciable extent, either before or during the rising and separation of the cream.

Two objects have constantly been kept in view in the older of these methods: to favor the rising of the cream.

and as far as possible to prevent the fermentation bacteria from developing their specific functions. We shall here dwell mainly on the latter object.

As we have seen, the milk always contains a larger or smaller number of bacteria when set. According to my experiments the number of bacteria in cream from Swartz's cans may vary from less than 100 to several tens of thousands per cubic centimeter—the conditions of creaming being the same in all cases. The variation depended entirely on the handling of the milk before setting. If the milk has been handled with the greatest cleanliness and according to the principles previously dwelt on, the number of bacteria in the cream will not only be smaller, but the bacteria found will not as a rule be of such undesirable forms as will otherwise be the case.

The means at hand for the checking of the fermentation bacteria during cream-raising are, of course, the same as stand at our disposal in the keeping of the milk, viz.:

1. Scrupulous cleanliness throughout the dairy, especially as regards the creaming-vessels, etc. 2. Cooling the milk as quickly as possible; and, 3. Light, fresh, and dry creaming-rooms.

The lactic-acid organisms are generally best fought by the first two methods, but the last method also tends to check them, though not to the extent in which it checks putrefactive and similar bacteria.

The oldest method of creaming of this kind is the *Holstein* system. In this method the complete rising of the cream is secured by the thinness of the layer of milk and by a rather high temperature, at which the milk-serum is but little viscous. The development of the bacteria is rather incompletely checked. The temperature sinks slowly in the pans, and the final temperature (55°–59° F.), while not very favorable to the bacteria, is yet by no means unfavorable; and as the milk is under the influence of this and still higher temperature for at least thirty-six hours, it is evident that a considerable bacterial growth will take place. It is also often very difficult in this method to fight especially the lactic-acid bacteria, and older writers on dairy matters, as Martens, dwell at length on the difficulty of keeping the milk and the cream sweet when this method is followed. The difficulty of keeping the wooden pans clean is another objection to the method. Martens also maintains as the first duty of the dairywoman "to have especial attention directed toward the cleaning of the dairy utensils. She should always be present at the cleaning of the milk-pans and personally examine every pan."

In spite of these disadvantages, the method when properly conducted gives excellent, well-keeping butter. The explanation doubtless is found in the minute cleanliness and dryness (see p. 112) which must be observed where it is used.

In the *Gussander* method, invented in the '40's by Major Gussander in Sweden, the milk is strained in still thinner layers than in the preceding method, and the temperature is generally higher. The rising of the cream is facilitated by the short distance to the surface and by the lower viscosity of the medium through which it has to pass. The milk is here not kept in cellars, as in the Holstein method, where a certain moisture of the atmosphere is likely to be retained, but in light, cheerful rooms, where scrupulous cleanliness is observed, and where fresh, dry air can all the time be maintained. Cleanliness was also facilitated by introducing metal vessels in the creaming of the milk.

The weak point in this otherwise attractive method is evidently the high temperature in the milk-room, for which reason the milk also, according to numerous testimonies, was very apt to sour. It is natural that the lactic-acid bacteria under such conditions would get the upper hand of other milk bacteria. Putrefactive and similar bacteria had very poor chances of life in a Gussander milk-room.

In the *ice method*, now generally used in our dairies, light and cleanliness are the main weapons for fighting the fermentation. But the bacteria are further checked in this method by cooling the milk. As before stated, the low temperature checks the growth and development of the bacteria, but it does not kill them. If the cooling is neglected or conducted so slowly that the bacteria present in the milk or in unclean vessels are allowed to develop and multiply before the temperature is low enough to stop these processes, injurious changes in the milk or its products may sooner or later be observed. If the cream does not become appreciably sour or of an undesirable flavor by such manner of procedure, it will still be found that the butter made from the cream is not of the good quality it would otherwise have been.

From the results obtained in the laboratory at Rütti (p. 88) we find how immensely quicker and stronger the development of bacteria will take place in milk of 77° F. than in milk 18° lower. If still lower temperatures had been applied it would have been found, as in my experiments (p. 89), that the development decreased more rapidly the further the milk was cooled down, and that it stopped entirely at 39° F. (4° C.).

In the ic method the milk is creamed in high, usually narrow tin cans. These cans are easily cleaned and steamed, and it is therefore not difficult to keep them sterile.

Without entering into a general discussion of the advantages of this method in our creameries and dairies, I desire to call attention to some points about it, the neglect of which will largely influence the keeping quality of the products.

First of all, I will recall what was said on pp. 62–66 concerning the necessity of the rapid cooling of the milk by the use of sufficient quantities of ice. It is necessary not only to use ice liberally, but to use it in the right way. It is therefore advisable to have finely-divided ice in the creamer instead of large pieces, especially in the first cooling of the milk, as the fine ice causes a more rapid cooling of water and milk. When a sufficient decrease in the temperature of the milk has been obtained, larger pieces of ice may be used. A mistake often made is to place the milk-cans very near one another, not allowing a sufficient quantity of ice between them for the rapid cooling of the milk. It may furthermore be well to remember that pure water must be kept in the creamer. In many creameries the same water is left in the tanks for weeks, although milk is often spilled into them, thus improving the water as a nutritive medium for bacteria. The water is, of course, kept cold by the ice floating in it, and the bacteria are thus prevented from increasing perceptibly; but water often splashes into the milk from the creamer or is spilled on the floor and walls, where it evaporates. The bacteria coming from the evaporated water may then float in the air, and thus easily infeet the milk.

Cream obtained by the ice method contains comparatively few bacteria, except in cases where the milk before setting was highly infected, or where sufficient cooling was not practised. We seldom find molds in it and never *oïdium* fungi, as in case of cream obtained by the shallow-setting system. At the temperature used in the ice method the molds can evidently not develop in the cream layer and form long, threadlike *conidia,* giving the cream a "velvety" appearance.

This system of cream-raising has an immense advantage over those previously described as regards the ease of combating the fermentation germs by the cooling process. If this is properly conducted, bacterial growth may be practically stopped, and no fermentations will set up. There is always a danger in this respect, however, as is plain from the fact that some milk bacteria will reproduce at a temperature of 50° F. (10° C.). Care must therefore be exercised in using the method if first-class results are wanted. But if the directions given are carefully followed and the milk on hand has not already been overloaded with bacteria, we may feel assured that the keeping quality of the products will not be diminished during the cream separation—a result which cannot be reached in any of the other methods so far described.

CHAPTER II.

SEPARATOR CREAM.

THE centrifugal method rests on an entirely different principle from those previously considered. The heavier parts of the milk, the skim-milk, are whirled against the circumference of a rapidly-rotating steel bowl, while its lighter parts, the cream, remain nearer the centre. The result is that not only is the cream separated from the skim-milk, but all filthiness present in the milk is also forced to the wall, where it forms a tough, sticky layer, called "separator slime." The separation takes place in the manner mentioned, both in the cream separator and the extractor.

By application of the separator method the cream may be separated from the milk as soon as this comes to the creamery. The time of infection is greatly shortened, the chances of contamination of bacteria decreased, and the bacteria already found in the milk do not get time to develop. For these reasons this method possesses a decided advantage over all other methods of cream separation known.

At a large number of separator creameries in this and other countries this point is not taken advantage of, however, as we often find that the milk, which is usually warm when it comes to the creamery, is left for hours in the hauling-cans, whereby of course its bacteria have an excellent chance to increase and start their characteristic fermentations. In many places this is done from ignorance; in other places because the number or capacity of the separators do not correspond to the quantity of milk received. If the danger involved in such treatment of the milk was properly understood, the expense of buying a sufficient number of separators, or separators of sufficient capacity, would not be considered.

We saw on page 68 the advantage of pasteurizing the unskimmed milk to be hauled away, so as to increase its keeping quality. Pasteurization of milk is also often practised for another purpose—viz., to obtain butter that will keep better. It is both expensive and a waste of time to separate the cream from such pasteurized milk by means of any of the older methods, while it may easily be done by application of the centrifugal method. Pasteurization of the milk before separation not only gives a product that will keep better, but also brings about another advantage, as shown by Börje Norling: the production of a thinner skimmed milk—i.e., the cream is richer in fat. This writer advises that new milk be first pasteurized, then separated at about 159° F., the cream and the skimmed milk to be cooled in separate coolers. He states that numerous comparative trials have shown that if milk is skimmed under similar conditions partly at common, partly at pasteurization temperature, the skim-milk will regularly show a lower fat content in the latter case.* The method of pasteurizing the new milk before the

* Lunde found in his pasteurization experiments the following average percentages of fat in the skim-milk, the speed and amount of milk run through the separator being the same in both cases: skim-milk from pasteurized milk, .14 per cent; from non-pasteurized

separation has proved less advantageous in my experiments, because the cream to a great extent transmitted the cooked taste to the butter. This was not the case when only the cream was pasteurized, although the temperature was the same in both cases. The difference doubtless came from the fact that a quicker cooling could be applied in the latter case. As I consider the presence of a cooked taste in butter a very serious fault, I cannot recommend pasteurizing milk intended for butter production, and shall not therefore here enter into the details of the process.

Distribution of Bacteria in the Centrifugal Process.

The centrifugal method has still another advantage over the old methods of cream separation,—an advantage of which is thought too little, viz., the ability to remove a large number of bacteria in the milk, so that the separated cream and skim-milk do not (as in the most favorable instances in the older methods) contain the number of bacteria which were found before the cream was separated from the milk, but contain even a smaller number than before separation. I have verified in numerous trials that a large number of the bacteria present in the milk treated were removed from the cream and the skim-milk by the centrifugal force and went into the separator slime. This can be ascertained by comparing the number of bacteria found in the milk before the separation with the number found in the cream, skimmed milk, and separator slime after the separation. I have made numerous examinations of this kind, experimenting with milk poor in bacteria

milk, .22 per cent fat—the former analyses ranging from .11 to .17 per cent and the latter from .18 to .35 per cent. See also Wis. Exp. Sta. Bull. 69.—W.

as well as with samples containing an immense number of them. The following table shows the results of some of these investigations:

Origin of Milk.	Number of Bacteria per Cubic Centimeter.			
	In New Milk.	In Skim-milk.	In Cream.	In Separator Slime.
Mixed evening and morning milk.	18,180	11,025	13,200	4,241,000
Morning milk.	6,500	2,025	3,800	1,320,000
" "	4,100	2,300	2,480	836,000
" "	1,890	680	550	560,600
" "	1,530	650	480	650,000
" "	1,640	360	450	150,800
" "	1,030	220	200	230,000

It is very peculiar that the cream in most of the above experiments contained a larger number of bacteria than the skim-milk. I cannot explain this phenomenon. It is apparent, however, that even the cream has been appreciably freed from bacteria and thus improved in keeping quality. The immense number of micro-organisms in the slime also gives evident proof thereof.*

* Weigmann (*Ldw. Jahrb.*, Erg.-Band I, p. 57; *Molkerei-Zeitung*, **8** (1894), p. 371) and Scheurlen (*Arb. Kais. Ges. Amtes.* **7** (1891), p. 269; Fühling's *Ldw. Zeitung*, 1892, p. 575; *Zeitschr. f. Nahrungsm. Unters.*, 1893, p. 3) found that by far the greater portion of the bacteria goes into the cream by the centrifuging, and only a minute quantity goes into the slime. Wyss (*Tagb. d.* 62. *Versam. Deut. Naturf.*, 1890; *Centralbl. f. Bact.*, **VI**, p. 587) found seven times as many bacteria in the slime as in the centrifuged milk, and Gernhardt (Inaug. Dissert. Univ. Jurjew, 1893, p. 76) found three to four times as many. It is possible that the point mentioned by the author in the following paragraph (see above)—the varying bacteria content of the milk—accounts for the difference in the results obtained by the different investigators. See also Exp. Sta. Record V, p. 646, and *Centralbl. f. Bakt.*, **16**, p. 969.—W.

Another observation made in this investigation which is also shown in the above table is that the fewer bacteria the milk contains the more completely has the separation purified the cream and the skim-milk. We are here again cautioned to observe greater care and cleanliness throughout the handling of the milk. The cleaner the milk we start with, the greater are the advantages offered by the facilities in the dairy for keeping the milk good, and the better keeping products we obtain; while, on the other hand, as has often been stated, slovenliness in the handling of the milk during the early stages stamps its mark even on the subsequent manufacturing processes and renders them much more difficult.

The greater portion of the separator slime is made up of the microscopic filthiness deposited on the inside of the separator bowl as a sticky mass,* the quantity of which varies according to the treatment of the milk. In my investigations this sticky layer has amounted to not less than .1 to .3 per cent of the weight of the new milk.† This large quantity of filth will remain in the cream and the skim milk in using any of the methods of cream separation mentioned above—a point too little considered, in which the centrifugal method has a decided advantage over its predecessors. This point alone is in my opinion so important and valuable that it might speak for the universal adoption of the separator method.

It must be observed, however, that the separators can-

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* See further "Afbildningar af komjölk," etc., p. 12.

†Fleischmann (*Jahresb. Agr. Chemie,* 1885, p. 619) obtained from .04 to .13 per cent of slime, the former quantity being obtained from the milk of pasturing cows, and the latter from cows fed in the stable in winter time; and Scheurlen (*Zeitschr. f. Nahrungsm.-Unters.*, 1893, p. 3), about .04 per cent (130 grams from 300 liters of milk). See Myers, The Residue of the Centrifuge, *Proc. Soc. Prom. Agr. Sc.*, 1891, p. 76. For danger in spreading tuberculosis by feeding separator slime, see *Milch-Ztg.*, 1893, p. 672; *Fuhling's Landw. Zeitschr.*, 43, p. 400.—W.

not retain a too thick layer of slime in the bowl, and if much filth is accumulated on it, part of it will again be washed off and will mix in the cream and the skim-milk. To prevent this new infection we must avoid running the separators many hours without interruption, and special attention must be given to their cleaning. When conducted in the right way the separation will, however, improve the milk, decrease its bacterial content, clean it and make it keep better.

The results of my investigations thus differ from those obtained by Professor Fjord in Denmark in his investigations of separator skim-milk, where he found that centrifuging the milk neither injures nor improves its keeping quality. He doubtless worked with highly infected milk containing large quantities of bacteria even after the separation, and these soon made their influence felt at the high temperature applied.

The nature of the different bacteria may also be of some importance in regard to this question. In making similar boiling experiments of separator skim-milk as conducted by Fjord in the investigation mentioned, I have as a rule been able to prove a very high keeping-quality in the separator milk. Exceptions always occurred in cases where the milk was very rich in bacteria before the separation.

[Scheurlen has also shown that even a strong separation only partially purifies a highly infected milk from bacteria, and different kinds of bacteria behave differently under the influence of centrifugal force. He calls special attention to the fact that tubercle bacilli and some lactic-acid bacteria are easily separated into the slime in separation, while, e.g., the typhoid bacillus is usually found in the cream.*]

* Author's addition to American translation.

In his investigations of tuberculous milk Bang did not succeed in purifying it entirely from bacilli by means of the centrifuge. I also have been unable to remove all bacteria from milk infected with the ordinary milk bacteria by means of separation. If we cannot obtain milk free from bacteria by the use of centrifugal force as applied in our ordinary separators, it does not follow that the decrease in the bacterial content of the milk before spoken of is of little importance. In case of infectious bacteria, as in Bang's investigations, the results proved on the whole of small account, as milk but slightly tuberculous must be considered injurious to health. But the matter is quite different in case of fermentation bacteria: the fact alone that their number is decreased by the separation makes this method decidedly better than all other methods of cream-separation now known.

The cream having been freed from a large number of its bacteria in the separator process, we must see to it that the advantage gained is not lost through bad treatment. The danger is here great from the beginning, as the temperature of the newly-separated cream is very favorable to the development of the bacteria, the temperature of the milk when separated being usually about 86° F. (30° C.). We cannot therefore be surprised that the cream will soon be filled with a large number of bacteria if its temperature is not rapidly lowered.

As both the cream and the skim-milk come from the separator in thin streams they offer a large surface of infection, and it is therefore absolutely necessary not to allow dirty or dusty persons to approach the separator; this is, however, permitted to pass unnoticed in many of our creameries. The air in the separator-room must for the same reason be kept pure and fresh; the cream-can must, of course, be as clean as possible, and preferably recently sterilized by steaming.

But these precautions alone will not suffice. We must also take measures to act directly on the bacteria found in the newly-separated cream, and check their growth. The measures applicable for this purpose are well known from the preceding. One is the *rapid cooling of the cream* to a temperature at which bacteria do not develop, and the other is *pasteurization* and *subsequent rapid cooling* of the cream.

Both these methods of preserving the cream are at the present too seldom applied in our creameries; there is no doubt that great harm is done by the neglect of these precautions, for we may easily, at this point in handling the milk products, lose all that has been gained by previous care and neatness in stable and dairy, and by the separation.

Cooling the Cream.—The advantage in cooling the cream need not here be further dwelt upon: cream acts in this way just as milk does, so that what was said concerning its cooling is true also in case of cream.

When the separator method was introduced in the creameries it was believed that cooling would not be necessary immediately after the separation, and it was expected that less ice would be needed in the creamery as a result. Experience soon proved this to be erroneous, however. The products would not keep well, and were not first-class. Then the cream and skim-milk were cooled, and the quality of the products was immediately improved. It is now considered a maxim that *the cream must be cooled as soon as it comes from the separator*.

We must not imitate foreign creamery-men in this respect, for they greatly neglect the proper cooling of the cream; the reason of this is not that they are blind to the importance of the cooling process, but they have only limited means of cooling. It is not sufficient to lower the temperature of the cream to 50°–54° F., as is done in many places. The consistency of the butter is fairly good even with such a cooling of the cream, but the keeping quality is often not what it ought to be. A full step must be taken, and the temperature lowered below 50° F., or still better below 43° F. A good result may then more confidently be expected. But the consumption of ice with this application of the separator method is of course considerable.

In this connection I want to call attention to a bad practice which is followed at some creameries where the cream is heated to 167°–176° F. In order that the consumption of ice be not excessive, the warm cream-can is left to cool slowly in a cooling tank filled with cold water. This cooling, however, takes place too slowly. If good coolers are not at hand, it is absolutely necessary to cool the cream in tanks filled with iced water, the cream being stirred all the time so that the cooling may take place through the entire quantity. The method of cooling the cream in the open air is not to be recommended, as in this manner it may easily be infected by dust and bacteria.

Many different kinds of apparatus for cooling the cream are found. The Lawrence cooler (see p. 64, Fig. 20) is not very practical for this purpose, the cooling progressing too slowly. The coolers working in connection with the pasteurizing apparatus to be mentioned in next chapter seem preferable. Fig. 26 shows a Danish cooler which offers a large surface for the cooling. In using this apparatus the cream is poured into the reservoir *A*, the bottom of which is provided with several holes through which the cream is conducted in a thin layer over the cooling cylinder *B*. The cooled cream is gathered in the basin *C*, and removed from it through the faucet *D*. The water used for cooling is conducted into the cylinder at *E*, and circulates through the spirals.

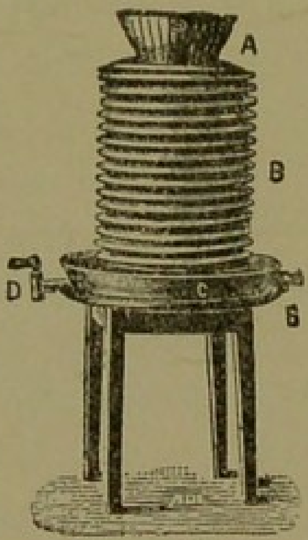

FIG. 26.

Pasteurization of Cream.—Considering the second of the measures mentioned for checking bacterial development in the newly-separated cream, viz., *pasteurization*, we note first of all that this operation must be conducted so that the butter made from the cream does not assume a cooked taste. For this reason the pasteurization must be made with special precautions. To avoid the cooked taste in butter it is often directed not to heat the milk above 150°–158° F., but in this way the power of pasteurization to destroy bacteria is in no small degree diminished. According to my experiments we may safely heat the cream to 165°–176° F. (75°–80° C.), provided either rapid and strong cooling is practised immediately after the pasteurization, or the cream ripened in a proper manner. I shall later on describe the latter method.

As regards the rapid cooling of cream, my experiments have shown that the cooked taste does not seem to reappear in the butter if the cream is cooled to 39° F. immediately after pasteurization. It may again be warmed to the temperature of ripening immediately after the pasteurization; an intense cooling seems to be the main point.

The cooling is beneficial in another respect as well, viz., in preventing the bacteria of the cream from developing. Here we again meet the same conditions as recently at the separation. The pasteurization does not kill all bacteria in the cream, nor is the separation able to remove all bacteria from the same; it is therefore in both cases equally important to prevent the bacteria remaining after the operations from developing. I must also emphasize that heating, as far as the keeping quality of the cream goes, has proved of but little benefit if not followed by rapid and efficient cooling. The pasteurization may be easily conducted without expensive apparatus in small or medium-sized creameries, if only the person to whom the operation is entrusted is sufficiently painstaking. There are always smaller quantities of cream than of skim-milk in creameries, and the latter therefore calls for apparatus of larger capacity. In case of pasteurization of cream, on the other hand, we may adopt simpler methods, e.g., to place the cream can into boiling water, and thus heat the cream to the desired temperature. Steam must not be conducted directly into the cream, as this will dilute it. In the method given the cream ought to be stirred frequently, as the desired temperature will then be sooner reached. This is important, for if the heating is done slowly the cream will assume an intense cooked or "beany" taste, which will reappear in the butter. A method which will secure more rapid heating is to place the cream-can in a wooden reservoir whose cover is provided with a hole into which the can fits rather snugly. Steam is introduced in the space between the wood and the can from a pipe, and the cream is stirred with a cream spade during the operation. This method of heating the cream has been employed for more than ten years at several Finnish creameries where "Paris butter" is made.

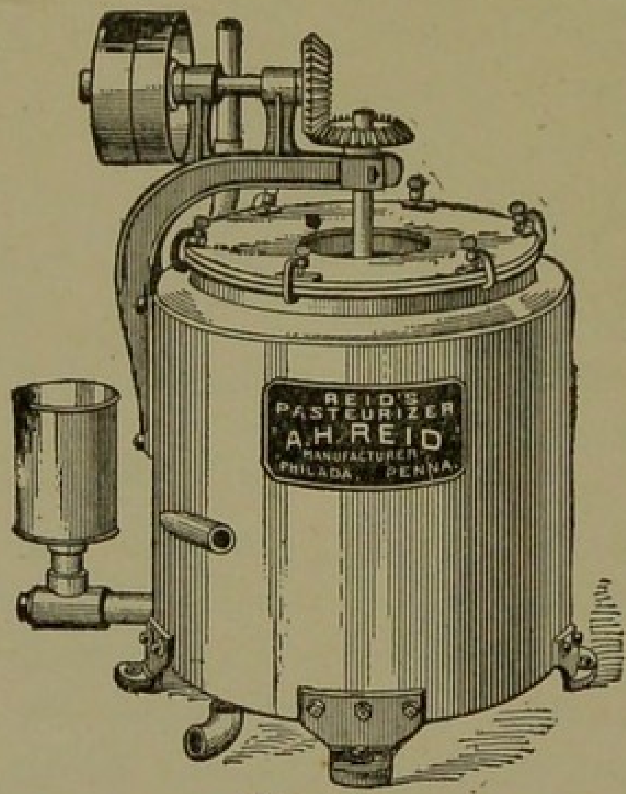

FIG. 26*a*.

Special pasteurization apparatus for cream are also found in the trade, and the better ones seem to serve the purpose very well. As the apparatus used for pasteurization of cream are essentially of the same construction as those used for pasteurizing milk or skim milk, we shall here only refer to the description of these in Part III of this book* (pp. 197–201).

[The three pasteurizers at the present found in American creameries or dairies are Potts' Pasteurizer (Fig. 26*b*),

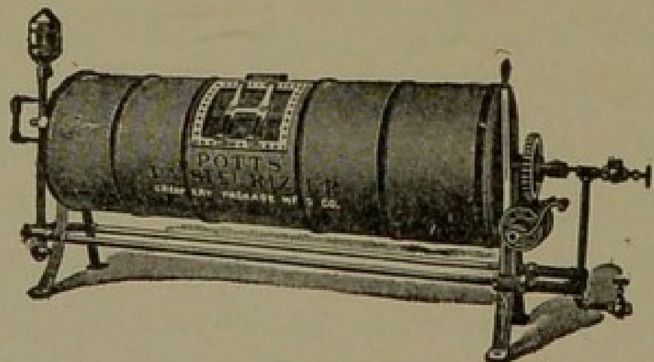

FIG. 26*b*.

Hill's Pasteurizer (Fig. 29*a*), and Reid's Pasteurizer (Fig. 26*a*). The two latter machines are modifications of the Fjord pasteurizing apparatus, shown in Fig. 27.—W.]

* See Wis. Exp. Sta., b. 44; Pa. Exp. Sta., b. 45; *Chem. Centralbl.*, 1893, II, p. 613.

PART III.

SKIM-MILK.

Before considering the factors which influence the keeping quality of skim-milk it will be in order to point out that there are different kinds of skim-milk of greatly differing qualities, and in many respects of different antecedents. These differences are mainly due to the different methods of cream separation by which the milk has been obtained.

Skim-milk from Gravity Creaming.

The skim-milk obtained by the old shallow-setting system is already sour when the cream is skimmed off, and as a rule it remains sour for a sufficiently long time before any other fermentation to all appearances occurs. So long as the lactic acid is not too strong in the skim-milk the lactic-acid bacteria may thrive there; but after a time their vital force is gradually weakened by the strong acidity which they themselves have produced, and to the same extent others, especially the butyric-acid bacteria, enter into full activity. The latter have up to this point only lived a torpor-like existence, but they now grow into activity; the pleasantly acidulated taste, which is the best quality of the skim milk, is lost and the applicability of the milk decreased.

The length of time in which this milk will keep slightly acid varies greatly. I have noticed cases where such milk has kept evenly sour for several days, and others where it assumed a rancid taste within twenty-four hours. The different conditions to which the milk has been previously exposed will largely decide how long the sample will keep. These conditions exert the same influence on the skim-milk as on any other milk, and we find that if the new milk has been handled carelessly the skim-milk obtained from it will possess a very inferior keeping quality.

The manner in which the sour milk is kept has also decided influence on its keeping quality. Proper cleanliness must above all be observed; the acidity should not be allowed to develop too far. Strong cooling or pasteurization need not be applied, but the temperature should be kept at a point that will allow the lactic-acid fermentation to continue, but not to develop excessively. This seems to take place best at 60° F. The lactic-acid bacteria then multiply easily (although not as rapidly as at 77° F.), and so strongly that they may hold in check the other bacteria found in the skim-milk. This is easily accomplished by keeping the sour skim-milk in a light room and in not too deep pans, and by stirring the milk occasionally. By these precautions, and by mixing some sour skim-milk with it every day, it is possible to keep such skim-milk of about even acidity for several weeks, as I have often seen done.

In the modern methods of creaming the cream is always removed in a sweet condition, and the skim-milk is also as a rule sweet. The problem of its keeping quality is therefore entirely different from that of sour skim-milk. In this case we understand the same by the term "keeping quality" as in case of new milk, for which reason all that has been said in regard to the keeping quality of the latter holds good also with sweet skim-milk.

Different kinds of sweet skim-milk will keep for a longer or shorter time according to the method of creaming practised and the treatment it receives. The skim-milk obtained from the Holstein method is often quite acid, although it ought to be sweet. This skimmed milk being often "blue-soured" and of poor quality, it cannot be expected to keep long, and at farms where the method is used the complaint is often made that the skim-milk causes the calves to scour. In the Gussander method the skim-milk is also reported not to keep well; in the deep setting system, on the other hand, it keeps so much the better. The skim-milk obtained by the ice method may be even model as far as keeping quality goes—i.e., if the milk has been properly handled previous to the creaming and later on has been treated in the dairy according to the strict directions of the ice method. We have seen that the skim-milk is not deprived of any of its bacteria in the ice method; all germs present in the milk before the cooling are found in it when they escape the torpor into which they are placed through the cooling. By pasteurizing the skim-milk the number and vital power of the bacteria found in the same may be diminished, and if it is at once properly cooled the advantages thus gained will be retained.

Separator Skim-milk.—The skim-milk offering the best guarantee for keeping quality is, however, that obtained by the centrifugal method of creaming. Docent Fjord correctly stated in a lecture in 1883 that separated milk must be considered the "cleanest of all milk." But this purity of the separator skim-milk is far greater and more important than he suspected at the time. He gave this opinion because he saw the great advantage arising from the removal of the microscopic impurities of the milk by means of the centrifugal force. It has now further been established that separator skim-milk contains fewer bacteria than even the milk from which it was prepared. The data given on page 184 give decided evidence on this point. Separator skim-milk will, therefore, keep better than any other not especially prepared milk. It is furthermore more palatable than other skim-milk, since it is purer and may be obtained in almost as fresh condition as new milk.* The separation may take place directly after the milking, and if the skim-milk is cooled immediately after this operation it will keep well.

Pasteurization of Skim-milk.—The keeping quality of the separator skim-milk may be further increased by pasteurization and subsequent rapid cooling. These operations are especially essential if the milk has become highly infected by bacteria in the stable or during the transportation. As shown by the table given on page 184 not even the separation is sufficient to produce skim-milk poor in bacteria, and it is therefore necessary to adopt further precautions to maintain the keeping quality of the milk, for which purpose pasteurization and cooling are especially

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* Fjord in *Tidsskrift for Landökonomi*, 1883, says: "As regards the sweetness of the centrifugal skim-milk it may be taken for granted that every housewife will prefer a sweet milk poor in fat for a half-soured, richer milk, no matter if the milk is consumed unboiled, or if it is to be previously boiled, by which process the sour milk is easily coagulated."

adapted. Our creamery-men ought particularly to note this fact, since the milk received by them is often highly infected with bacteria.

If further proof of the importance of pasteurization and cooling of the skim-milk is needed I may refer to the 22d Report of the Royal Danish Experiment Station. The results of lengthy practical investigations in this line, carefully conducted by Mr. A. P. Lunde, are published in this excellent report and form a worthy continuation of Fjord's experiments. The results present the most striking proof of the importance and necessity of increasing the keeping quality of skim-milk by the operations mentioned.*

A short explanation may be in order concerning the different pasteurizing apparatus and coolers at present on

* The following summary of experiments in heating skimmed milk to different temperatures and subsequent cooling, conducted by Fjord (1884) and Lunde (1890), show that the keeping quality of the milk is directly dependent on the degree of heat and of cooling applied. The milk was cooled to 12½° C. (54° F.) in the experiments of 1884, and to 25° C. (77° F.) in those of 1890. The figures given represent the number of hours during which the skim-milk could stand boiling.

	No Heating Applied.	Skim-milk Heated to						Skim-milk Cooled to
		50° C. (122° F.)	60° C. (140° F.)	65° C. (149° F.)	70° C. (158° F.)	80° C. (176° F.)	90° C. (194° F.)	
1884.	11.8	17.0	27.8	34.8	37.0	40.4	41.2	12½° C. (54° F.).
1890.	5.0	6.9	20.8	28.0	36.9	38.0	41.6	25° C. (77° F.).

(22d Report Copenhagen Experiment Station, 1891, p. 35).

Lunde (*loc. cit.*, p. 144) concludes from his numerous experiments with pasteurization of skimmed milk that its keeping quality was only slightly increased by the pasteurization if this was not followed by a cooling.—W.

the market. This whole question of the treatment of the milk being a result of the investigations of late years, the apparatus bear in general evidence of being first attempts.

The pasteurization apparatus most tried in practice at the present is doubtless the one constructed by Prof. Fjord in Denmark, of which a cut is given below. The milk

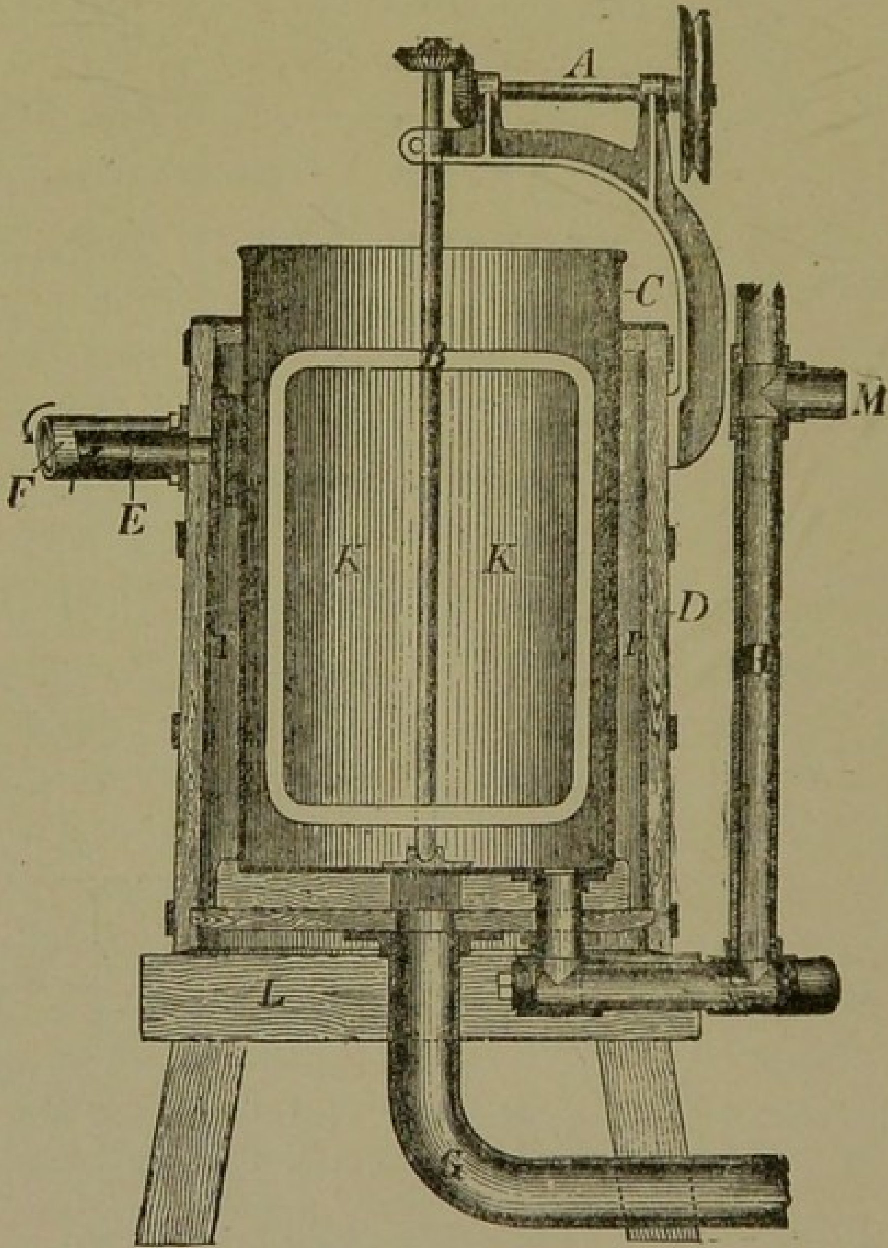

FIG. 27.

reservoir is of tinned copper and is surrounded by a cover of galvanized iron, between which the steam is conducted. A stirring apparatus resembling a churn-pole is made to

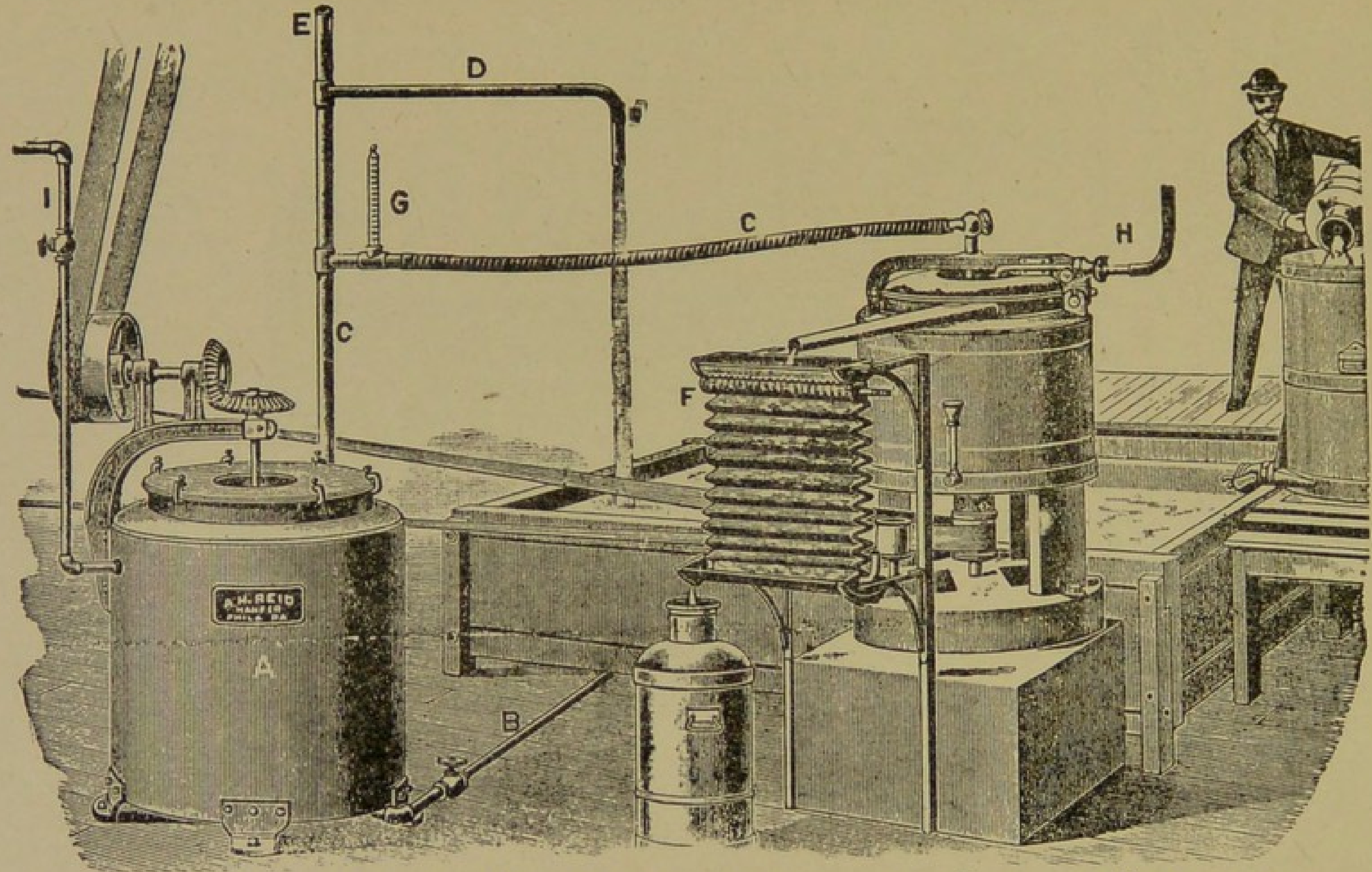

FIG. 28.—ARRANGEMENT OF PASTEURIZER, SEPARATOR, AND COOLER IN CREAMERIES

Milk flows through supply-pipe and regulating-valve *B* from receiving-vat into pasteurizer *A*, is pasteurized and raised through pipe *CC* into separator. Cream flows over cooler *F*, skim-milk passes out tube *H* to skim-milk vat. *I*, steam-supply pipe and regulating-valve. *G*, thermometer.

rotate in the milk-can. This keeps the milk in constant motion and prevents it from scalding. Fig. 28 shows how the apparatus is combined with a separator and a cooler; the latter is of a similar construction as that shown in Fig. 26.

Another pasteurizing apparatus in the trade is that manufactured by the Swedish Separator Company in

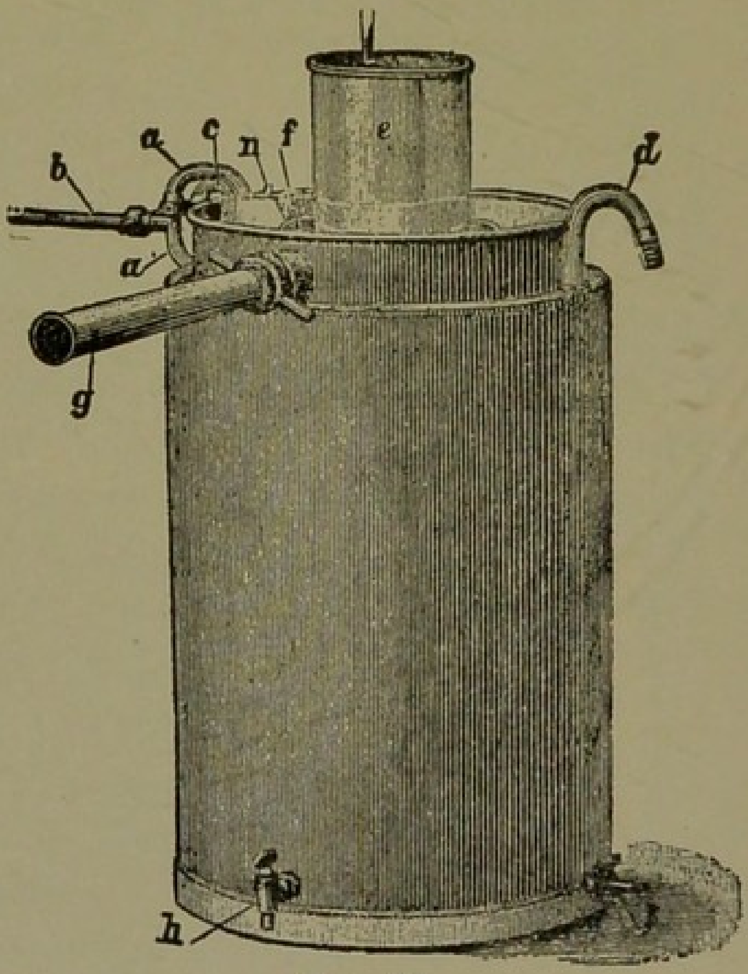

Fig. 29.

Stockholm (Fig. 29). The apparatus consists of two copper vessels with double walls and bottom, placed inside of one another at a distance of $\frac{1}{8}$–$\frac{1}{5}$ of an inch. The milk, which is supplied from cup *e*, is heated between the vessels and let out at *g*, and after finished pasteurization at *h*. Steam enters the vessels through the pipe *b*, which conducts it to the bottom of both vessels; the condensation water escapes at *c* and *d*, and after finished pasteurization from *l*.

The apparatus is said to work well, is easily cleaned, and may easily be combined with a cooler. No stirring contrivance is necessary to avoid scalding of the milk, this being in motion during the whole heating in a thin layer between the two warm surfaces.

A pasteurization apparatus constructed by Bitter has been adopted to some extent in Germany. It consists of a cylinder holding about 50 quarts and supplied with a cover; a three-centimeter ($1\frac{1}{5}$-inch) worm is placed in the same, through which the steam circulates and heats the milk in the cylinder, which is stirred by means of a crank. Forty quarts of milk may be heated to a temperature of 167° F. in fourteen minutes. Bitter has also constructed hauling-cans which are sterilized from the waste steam and afterwards filled directly from the cylinder, or still better directly from the cooler. The latter stands in direct connection with the pasteurization apparatus, and according to Bitter's instructions, ought always to be sterilized by steam before being used.

Besides the three pasteurization apparatus briefly described in the preceding, which represent three different types, a large number of others have been constructed differing more or less from these. As most of these apparatus are new and rather untried, it may be safest for the time being only to buy them on a guarantee from the manufacturer or the dealer.*

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*For descriptions and illustrations of other apparatus than those here mentioned, see Weigmann, "Milchconservirung," 1893, pp. 17–41.—W.

Before leaving this subject it may be well to draw some general conclusions from what has been treated in the preceding chapter—conclusions which may deserve attention also of others than dairymen.

Skim-milk is used as an article of food in the household of nearly every family in this country, as well as in many public institutions. We often find a prejudice against separator skim-milk, however, and it is therefore well to inquire whether or not this prejudice is well grounded and in harmony with the facts given in the preceding.

Separator skim-milk, as we have seen, differs from gravity-process skim-milk in the following points:

1. It has not been standing for a long time during cream separation.

2. It has lost the disagreeable macroscopic impurities of the milk.

3. It has fewer bacteria than the new milk from which it is prepared at the time of separation, and will therefore keep better.

4. If treated in the proper manner after separation it will also continue to remain comparatively free from bacteria.

Skim-milk separated by gravity process has, on the other hand, the following shortcomings:

1. It contains the greater portion of the disagreeable filth with which it has been mixed in the barn and elsewhere, since straining only frees the milk from the coarsest impurities.

2. It has been exposed to a cream separation lasting twelve hours or more, when the bacteria in most dairies have had an opportunity to develop.

3. Only after pasteurization and subsequent proper cooling will this skim-milk reach the high degree of comparative freedom from bacteria possessed by the separator skim-milk.

In view of these conclusions we cannot but consider the prejudice against separator skim-milk for human food as unfortunate. It is objected that separator skim-milk is so entirely void of all fat that it is not fit for human food. To this it may be answered that:

1. Equally poor skim-milk may be obtained by the ice method if the milk is left standing for several days.

2. Rich skim-milk may also, if desired, be obtained by means of the centrifuge.

3. By mixing new milk or cream with poor skim-milk any quality of rich skim-milk may be obtained.

The mere fact that the skim-milk is obtained by the gravity methods is no guarantee that it is rich; it is often its macroscopic impurities which produce the impression of richness (see p. 139).

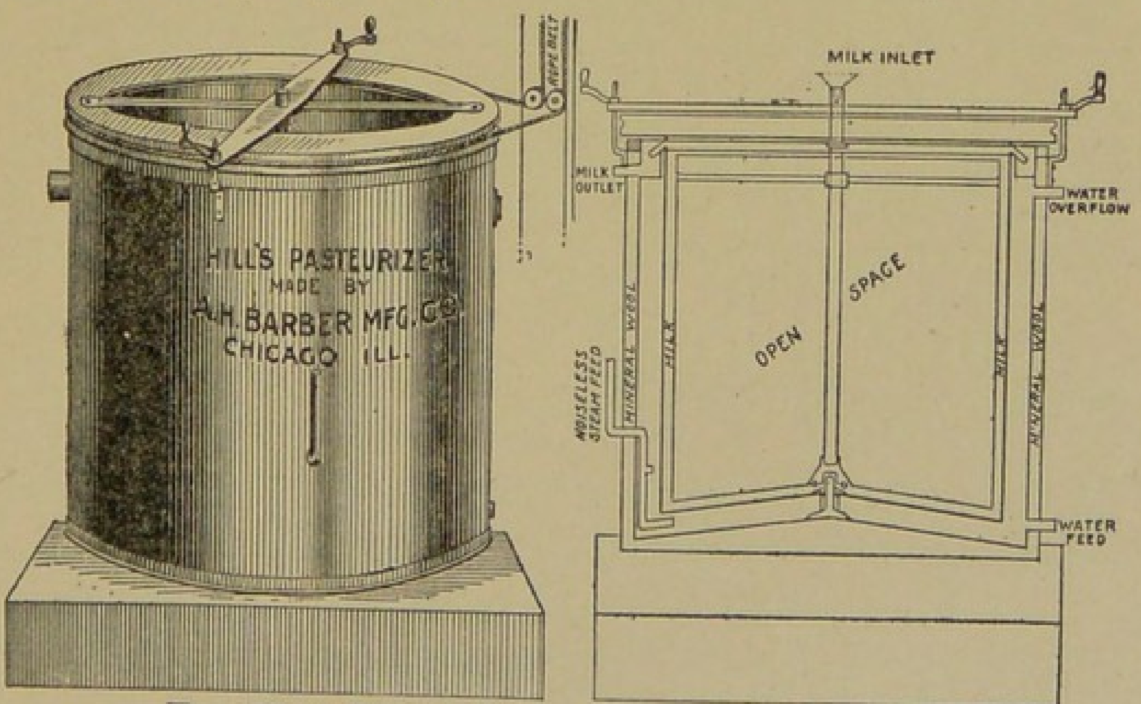

FIG. 29*a*.—HILL'S PASTEURIZER. (See p. 192.)

PART IV.

BUTTER.

CHAPTER I.

TREATMENT OF CREAM PREVIOUS TO THE CHURNING.

In describing the treatment of cream preparatory to the churning, and in examining the conditions influencing the keeping quality of the butter, we note that the different methods of cream separation do not produce the same kind of cream. We thus distinguish between two main groups—the acid cream obtained from the shallow-setting system and the sweet cream obtained in the deep setting systems.

It is natural that raw products so different as these two kinds of cream demand a radically different treatment, for which reason they ought to be treated separately. To avoid repetition the treatment of sour cream from the shallow-setting system will be explained after the sour cream obtained by ripening of sweet cream has been considered, and we shall therefore first take up the treatment of sweet cream preparatory to churning.

Sweet-cream Butter. — The treatment which sweet cream must undergo depends, first of all, upon how the cream and milk from which it was made have been previously handled, and on the kind of butter to be produced. Different kinds of butter seem to require cream of different quality, and the sweet-cream butter seem to be specially particular in this respect.

The cream used for the manufacture of this kind of butter must not have undergone the least decomposition, since the most important point in this butter is that its taste has not been changed by any acid fermentation in the cream or by other processes. Sweet-cream butter is the most delicate, and has the poorest keeping quality of any kind of butter. In its manufacture the treatment of both milk and cream must therefore, more than ever, be directed toward checking the growth of the bacteria. The main precautions to be taken in the manufacture of sweet-cream butter are as follows: rapid removal of the milk from the stable where the milking has been done under as cleanly conditions as possible; sterilization of milk vessels; rapid cooling in a light and clean room, or preferably centrifuging, and subsequent strong cooling toward freezing-point (pasteurization cannot be applied, since sweet-cream butter easily assumes a cooked taste); then rapid heating to the temperature of churning, and the most careful churning. Even a partial neglect of these precautions will tell on the quality of the product in one way or another. On account of the delicate nature of the sweet-cream butter it has not obtained a general sale on the large markets.

Paris Butter.—In the manufacture of "Paris butter" or "St. Petersburg butter" we can reach a far better keeping quality than the sweet-cream butter can ever claim by the application of the method adopted in the manufacturing of heating the cream to 158°–194° F. (70°–90° C.), preferably to 167°–185° F. (75°–85° C.). This is a real and thorough pasteurization, and I need not therefore further explain the advantages of the system or its manipulation. Here it may be pointed out that the pasteurization may be conducted very thoroughly; for a cooked taste in the butter is not objectionable in this case, but is, on the contrary, a desideratum. I cannot leave unmentioned that this cooked taste enables the butter-maker to hide all kinds of faults in the butter arisen through bad treatment in the churning or working of the butter, or through careless handling of the milk or cream.

One of the most important conditions in the making of this butter is that the cream be effectively cooled immediately after the pasteurization to a temperature below 50° F. The butter will then be firm and will keep well.

In order to get rid of the bacteria more completely, I have applied the method of intermittent sterilization (see p. 15) for the pasteurization of the cream, heating this two or three times to 140°–149° F. (60°–65° C.), with cooling between each heating. The last heating was always continued up to 158° F. (70° C.). The result was an extraordinarily well-keeping "Paris butter." When the temperature was not raised above 140° F. (60° C.) the first time, and only three heatings were made, the butter had a normal taste, while if the temperature was raised to 149° F. (65° C.) the first time the butter possessed a somewhat too pronounced cooked taste.

Besides improving the keeping quality of the butter the pasteurization of the cream is beneficial in killing tubercle bacilli as well as other infectious bacteria that may be found in it. According to Bang's investigations the tubercle bacilli in milk are killed by heating to 176°–185° F. (80°–85° C.).* This occurred if the milk was only heated up to the last temperature given, and not kept at this temperature for any length of time. A temperature of 144° F. (62° C.) made the infected milk greatly less dangerous, and at 162° F. (72° C.) it generally grew entirely harmless. This matter is of importance, for Gasperini has directly proved that the butter can contribute to the spreading of tuberculosis. Even 122 days after the milk was infected with tubercle bacilli the butter made from it contained virulent bacilli which killed animals inoculated with it.

Lafar also found that spores of typhoid, cholera, and tubercle bacilli would retain their vitality for a sufficiently long time in butter to carry these diseases to living beings.

Sour-cream Butter.—In the manufacture of sour-cream butter, other methods than those given must be followed in several respects. It is here necessary that a lactic-acid fermentation shall have taken place in the cream.

As is well known, there are two different kinds of sour-cream butter in the market, viz., farm (or dairy) butter and creamery butter. In case of the former kind the lactic-acid fermentation has usually taken place slowly during the creaming in shallow wooden pans, while in the manufacture of the latter kind all fermentations were checked by cooling during the cream separation, and a comparatively rapid lactic-acid fermentation was started in the cream after the skimming. The lactic-acid fermenta-

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* See foot-note on page 158.

tion is in the former kind usually caused by bacteria found in large numbers on the walls and bottom of the pans, or is started by means of buttermilk, sour milk, and skim-milk. No pure cultures are here applied; but the bacteria happening to be found in the pans or the milk are given full liberty to produce their characteristic fermentations, in the hope that the lactic-acid bacteria will be victorious. This hope in some cases miscarries—other fermentations occurring along with the lactic-acid fermentation, while in other cases this planless ripening yields surprisingly good results. As before stated, I have thus at several farms met with buttermilk obtained after ripening of such spontaneously soured cream which proved to contain almost exclusively lactic-acid bacteria.

The reason why these samples of buttermilk contained practically pure cultures of lactic-acid bacteria doubtless lay in the great cleanliness and strict care of which all the dairy work at these farms bore witness, as well as in the skill with which the creaming and ripening process was conducted. I have still oftener met with ice or separator creameries where practically pure cultures were found in the buttermilk.

The method used in bacteriological investigations for obtaining pure cultures originated with Pasteur, who published his first experiments in this line in 1857. Successive inoculations are made of mixtures of bacteria in different samples of the same substratum in order to learn which of the bacteria thrive best in the medium at hand. If different kinds of bacteria are inoculated in a certain medium, the organisms for whom this medium is most favorable easily gain the upper hand over the others.

If a mixture of bacteria, e.g., those found in ripened cream—is inoculated into sterilized milk, certain ones will soon gain superiority and produce their specific fermentation. If some of the soured sample taken when the fermentation is most active is then inoculated into a new lot of sterilized milk and the inoculation repeated in the same way, cultures of a certain bacteria are after awhile obtained which in most cases may be considered pure. The substratum has then offered so favorable conditions of life to this kind of bacteria that it has been able to suppress all others. In this manner I once obtained a pure culture of a lactic-acid bacteria from a very impure sample of milk.*

How do these conditions occcur in practice in the ripening cream in shallow pans? In the first place the lactic-acid bacteria are favored in every way in these, milk being the most favorable nutritive medium imaginable. Secondly, souring material is transferred partly unconsciously (the wall and bottom of the pan), partly consciously by addition of sour milk in which the fermentation is at its height. It will be seen that there are here many points of similarity with the method applied in laboratories for production of pure cultures. Conscious infection by means of sour milk does not often take place in farm-dairying, and is only resorted to when the unconscious infection has proved insufficient. I have, however, found places in Savolaks where such inoculation of acid bacteria has been the rule and was applied almost daily. This infection in one place occurred by dipping the wooden spoon used in skimming the sour-milk pans into the pan con-

* "Studien über die Zersetzungen der Milch," in *Fortschritte der Medicin*, 1889, pp. 122, 123.

taining sweet milk.* Thanks to this manner of procedure, the souring took place more rapidly.

In the unconscious infection of fermentation-starters, the cause usually lies in the fact that the milk-pans used for creaming have not been sufficiently cleaned. The result, however, in this case must evidently be more uncertain. Strange to say, we rarely find other than lactic-acid bacteria in excessive numbers in sour milk at our farms. The reason is doubtless that these bacteria are not checked as strongly in their development as others, the milk-pans being placed outdoors in the sun, dried and aired, to which treatment the putrefactive bacteria are very especially sensitive. If the pans be thoroughly sun-baked they become wholly sterile, as we saw before, and the souring of the milk has then to be started by inoculation with sour milk.

The inoculated milk is mixed with all kinds of bacteria, and the ripening is not therefore always successful. One result of this fact is that farm butter is so much poorer in winter, when milk is produced in the stable. Comparatively good pure cultures may, however, be obtained under the primitive conditions present in the manufacture of farm butter. If an effort is made to improve these conditions by introducing greater cleanliness in stable and dairy, and by increasing the knowledge of the principles of dairying among farmers, the result ought to be still better. If, for instance, the milk is pasteurized before being creamed, we should soon find that the souring will always take place in a proper manner also in the shallow setting system.

* At farms in Norway this inoculation is often effected by placing a little pure sour milk at the bottom of the milk-pans.—W.

Adding sour buttermilk, etc., to cream is also practised in the ripening of cream from modern methods of creaming; and here it will happen oftener that pure cultures of a single bacterium are obtained. The better conditions at the creameries and dairies using these methods tend to bring about this result; and the application of accessories, as pasteurization of the cream, etc., would clearly still further forward it.

It is by no means an easy matter to properly conduct the ripening of the cream under differing conditions of temperature and facilities; it requires great care and power of observation as well as a good store of knowledge on part of the butter-maker. The ripening of the cream has such a decisive influence on the qualities of the butter that cream of the best quality may be entirely spoilt by careless ripening. But, on the other hand, a proper ripening cannot possibly be conducted in cream poorly cared for and containing a large number of injurious bacteria. The quality of the butter depends more than is generally acknowledged on the manner in which the milk, the cream, and butter have been treated, and above all, on the ripening of the cream. Martens said as early as 1869: "Although other conditions, as the winter feeding, the pasture, the milk-cellar, etc., greatly influence the quality of the butter, these factors very often get the blame for faults originating through carelessness in the treatment."

The first condition for obtaining a proper ripening is that the raw material shall be good. If the quality of the cream is uncertain it is always safest to pasteurize it before ripening. If this operation be well done, and the cream be rapidly cooled immediately after the pasteurization, the sour-cream butter will not, as we saw before, have a cooked taste.

The Danish experiments spoken of on page 197 show conclusively that pasteurization properly conducted never injures or lowers the fine quality of the butter, but, on the other hand, is very beneficial to the same. The butter will keep better, at the same time as bad flavors and taste are prevented from appearing in it. The yield of butter obtained will be somewhat lowered, partly because the buttermilk will be richer, partly because the butter will contain less water;* but this decrease is in reality insig-

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* As an average of 51 trials with pasteurized and non-pasteurized cream, Lunde obtained 3.73 lbs. of butter from 100 lbs. of milk in case of ordinary cream, and 3.68 lbs. in case of pasteurized cream, or a loss of 1.3 per cent.

He obtained the following average results as regards the *water content* of the *butter* made by the various processes:

Normal cream (15 trials)	14.35 per cent.
Pasteurized cream "	13.74 "
" milk "	12.85 "
Normal cream (22 trials)	14.17 per cent.
Pasteurized milk "	13.03 "

The buttermilk contained on an average for all experiments the following percentages of fat:

Normal cream	.33 per cent.
Cream pasteurized	.37 "
Milk pasteurized	.55 "

See also Berg, Nordisk Mejeri-Tidn, 9, p. 126; Exp. Sta. Record 5, p. 1025.

Lunde (22d Report Copenhagen Experiment Station, 1891, p. 110) summarizes his work on pasteurization as follows: "If a creamery works under normal conditions and makes first-class butter, it will nificant, especially since a lower water content must be considered a direct advantage. The lower percentage of water has also in a measure the effect of making this butter keep better than butter from non-pasteurized cream.

The second condition for a good ripening of the cream is that the butter-maker shall be well informed on dairy mat ters and shall watch the process himself. He should be present from the beginning to the end every time the starter is prepared; should be present when the ripening of the cream is begun; should carefully follow the whole process, and when it is done, examine the sourness of the cream. Carelessness in the ripening at once stamps the butter-maker as incapable.

Ripening Room and Vessels.—To secure a proper ripening of the cream the creamery should contain a separate ripening-room, as it is otherwise very difficult to produce a good fermentation. In many places the ripening-can (or vat) is placed in the separator-room. This practice is reprehensible, among other reasons because an even temperature cannot possibly be maintained there, and neither can the atmosphere be kept properly dry; the strict cleanliness necessary where the ripening-vat is placed cannot possibly be observed in this room. The ripening-room should be well isolated from dwelling-rooms and other creamery-rooms. It should not be directly connected with

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hardly, according to our experiments, pay to introduce pasteurization, if a somewhat higher price than before be not obtained on account of the better product. If, on the other hand, a creamery has difficulties in making first-class butter, so that the price is always discounted because this or that shipment was of inferior quality, pasteurization will as a rule be an efficient means of removing the trouble and again obtaining the previous price." See Wis. Exp. Station Bull. 69, for experiments on pasteurization in butter making, and a general discussion of the subject for American conditions; also Penna. Exp. Sta., Bull. 48, and Farmers' Bull. No. 92.—W.

the cheese-room or curing-rooms, for the fermentation processes favored in these are of a wholly different nature and inimical to the changes to be brought about in the ripening of the cream. It is also evident that the ripening-room ought not to serve as a passage-room, and that it must be free from draught and equipped so that an extreme cleanliness may exist throughout. It must be well ventilated and kept at an even temperature (from 50°–65° F.) The air should be dry, as it is otherwise very difficult to prevent all kinds of fermentation from arising.

The room must, of course, be provided with large windows, so that light and sunshine may enter into it. It need not be very large and must not be used for any other purpose—except, perhaps, for storing of butter ready for shipment.

Wooden cans or tin vats are used for ripening cream. At the present the former are most used in Finnish creameries; and if manufactured of hard, close-grained oak, they may without difficulty be used for some time, as they can then be easily and thoroughly cleaned and sterilized; but if old and made of soft, loose wood, they have a very deleterious influence on the ripening, as they cannot be properly cleaned even by steaming, and the result is that all kinds of bacteria lodge in them which may give rise to faulty ripening. In my opinion the ripening-vats prepared from tin, or tinned copper, are always to be preferred, as they may easily be kept clean and sterile. Metal vessels are sometimes objected to on account of being good conductors of heat; but if a proper ripening-room the temperature of which can be regulated is available, this objection will be of no importance. If such a room cannot be obtained, an even temperature of the cream may easily be obtained by enclosing the ripening-vessel in wood, hay mattresses, etc.

In the creameries of North Germany the ripening usually takes place in small tin vessels placed in water-basins, the temperature of which is regulated by means of steam or ice. In many respects this is a very practical method; but it has the disadvantage that a good deal of moisture is introduced into the ripening-room, so that it becomes very difficult and almost impossible to keep the room free from colonies of mold and bacteria.

The Ripening Process. — In many places abroad—for instance in Germany—the contents of the ripening-vat are left to sour, without the addition of any starter, as in case of the old shallow-setting system. This method is, however, too slow and uncertain, and the application of a separate acid starter is therefore always to be recommended. We must carefully watch so that the cream is not contaminated or mixed through the starter with a fluid containing faulty fermentations. The qualities of the starter must therefore be daily tested by taste and odor, and the progress of the ripening process be watched by repeated careful observations.

Acid Starter.—At our creameries three different kinds of starters are generally used at the present, viz.: (1) *buttermilk from the last churning;* (2) *ripened cream;* (3) *buttermilk from another creamery.* The well-known Danish dairy instructor, Böggild, treated this topic in a lecture delivered in Odense in 1890. The following description and discussion of the ripening process is taken from the lecture:

1. *Buttermilk Acid Starter.*—"There is no lack of examples that older, well-conducted creameries have used buttermilk as starter during a series of years; but it would

be incorrect to conclude from this that such a method of procedure is applicable under all conditions, for we have learned by experience that ripening faults may be transferred from one lot of cream to another by the application of buttermilk, and may even be increasing until the method of ripening is changed. The application of buttermilk from the previous churning can therefore only be recommended as long as the ripening process occurs in the proper manner.

Sour cream from the mess ready for churning is used in place of buttermilk in some creameries. This has the same advantage and the same danger as the use of buttermilk, and is only to be preferred where there is reason to suspect that injurious micro-organisms or other impurities have been added in the churning or the washing-down of the cream. Both buttermilk, cream, or any other kind of starter used must be kept at a low temperature from the time it is ready and till it is to be used, so that it does not become damaged.

2. *New-Milk Acid Starter.*—The application of new acid starter is of but recent origin; it was previously prepared from a mixture of water and fresh milk, but it is now generally made from cream, fresh milk, or partly skimmed milk. A suitable quantity of any of these liquids is heated and kept at a temperature most favorable to the development of the bacteria desired for the production of butter; the result of the application of the new starter depends largely on the success obtained in this process.

The object sought in using a new starter in place of buttermilk is to improve the ripening process. It must therefore be an invariable rule to examine it carefully as to appearance, odor, and taste, and to compare it with the buttermilk. If the buttermilk is better than the new starter, the former should be used. As cream differs from milk only in its greater fat content, and as fat does not play any part in the nutrition of the lactic-acid bacteria, there is no reason to prefer cream for milk as a starter. Even if the cream does not give a proper new starter it is generally used anyway, as it represents a certain quantity of butter, and is not therefore fed to the hogs ; neither is it churned separately, but is used as starter on the supposition that it is as it ought to be.

On the basis of experience gained at Danish dairies creamery-men are advised always to prepare new starter, to compare it with the buttermilk, and to apply the one that proves the better. The milk best adapted to preparation of starter should be found by comparative trials with the milk from different patrons. The patron furnishing this milk should then be asked to send the milk from only fresh-milking, well-fed cows in a separate can; and this should either be sent to the creamery while still warm or subjected to a careful cooling on the farm. Immediately on arrival of the milk at the creamery the butter-maker should place it in one or two common cylindrical milk-cans previously well cleaned with soda or lime and scalded with boiling water; the milk is then cooled as rapidly as possible in ice or cold water. A layer of cream will form during the forenoon, and this is then removed with an ordinary skimmer and poured into the sweet cream from the centrifuge. The partly-skimmed milk is used for preparation of starter.* The milk is now to be heated,

* In my opinion separator skim-milk from a well-conducted farm is to be preferred for such sweet, partly-skimmed milk.—G. G.

which may best be effected by lowering the milk-can into hot water, while the milk is continually stirred by means of a galvanized-iron rod supplied with a round disk. This as well as the milk-can and skimmer must of course have been thoroughly cleaned.

At different places and at different seasons the milk must be heated to a temperature of 77°–95° F. (25°–35° C.) to become evenly sour in the course of eighteen to twenty hours. The exact temperature required is determined by experiment. When the correct temperature has been reached, the milk-can is carefully placed, so that none of the contents is spilled, into a barrel filled with hay. The can should be covered with a clean cloth, on which a neat hay mattress is put; the milk may now be left alone until the next day. As soon as the work begins in the morning the butter-maker should examine the starter, for the ripening process may be finished. This may conveniently be done by placing the vessel in cold water when the milk becomes evenly sour. In the majority of creameries it is most convenient to have the acid ready at 8 to 10 A.M. The upper inch layer of the milk is removed with a skimmer, as it sometimes is less palatable than the rest of the acid. The starter is then mixed with the stirring-rod and placed in cold water until used.

The new starter does not usually taste as sour as the buttermilk, and a somewhat larger quantity must therefore be used of it. As a disadvantage in the method may be mentioned that the souring does not always progress in the same manner, so that the butter on separate days of even the same week may prove of different quality, while an even quality of butter is easily gained by using a buttermilk starter.

The use of a new starter is to be recommended when the quality of the butter is deteriorating or is unsatisfactory, and above all when milk varying in freshness, purity, and general qualities is sent to the creamery.

Where the quality of the butter is not satisfactory. and where it also proves difficult or impossible to prepare good new acid, it will be necessary to apply buttermilk from another creamery.

3. *Buttermilk from Another Creamery as Starter.*—This should of course be obtained only from a creamery where the butter is good, and where the ripening is successfully conducted at the time. The practice of using buttermilk from another creamery is very old, and has especially been used in places where proper churning has been conducted under great difficulties, and where the cream has not soured evenly, but has remained thin and turned bitter and "off flavor." However simple this remedy may seem it has not often been resorted to—doubtless because butter-makers have considered it a reflection on their ability not to get out of the difficulty by their own efforts. The practice seems, however, now to be more generally followed as the great importance of the ripening of the cream for the quality of the butter is better understood. With the experience of late years we may say that in some cases it is a sign of ability and care on part of the butter-maker rather than the other way, if he tries to obtain a good starter from another source when his own has for a long time proved unsatisfactory.

It has happened in some cases that a butter-maker has succeeded in getting the ripening process in proper order by a single application of good buttermilk from another creamery—good results having later been obtained by applying buttermilk from previous churnings; but there are plenty of examples that the difficulty is not always as easily adjusted, the ripened cream after some days again being of the same undesirable quality as before. To counteract this it has long in all such cases been a universal remedy to make a general housecleaning. The ripening-vat, churn, and other wooden utensils are carried out in the open air for some days; the creamery-rooms are whitewashed, etc. This method of procedure is doubtless both practical, correct, and necessary; but when it proves insufficient the attention must also be directed toward the other side of the subject, and an especially good starter must be provided for several days ahead. This may be secured by obtaining good buttermilk daily from another creamery, but if the distance is too great, a culture of the bacteria of the buttermilk obtained may be carefully kept and a portion of the same used daily as a starter."

Pure-culture Acid Starters.—By the preceding methods of securing a good acid starter much is, however, left at a venture. We do not know to which lactic-acid bacteria the successful outcome is due; and neither are we certain if the cream is not infected by injurious bacteria from the starter. To avoid this a new method of preparing the starter has been introduced in some foreign creameries during the last couple of years, according to the principle which has proved of such great benefit to the fermentation industries, notably the brewing industry. As long as yeast containing fungi and bacteria of all kinds was used in the manufacture of beer there was no certainty of a successful fermentation. A yeast fungus sometimes obtained the superiority, a bacterium another time, and the result was therefore often different from what was wanted; the beer might turn bitter, be "off flavor," etc., although the raw products used were of the very best quality. Until lately we were placed in the same difficulty in the fermentation industry called the manufacture of sour-cream butter. The composition of the starter used is not known, and it perhaps contains a large number of injurious bacteria. Although the quality of the cream was excellent, a bitter, oily, turnipy or other kinds of diseased butter may have been obtained owing to the introduction of injurious bacteria into the cream from the starter. The effort has perhaps been made to produce good milk, to handle it properly throughout, to take good care of it during the transportation to the creamery, to care for it there according to all the rules of the art, to cool, separate and pasteurize it—a relatively germ-free cream being thus obtained; and after all this the delicate product is calmly mixed with a fluid the qualities of which are only partially known, and all preceding efforts may thus be overthrown. By a good deal of practice and experience the ripening may certainly be successfully conducted in this way. A Danish butter-maker has thus, as I recently learned, been using the same kind of starter for fourteen years without having ever had a faulty ripening. In the same way experienced brewers were able to make good beer also before the introduction of pure cultures; but there could be no certainty of a good, uniform, and well-keeping product until the adoption of the latter process.

Butter-makers cannot prepare such a starter themselves, however, but are obliged to turn to a bacteriological laboratory that can furnish them with pure cultures of lactic-acid bacteria. We shall return to the pure cultures of these bacteria at the end of this chapter in connection with a further description of the nature and characteristics of the different lactic-acid bacteria.

The methods of applying these pure cultures in the creamery business were vague and uncertain until of late; the solution of the problem was only a couple of years ago in its first stage of development.

Storch (Copenhagen) recommends the following method of procedure for the application of pure cultures: "The starter is to be prepared daily by means of a pure culture; the latter may best be supplied to the creamery in especially-arranged vessels, from which it may be drawn in small portions without danger of contamination; the creamery-man adds a sufficient quantity to as much new milk (or perhaps preferably separator skim-milk) as the creamery is in the habit of using for a starter. Before adding the pure culture the milk is heated above 158° F., and at once cooled to the temperature at which the ripening will take place safest and quickest. It is possible that another heating of the milk to 158° F. after a day's interval will be found necessary. When sufficiently acid and completely curdled this milk is ready to be used as a starter."

Weigmann (Kiel) gives the following method: "The pure culture is to be ordered from a bacteriological laboratory; full-skimmed separator skim-milk is used in preparing the starter. The bacteria found in the same are weakened or partially destroyed by cooling or heating; if cooling be applied it must be very effective (37°–30° F.). It is, however, better to heat the milk to 140° F., cooling it at once afterwards to 68°–77° F. A portion of the pure culture is then added, at the same time stirring the milk carefully. The starter will be ready the following day, and should be renewed every day by adding sweet skim-milk. When a disease of the butter is being fought, pure cultures must for some time be applied every day for preparing the starter; otherwise a fortnightly application of pure cultures will suffice."

In my latest experiments with pure cultures in practical dairying I have used the following method of procedure: Morning milk from a well-kept farm was separated as soon as it came to the creamery. Part of the skim-milk obtained was carefully pasteurized;* then cooled to 77°–82° F. (25°–28° C.), and the pure culture added. The temperature was not lowered below 68° F., and the milk, which was covered by a clean cloth during the whole time, was therefore curdled as early as the afternoon of the same day. The cream separated in the morning was pasteurized (at 158° F.) and cooled to about 39° F. It was kept at this low temperature for at least six hours; but perferably until the evening, being occasionally stirred. At about 6 P.M. it was heated to 73° F., the starter was added, and the cream-can then kept wrapped in a hay mattress at ordinary room temperature (64° F.). The cream was stirred at least twice during the evening, with an hour's interval. It was usually properly acid and uniform the next forenoon, and after some cooling was poured into the churn.†

* This milk may safely be heated to 185°–194° F. (85°–90° C.). Even if the starter has a cooked taste, the cream ripened by it will not according to my experience have this taste unless extraordinarily large proportions of starter are used.

† The starter used by C. O. Jensen in his experiments was prepared in the following manner, according to his own description: "200–600 cc. (about 7–20 oz.) of milk was drawn from the cow, the udder and teats having been washed with a corrosive-sublimate solution (1.1000); the teats were then wiped with a steamed towel,

The question of how often the new starter should be prepared from the pure culture cannot as a matter of course be answered so as to apply to all conditions, as these vary greatly at different creameries. The only rule that can be given on this point is to use it as often as it proves necessary. The new starter is propagated in the usual way, separated and pasteurized skim-milk obtained from new milk drawn and treated throughout with the most minute care being always used.

The new starter must be watched to prevent the fermentation from proceeding too far, lest the acidity grow too strong for the lactic-acid bacteria, thereby offering other bacteria—e.g., the butyric-acid starters—favorable conditions of life. According to my experiments this stage will occur when the cream contains about .85 per cent of lactic acid—a degree of acidity which but slightly exceeds that usually

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and my hands were also washed with sublimate solution and wiped. The milk was drawn directly into a sterile flask provided with a cotton plug, through which a piece of glass tubing about one half inch wide and three to four inches long was placed; the latter was also closed with a small cotton plug. This plug was removed in milking, and the narrow tube was after the milking again closed with the plug. As a still further precaution this milk was heated in the flask up to 158° F. (70° C.) for ten minutes and rapidly cooled to about 77° F. (25° C.). The seeding with the lactic-acid bacteria was done by introducing a recently-ignited capillary glass tube into the agar-agar culture and placing it in the milk through the glass tube in the cotton plug. Treated with sufficient care the milk was never contaminated, which fact was always directly ascertained. The inoculated milk was left standing at 77° F. (25° C.), and always soured evenly in the course of 16–20 hours. From this soured milk agar-gelatine cultures were made, which in their turn were used the next day for preparing the new starter.

found in buttermilk. C. O. Jensen states that the lactic-acid bacteria even succumb at about .75 per cent acidity. Too sour starters may therefore cause a great deal of damage—first of all because injurious bacteria have been allowed to multiply in them. When these reach the cream they are again placed under unfavorable conditions, but even if they are not allowed to multiply there to any appreciable extent they will be present in relatively large numbers and go over into the small gatherings of liquids in the butter. The acidity will easily increase farther and butyric-acid bacteria, if present, will start their fermentation—rancid, spoilt butter being the result. Other bacteria, as those of "oily butter," may in the same way be propagated from the starter to the butter. It is therefore of the greatest importance to keep the fermentations in the starter in check. No bacteriological analyses or other intricate methods are necessary to determine when the starter is done and when the fermentation should be stopped by cooling. A skilled butter-maker can easily determine the question by taste, odor, and appearance of the starter.*

The proper ripening of the cream is, as has often been stated, one of the most difficult problems of dairying, since it can very easily fail or be influenced by exterior conditions. It is above all essential here as everywhere else to observe the most minute cleanliness, and to watch all one's movements to prevent any possible infection to the cream.

At many places the cream is run directly from the separator into the ripening-vat; but this method is to be rejected, as all kinds of irregularities in the ripening of the cream will easily then arise whereby the solidity and grain

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* See foot-note on p. 227.

of the butter may suffer. The cream should be cooled strongly and kept for a while at a low temperature. Weigmann gives observations in a similar direction, and is of the opinion that such a cooling (for at least four hours) weakens the vital power of the bacteria in the cream. It is also beneficial to keep the temperature of the cream uniform by occasional stirrings, thus securing an even ripening and removing odors, etc., possibly present in the cream. It is of course greatly preferable to pasteurize and then cool the cream immediately after the separation.

The ripening of the cream is usually finished within 18–20 hours in our creameries. This is called *slow ripening*; the *rapid ripening* lasts 6–10 hours. The question which of the two is preferable is at the present one of the points of dissension in dairying.

The length of the ripening period depends on (1) the *quantity of starter used*, and (2) *the temperature at which the cream is kept*. If a high temperature and a large quantity of starter be used, the ripening will of course take place rapidly. By varying both factors the ripening may take place in the time which experience has shown the most preferable under the conditions present. The duration of the ripening period is in my opinion not so important for a successful ripening of the cream as are the quality of the cream and the starter, and the degree of cleanliness which pervades the whole process. In my first pure-culture experiments I used such small quantities of the starter that it took thirty-six hours to ripen the cream, and a well-keeping, fine butter was obtained; on the other hand, as good and perhaps better may be obtained by a short ripening period when the proper precautions are preserved. This being the case nothing is gained by a long ripening, since the time during which the cream may be infected with bacteria is thus only increased.

In rapid ripening greater watchfulness is necessary and the progress of the fermentation must be repeatedly examined, for the rapidity of the process greatly increases the danger of its progressing too far. It may be added that if the cream turns too acid, lumps of casein will separate out and later on be taken up by the butter, which will then not keep well, casein, as is well known, being very unstable and easily attacked by putrefactive bacteria. When ripe for churning, the cream should not contain any separated lumps of casein.

The cream must not, on the other hand, be ripened too little, as the taste will then not be as desired; the souring will continue in the butter and will there take place under wholly new conditions, the regulation of which we have not in our power. A good acidity, not too mild and not too strong, is most desirable for the production of a well-keeping butter *

* It would be of great advantage to butter-makers, and more especially to novices among them, to possess a method by which the proper acidity of the cream could be accurately determined. In laboratory-work and in investigations conducted by dairy chemists the method of titration of the cream by means of an alkali has long been practised, but it was not adapted to factory purposes in our country until 1890, when Dr. Manns published (Bull. 9, Ill. Exp. Station) what is known as *Manns' Acid Test.* The method rests on the principle that the compound phenolphtalein gives an intensely red color to alkaline solutions ; a solution of an alkali (either potash, soda, lime, or baryta may be used) of known strength is added until the liquid assumes a permanent red color, and the acidity of the cream can then be calculated. The description of the Manns test is given as follows :

Directions for the Use of Manns' Test.—1. Stir the cream thor-

In case the butter is consumed within a short time a mild acidity of the cream may be all right, but if intended to be kept for a longer time (as in case of export butter) the ripening should be allowed to proceed farther.

If a good starter made from a pure culture is available, a comparatively large quantity may advantageously be used to secure a rapid ripening of the cream. This would seem especially important in case the cream is poor and impure, for the injurious bacteria found in it are then at once placed in minority; a mass infection of the cream is started by which means the undesirable forms of bacteria are prevented from developing.

Pure Cultures and Shallow Setting.—It may be of interest in this connection to examine in how far pure cultures

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oughly; insert small end of pipette in cream and draw until nearly full; then put the finger over upper end of pipette and allow cream to escape slowly (by admitting air) until mark on neck of pipette is reached. Transfer to a tumbler; rinse the pipette three times with lukewarm water, adding the rinsing water to the cream in the tumbler. Now add to contents of the tumbler three drops of the solution marked "Indicator" (phenolphtalein).

2. Fill the burette up to the O mark with the solution marked "Neutralizer" (alkali solution).

3. While constantly stirring the cream with the glass rod, allow the liquid to flow from the burette into the tumbler until the entire contents of the tumbler shows a pink tinge. Stop adding the solution from the burette the moment the color is permanent.

4. Read the level of the liquid remaining in the burette. The reading shows the amount of acid present.

The experience of those using the test indicates that where the acidity of the cream is right, to secure the best results in yield and flavor of butter from 38 to 42 cc. of the neutralizer will be required for the test. It is a simple matter for each butter-maker to learn by experiment the exact degree of acidity and churning temperature suited to the best results, and with these as standards reduce the are applicable in case of the shallow-setting system of creaming. In experiments in this line I prepared the acid starter by means of pure cultures, in the manner given before, added the same to the milk, and found that in this way a much more rapid and more certain fermentation was obtained than by the ordinary plan. The main condition of a successful outcome proved to lie in proper restriction of the fermentation, so that the casein of the milk does not coagulate before the creaming was done. The butter made kept very well, especially when the milk was pasteurized and cooled previously to setting.

Lactic-acid Bacteria.—A large number of bacteria pos-

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process of butter-making to a certainty. By testing his cream in the afternoon, the butter-maker will be able to set it to ripen at such a temperature that it will show the proper acidity for churning the next morning.

In testing the milk for cheese-making the same directions are to be followed, excepting that a much less acid condition is required; probably from 15–20 cc. will give the best results. The whole numbers are cubic centimeters; the intermediate divisions are fractions of a cubic centimeter.

Precautions in Using the Test.—The solution marked "Neutralizer" is prepared of a certain strength. It is essential that this strength remain constant. Never let this solution stand without a stopper. Keep in glass or stoneware."

The necessary apparatus and chemicals may be obtained from dealers in dairy supplies. Lately Prof. Farrington has published a method of testing the acidity of cream with alkaline tablets of a certain strength. For a description of the manner of procedure in applying the tablets, see Bull. 32, Ill. Exp. Sta., and Farrington Woll Testing Milk and its Products, 21st Edition, 1912, pp. 125–136.

Concerning the relation of the acidity of the cream to the yield of butter, see Sebelien, *Ldw. Vers.-Sta.*, 34 (1887), p. 93; Manns, Bull. 9, Ill. Exp. Sta. (1890); Wallace, Bull. 22, Iowa Exp. Sta. (1894).—W.

sess the quality of producing lactic acid in the milk ; they are able to develop at temperatures above 52° F. (11° C.) —the optimum temperature as regards their power of fermentation lying between 82° and 100° F. (28° and 38° C.). The different bacteria show great differences, however, as regards both their optimum temperature and the different substances besides lactic acid which they produce in milk. The majority of the lactic-acid bacteria are *aerobic ;* the statements made in some text-books to the effect that these organisms cannot give rise to regular fermentations in the presence of air are therefore erroneous. The advantage of stirring the cream during the ripening is apparent from this.

If the sour milk or cream found in practice is examined bacteriologically, we usually find that several different kinds of lactic-acid organisms are active in it at the same time, and that neighboring creameries may operate with wholly different forms of lactic-acid bacteria. Storch also says in his comprehensive and valuable work on the "Souring of the Cream": "Every time I obtained new samples of butter I received new bacteria. The explanation that there are no two lots of butter in Denmark possessing exactly the same flavor is found in this."

This is not the place to treat exhaustively the special qualities and morphological characteristics of the different lactic-acid bacteria.* Some few observations on this point may properly be made here, however. All investigations

* Those studying these questions are referred to the work by V. Storch, just mentioned, to the special reports by H. Weigmann in *Landw. Wochenbl. f. Schleswig-Holstein*, to G. Marpmann's article in *Ergänzungshefte zum Centralbl. f. allgemeine Gesundheitspflege*, 1886, to C. O. Jensen's bacteriological investigations reported in Bull. 22 of Copenhagen Agr. Exp. Station, to L. Adametz's researches, a summary of which was given at the Agricultural Congress in Vienna,

have thus shown that cream can be ripened by means of carefully-prepared pure cultures in such a manner that pure and well-keeping butter is made from it, but that there seem special difficulties in obtaining a distinct flavor in the butter. Bacteriologists have gone to a great deal of trouble in searching for a bacteria which would produce not only a strong fresh acid taste, but a good flavor, with but little success; so that Spallanzani finally says in despair that fine flavor and keeping quality are characteristics which only to a certain extent go hand in hand, and Weigmann doubts that there is any single bacterium possessing the faculty of bringing about this double end. Jensen makes the following demands to a lactic-acid bacterium to be used in creameries: (1) that it will sour the cream rather strongly in comparatively short time, so that it can compete with other bacteria present; (2) that it will thrive at a relatively low temperature (60°-72° F.); (3) that it will coagulate the cream and milk to a uniform homogeneous mixture, and give it a slightly sour taste and odor; (4) that it will produce an agreeable aromatic taste and flavor. But, he adds, we know at the present no acid bacterium that fills all these conditions.

In my experiments along this line I have not, among the numerous bacteria examined, been able to show any one bacterium possessing all the valuable qualities desired; but by cultivating two different organisms, and mixing them at the same time in the milk used for a starter, I have succeeded in obtaining a starter which produced both good acid and an excellent flavor in the cream. I have either

1890, to "Die Milch" by H. Scholl, 1891, and to my book on "Saprophytic Micro-organisms in Cow's Milk" (in Swedish), published 1889.—G.G.

used a short bacterium previously described by me * under the name of *bacterium acidi lactici* as acid-former, or another longer staff-like bacterium which I have found present in many places in our country. Both these organisms produce a very marked and pleasant acidity, develop well under ordinary creamery conditions, and seem splendidly adapted to this object. Neither produce any special flavor in the cream or the butter, but do not, on the other hand, give undesirable qualities to it. I have obtained flavor by the application of either of these bacteria in connection with one of the yeast-fungi previously described † as producing both alcohol and lactic acid in milk. This yeast-fungus, which I have found in sour and in stringy milk in several parts of our country, thrives very well together with either of the before-mentioned lactic-acid bacteria. By the co-operation of these organisms the cream obtained an agreeable acid and flavor, and the butter seemed to keep well and was of good taste and flavor. By cultivating several distinct bacteria in symbiosis in this way it seems that very favorable results may be obtained, if I interpret rightly the data now at hand. ‡

* Fortschritte der Medicin, vol. VII, pp. 124–131.

† *Loc. cit.*, and p. 107 of this work.

‡ Literature on the subject of pure cultures: Storch, "Flödens Syrning" (Ripening of the Cream), 18th Rep. Copenhagen Exp. Sta., 1890; *Bied. Centralbl.*, **20**, p. 48; Weigmann, "Use of a Pure Lactic Germ for Ripening Cream," *Milchztg.*, 1890 and 1892; *Ldw. Thierzucht*, 1891, 527; *Hyg. Rundschau*, 1892, No. 17; Adametz and Wilckens, "Souring of Cream by Pure Cultures of Bacteria," *Ldw. Jahrb.*, **21**, p. 131; Lafar "Artificial Souring of Cream by Pure Culture," *Oest. Ldw. Wochenbl.*, 1893, Nos. 16 and 19; Klein and Kühn, "Experiments with Pure Cultures," *Der Landwirt* 1893, No. 53; *Bied. Centralbl.*, 1894, p. 495; Conn, "The Fermentations of Milk," 1892, pp. 67–69; Georgeson, "Dairy Industry in Denmark," 1893, pp. 44–46; Ottawa Exp. Sta. Rep. 1894, p. 86; Pa. Exp. Sta. b. 44; Copenhagen Exp. Sta. b. 32.—W.

Latest Investigations.*—Since the above was written (1891) the question of the application of pure cultures in the ripening of the cream has taken a great step forward so that it now may be safely said that the problem is practically solved. Pure cultures that will keep are now in the market; they are put up in a practical manner, and as a rule contain pure distinct cultures of bacteria. Denmark has again taken the lead in this matter, and now furnishes an article which is as easily applied as, e.g., rennet extract. According to what I have been able to ascertain pure cultures can be bought in Denmark from not less than three firms—Blauenfeldt and Tvede, Copenhagen; Chr. Hansen, Copenhagen; and Quist of Nonneberg.

Pure cultures inoculated in a fluid were at first introduced in the trade, but it was impractical both to ship and to apply the cultures as put up in vials. Such liquid pure cultures do not, on the whole, seem to be able to keep very well; they may, however, be applied with advantage if they can be used when fresh and are kept under favorable conditions; the shape of the vials in which the cultures are shipped has also been improved of late. The solid pure cultures recently placed on the market are better, especially if the pure culture cannot be secured fresh. These can stand being kept for months, even half a year, without being appreciably changed in their qualities.

At the creamery of the Mustiala Dairy Institute, solid normal starter from Danish Butter Color Company, Blauenfeldt and Tvede, Copenhagen, is at the present being used with great success. In applying it the following directions given by the manufacturers are followed:

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* Author's addition to the present translation.

1. "*Treatment of the Solid Starter as it Comes from the Laboratory.*—Ten liters of skimmed milk are heated to 176° F. (80° C.), kept for two hours at that temperature, and then cooled to 90° F. (32° C.). The whole contents of the vial are then added and carefully mixed with the milk. The milk is placed in warm water, which must be kept at the same temperature throughout the souring, and the can is covered lightly—e.g., with cheese-cloth. The milk sours evenly after about eighteen hours, when it is cooled and left undisturbed until it is to be used. The upper layer is skimmed off before using the milk. The starter has a pure acid taste; it is somewhat granular, but this will entirely disappear during the later treatment.

2. *Treatment of the Starter from Day to Day.*—In the later treatment a quantity of skim-milk is taken sufficient both for the souring of cream and for next day's milk. The milk is heated to 176° F. (80° C.) for two hours, then cooled to 82° F. (28° C.), and a quantity of the starter prepared the preceding day is added, corresponding to ten per cent of the milk (one liter per ten liters). The starter should be ready in six to seven hours. It must be carefully watched, so that the temperature does not sink below 81° F. (27° C.) during the ripening. When the starter is done it is at once placed in ice-water, where it is left without stirring until it is to be used. The following days we proceed in the same manner; a sufficient quantity of skim-milk is pasteurized, ten per cent of the preceding days' starter is added; and so on until a new pure culture is taken.

The ripening of the cream, churning, and all the other work in the creamery are conducted in the ordinary manner. The temperatures are kept as usual. In the ripening of the cream it must be observed that this does not turn too sour; this is easily avoided, however, if the cream is cooled just when the right degree of ripeness is obtained, or if the cream is kept somewhat cooler the next time.

New acid starter ought to be prepared every day instead of using buttermilk, as in this manner bacteria are best prevented from being introduced by bad milk. How often the normal acid starter is to be renewed depends on so many conditions—as the care used in preparing the starter and in preserving it, the quality of the milk, etc., that it is difficult to give any rule; but it may be done from once a month to once a week. If it should happen that the starter is not good or will not keep, it either comes from lack of care in the preparation, or from the fact that the milk used is not germ-free, the heating done having not been sufficient to kill the bacteria. Private dairies are in such cases advised to take the milk from three cows and skim it next day, and then treat it as mentioned above. At creameries good morning milk from a single patron is taken for a starter. If it should happen that starter is not ready when needed, owing to milk being too cold, the starter is, without being stirred, placed in a vessel with water at 77°–81° F. (25°–27° C.), according to the season, when it will be ready in from one to two hours. In this heating process it must be carefully watched, that the starter is rapidly cooled as soon as done.

The best results in using normal acid starter for ripening will be obtained when the cream is pasteurized.

One lot of normal acid starter is sufficient for about ten kilos (22 lbs. or a little more than 2½ gals.) of skim-milk. The following proportions of cream and starter should be observed:

For pasteurized cream, 5–10 per cent.

For non-pasteurized cream at proprietary creameries, 4 per cent or more.

For non-pasteurized cream at other creameries, 5 per cent or more. All vessels and utensils must be kept carefully clean. 'Normal acid starter' is kept stoppered, and the whole quantity used at once."

This carefully-prepared method should be strictly followed, even in minute details, if the full benefit is to be derived from it. I must particularly warn inexperienced persons against "improving the same" or "making it simpler." Only uncertainty is gained thereby, and the real benefit is lost.

It must finally be emphasized, in speaking of pure cultures as fermentation starters for ripening of cream, that *in the majority of cases it will hardly pay the trouble of applying such if the cream to be ripened be not previously pasteurized.* The cream may contain so large a number of injurious bacteria that the favorable influence of the pure culture is greatly diminished and may even be abolished. Pasteurization of the cream may be compared with a fallow field, in which nearly all weeds are killed, and a good acid starter with pure and good seed. It is of but little use if such seed is sown in a soil full of weed-seeds capable of germination; in the same way it is of but little benefit to add a pure culture to a cream containing many injurious bacteria. The impurities may overpower the good seed, and the result will be poor.

CHAPTER II.

THE MANUFACTURE AND HANDLING OF BUTTER.

THE cream having been properly ripened, the churning may take place. Also during this process it is necessary to observe all kinds of precautions to protect the cream from infection. The churn should as far as possible be sterile and should be aired and steamed before being used. A very common mistake in creameries is to leave the churn standing without cover in an upright position when not in use, as it were, to catch all the dust and the bacteria slowly settling from the air. Some water will usually gather at the bottom of the churn; and with high temperatures as a rule reigning in our creameries, we have conditions very favorable to bacterial growth, and that in the very vessel in which the butter is to be manufactured. It will not improve the matter if the cover is always kept on the churn, as this will then not properly dry out. The churn should be kept upside down when not in use, or if movable should be kept out of the way. The temperature of the churn should be properly adjusted before the churning by rinsing it with recently-melted iced water or boiled and subsequently cooled water. If the churn is kept in a proper manner, no special sterilization will be necessary directly before the churning.

In order to get through early with the creamery-work, the cream is in many places churned and even the butter worked early in the morning before it is perfectly light. This custom ought not to be followed, for it is impossible to observe the necessary cleanliness in semi-darkness, and to make the necessary and accurate observations without which a good churning and working cannot be accomplished. The work should take place in full daylight from beginning to end; if the creamery-work thereby extend somewhat later it cannot be helped.

The butter can lose its keeping quality already in the churn—above all by the application of a wrong churning temperature, so that it cannot be properly freed from the buttermilk. The butter granules should remain separate and clear at the end of the churning, and the buttermilk easily drain from the butter.

When the butter has come all operations aim at the complete removal of the buttermilk particles from the butter. As shown by Duclaux, pure butter fat is not a nutritive medium for the bacteria; but besides fat, butter contains both air and water, as well as buttermilk, with its ash materials and albuminoid substance. It is from the albuminoids (casein, albumen, etc.) that danger of spoiling threatens, for they are especially readily attacked by bacteria and furnish them with the necessary nutrients. The importance of diminishing the quantity of buttermilk present in the butter is therefore evident; it would doubtless increase the keeping quality of the butter if the buttermilk could be entirely removed, but the butter would then lose its peculiar flavor and become fat pure and simple.

The importance of a small bacteria content of the buttermilk also follows from what has been said. It is intimately mixed with the butter, and forms a favorable breeding-place for the fermentation bacteria dangerous to the keeping quality and flavor of the butter. The buttermilk is nothing but the cream minus the butter, and the maker who secures cream of a good quality at the same time gains good means of transferring this quality to the butter.

Influence of Air and Light.—But the keeping quality of the butter also depends on other conditions than the quality and the amount of buttermilk in it. Duclaux has shown through numerous experiments that the butter must be protected from the influence of air (oxygen) and light. Precautions in this direction should, he says, be taken even in the churn—e.g., by washing the butter with water poor in oxygen; well-water or spring water should be used for washing and not lake or rain water. Duclaux considers the latter injurious both on account of their larger content of oxygen, as well as the probable presence of numerous micro-organisms in them. The advantage of the application of ice-water for this purpose has already been dwelt on (see p. 136). The butter must farther be protected from direct sunlight.

Some dairymen advocate washing the butter with skim-milk; but this practice cannot be recommended, as the casein of the skim-milk will be coagulated by the acid buttermilk, and cannot be completely removed by subsequent washing and working of the butter. The butter may advantageously be washed with ice-water (about 4° C.), as is done in the making of "Paris butter." The cold water will harden the butter granules and favor the expulsion of the buttermilk; the butter as a result will contain less water and less buttermilk. Warmer wash-water does not seem to produce the same effect. It is objected that the butter is apt to be too hard by this method, but this shortcoming can be remedied in the working.

Whether this strong cooling is applicable under all conditions in the manufacture of sour-cream butter I cannot say; the method has proved very satisfactory in the manufacture of "Paris butter."

The churning should not be stopped too soon; the butter granules ought to be well formed before being taken out of the churn (about the size of wheat-kernels or smaller). In taking the butter out of the churn it is often rinsed with water; this method is hardly to be recommended. It arises from the desire to obtain a mildly-acid butter or one entirely free from acidity, resembling somewhat sweet-cream butter in taste. It frees the butter from excessive acid and buttermilk, but the flavor of the butter will be apt to suffer at the same time. The ripening may therefore rather be conducted so that no excessive acidity arises and the churning so arranged that the buttermilk drains off without such a washing.

When the butter is taken out of the churn it is usually left in the butter-trough for a while to allow the buttermilk to drain off. The butter should here be kept covered to prevent dust, etc., from falling into it, and so as not to expose it to the action of light.

Working the Butter.—The butter worker should repeatedly be washed with boiling-hot water before being used and then cooled with iced water. It is at present the fashion at our creameries to work the butter very lightly the first time, so that a good deal of buttermilk is left in it. By this method, which springs from a fear of overworking the butter, it seems to me, however, that the matter is brought over on the wrong track, for the only chance for a complete separation of unnecessary buttermilk from the butter is offered in the first working. In my opinion all possible pains should be taken to make the working thorough. But the overworking?—it is objected. "If the butter is overworked it will not give off its buttermilk and cannot possibly keep well." This is correct, but it is also a fact that if the churning has been properly done the first working can very well be made so thorough that the greater portion of the buttermilk may be removed without risking any overworking of the butter. It seems to me that it is a confession of lack of ability on the part of the butter-maker to say that his butter cannot be properly worked the first time without being overworked. Only sufficient buttermilk should remain in the butter at the first working as is necessary for the solution of the salt.

Between the workings the butter is kept cooling either in tin trays or placed in a cooling-chest, at the bottom and cover of which ice is kept. In many creameries I have seen colossal refrigerators used for this purpose which it is very difficult to air out properly. We therefore find in them a disagreeable, sour smell, and their walls are often covered with a slimy film of bacteria or all kinds of molds. These infectious spots, with which the butter comes in contact, must of course be removed. We also find working-troughs in some creameries that are of the same kind as the cooling-chests—too heavy to be carried outside and apt to be left to mold in the moist creamery. In many respects practical refrigerators introduced at Danish creameries are, in my opinion, objectionable for the same reason.

Salting the Butter.—The butter should not be salted too early—i.e., while it still contains a great deal of buttermilk. If this is done the effect of the salt to drive out superfluous buttermilk is largely lost, the fluid being in this case too much diluted. Salt is not added to make up for the weight lost in the working, but to continue the work which this process could not finish. The salting can, of course, also be done too late—when the butter is too dry or has already been overworked. The salt may increase the keeping quality of the butter to some extent.*

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* Some writers argue that the keeping quality of the butter is due entirely to the salt which it contains. This assertion is not justified, however. While it is well known that salt has strong preserving properties it does not generally check the growth of the pathogenic (disease-producing) bacteria. The only one of these organisms which according to Foster's experiments was influenced by the salt was the cholera bacillus. The typhoid bacillus was not at all incommoded by common salt, and tubercle bacilli only after having been exposed to the action of salt for a long time. As regards the non-pathogenic bacteria found in milk I have ascertained that they are generally but slightly influenced by salt that may be present in the substratum. If the conditions are otherwise favorable for these organisms even a high salt content in the nutritive solution will not check their development. In the experiments mentioned I grew lactic-acid bacteria, among other mediums, in sterilized brine which had previously been a preserving fluid for butter. They developed vigorously in it and fully retained their ability to produce lactic fermentation, although they went through a long series of inoculations from one sample tube with sterilized brine to another. If, on the other hand, salt was added to this brine so that the solution became saturated, the lactic-acid bacteria developed only slowly and feebly and after having been grown in 3 to 4 such solutions, they died out entirely. As regards the influence of salt on other bacteria found in milk, I have only ascertained that certain putrefactive bacteria are very sensitive to the action of salt, while e.g., the butyric-acid bacillus, i e., the form of the same with which I have experimented, is only slightly disturbed by a high salt content in the substratum. Salt therefore influences as a rule only slightly the growth of bacteria. It may be noted in this connection that the preserving influence of salt, e.g. in butter-making, is largely due to the fact that it indirectly counteracts

Cleaning of Churn.—The buttermilk should be removed from the churn as soon as possible after the butter is taken up, and the cleaning of the latter should take place at once. The churn with cover is washed with cold water and then brushed with hot water, after which it is thoroughly steamed, or filled one fourth full with boiling-hot water, which is churned for five minutes and then drained off. The churn and cover is carefully brushed with pure dry salt, and rinsed with hot water and aired. This lengthy process has proved most satisfactory in practical creamery-work. When cleaned in this way the churn will retain a sweet smell—which, I am sorry to say, is not often met with in the churns of our creameries.

The butter should be left for some time after salting to allow the salt to dissolve. At a temperature of 46°–50° F. the butter needs 3–4 hours before the salt is dissolved and before the consistency necessary for the last working is reached.

When ready the butter should be firm, of a clear, not milky color; should show a dry surface, and when packed in the tub should not lose appreciable quantities of brine even during a long transportation.

The tub must be properly cleaned and sterilized before the butter is packed into it.

The butter is to be packed closely and firmly in the tub

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the development of bacteria. It leads to unite the small drops of buttermilk in the butter to larger, which may be easily expelled in working. Unfavorable conditions are thereby created for the bacteria, the moisture necessary for their development being removed for the larger portion of the butter; and the salt content where some fluid remains becoming so concentrated that the bacteria are checked in their development.

so that no air-spaces will appear in it. The rancidity seems to start from such interstices, the butter being also often discolored in such places. The tub should always be packed full of butter; rather than sending half-filled tubs they should be left until next shipment. Neither should tubs be sent containing soft butter that has not yet been cooled for a sufficiently long time. Such butter cannot stand transportation, turns easily off flavor, and suffers great shrinkage. There is no harm done if these tubs are left till next shipment, if the butter is well made and tubs treated according to directions given.

At most of our creameries the butter when once in the tubs is not considered in need of any farther care on part of the butter-maker, and it is largely left to its own fate. The tubs are kept in an out-of-the-way place, exposed to all kinds of moisture and temperatures. But much is left at stake in this way. As before, bacteria must be prevented from injuring the butter, and this can most easily be done by means of cooling.

Bacteria in Butter.—When packed a larger or smaller number of bacteria is always found in the butter. The number will differ according to the treatment which the milk received and according to the kind of butter produced. In a sample of sweet cream butter examined bacteriologically I found a comparatively small number of bacteria an hour after it was worked, and the different samples of "Paris butter" (see p. 205) analyzed contained still fewer such organisms—viz., from 120 to 300 per c.c. As would be expected, a far larger number have been found in fresh sour-cream butter—viz., not less than 2000–55000 per cc. During the first days a perceptible increase in the number of bacteria was noticed in all samples of butter, especially in the outer layer. In the centre of the tub a comparatively small increase took place during the first hours, but it soon stopped, at least if the butter had been well worked. The lively bacterial increase in the surface layer spread very slowly toward the centre.

Lafar (Munich) found an immense number of bacteria in sour-cream butter examined by him, which presumably had not received the best treatment. In most samples ten to twenty million bacteria per gram ($\frac{1}{28}$ of an ounce) were found, and he adds that it is not stretching matters to assert that more living organisms are often consumed with an ordinary good-sized sandwich than there are inhabitants in Europe.*

The outer layers of fresh sour-cream butter will be found to contain a large number of the bacteria that took part in the ripening. But these do not generally appear to thrive long in butter, unless it is soft and contains a good deal of buttermilk. Samples of butter of different origin have shown great difference in this respect. If a sample is dry and hard, the lactic-acid bacteria and even some putrefactive bacteria will soon disappear, so that butter after four or five days will present an entirely different picture to the bacteriologist than before. In place of the staff-like bacilli found, other wholly different forms seem to appear, such as several kinds of *sarcina* and small *micrococci*. These forms multiply rapidly, and according to what I have been able to find out, do not in general exert any bad influence on the quality of the butter—at

* Sigismund (Inaug. Dissert. Univ. Halle a. S., 1893) found from 26,000 to over 2,000,000 bacteria per gram in eight samples of Halle butter. See Exp. Sta. Record V, p. 646; and *Hyg. Rundsch.*, **4**, p. 1132; **9**, p. 57; Ia. Exp. Sta. Bull. 21; *Arch. f. Hyg.*, **13**, p. 1; Copenhagen Exp. Station Bull. 22, p. 51.—W.

least when alone. The staff-bacteria have not disappeared entirely, but are in a great minority.

If, on the other hand, a sample of butter is soft and contains large quantities of buttermilk, the bacilli will retain their superiority all the time; the lactic-acid bacteria appearing first and later on others, giving rise to more or less harmful fermentations. The importance of these conditions for the keeping quality of the butter is evident without any farther elucidation.

If the butter be cooled, the increase of bacteria spoken of will be found to cease very soon. The cooling of the butter in tubs takes place very slowly, even if good refrigeration is used, and it seems especially to last long before the cooling reaches the centre. My investigations show, however, that it is not very important that the cooling act on this part of the butter, as no significant bacterial growth takes place in the same. Even a slight cooling of the butter seems to be of benefit, if it is only sufficiently prolonged. Professor Fjord,* who investigated this subject found that a cooling to only about 43° F. proved sufficient to check the spoiling of the butter; but, says Fjord, "it must be remembered that this result could only be reached when the butter was cooled from the time it was packed in the creamery to within two or three days before the scoring took place. If such cooling takes place in practice, both creameries and the railroads and the steamers should have cooling-rooms for the storage and shipment of the butter."

It is not difficult to arrange for the proper cooling of the filled butter-tubs in our creameries. Ice-cellars are also found on most farms in our country (butter should

* See Eighth Report of the Copenhagen Experiment Station, "On the Cooling of Butter," 1888.

not, however, be kept in the same room as other articles of food). If it is not convenient to keep the butter in these, a small room may without much expense be fitted up for the purpose in connection with the ice-house. The room should be isolated from the heat of the surrounding air in the same way as the ice-house, by means of sawdust or similar material. It may also be advantageous to renew the sawdust every year, or to take it out to be dried, to prevent the spreading of fermentation-germs and to decrease its heat-conducting properties, which are increased if allowed to grow wet. A Danish cooling-room which I saw was adjoining the ice-house, from which two openings (about 8 inches square) were made into the cooling-room, one near its ceiling, the other near the floor. The cold air from the ice-house came in from the lower opening, and the warmer air from the cooling-room went out above. By this arrangement the cooling-room was kept both cool and dry.

Transportation of Butter.—The butter-tubs must be protected against being heated during the transportation to the railroad station or steamboat. This is especially important where the factory is located at some distance from the station. To avoid this heating the butter should not be hauled in day-time during the hot season, or else directly before shipping, and the hauling-wagons should be provided with a double-walled cover, between the walls of which dry bran, saw-dust, or powdered charcoal may be packed.

The refrigerator-cars run on our railroads, and the refrigerator-rooms on steamers, are of the greatest service to the butter-producer. The benefit derived from this arrangement is, however, greatly lessened if the tubs are not properly cared for during the hauling to and the delivery at the station. A reliable driver should do the hauling, and he should be especially instructed to guard against the heating of the tubs. The latter ought not to be taken from the wagon too early and should preferably go directly from the wagon into the refrigerator-car.

Extractor Butter.—The extractor butter will contain but few bacteria if the milk from which it is made was produced under proper conditions of cleanliness. Besides the advantages of the separation of the milk, the chances of infection of the cream are lessened to the greatest extent possible. It is a sad fact, however, that the shortcomings of the extractor seem to have prevented its general applicability up to the present time. It cannot, of course, be used for the manufacture of sour-cream butter; the sweet-cream butter made by the extractor seems to have a tendency to softness and a high buttermilk content. "Paris butter" made by means of the extractor from thoroughly pasteurized cream is, on the other hand, in my experience, of the highest quality. I have not been in position to make any investigation of the keeping qualities of the extractor butter.

The Radiator * is another machine by means of which the milk can be made directly into butter (see Fig. 30). It is manufactured by *Aktiebolaget Radiator*, Stockholm. This apparatus, which I have had occasion to test critically, has proved considerably better adapted to satisfy the demands for good sweet-cream butter possessing firmness and good flavor than can the extractor. The pasteurized milk is separated at pasteurizing temperature, by which method a good yield and close separation is obtained; the cream is, immediately after the separation, cooled in the apparatus to ordinary churning

* Author's addition to the present translation.

temperature, and the churning is then conducted by a very ingenious arrangement. The fine granular butter which

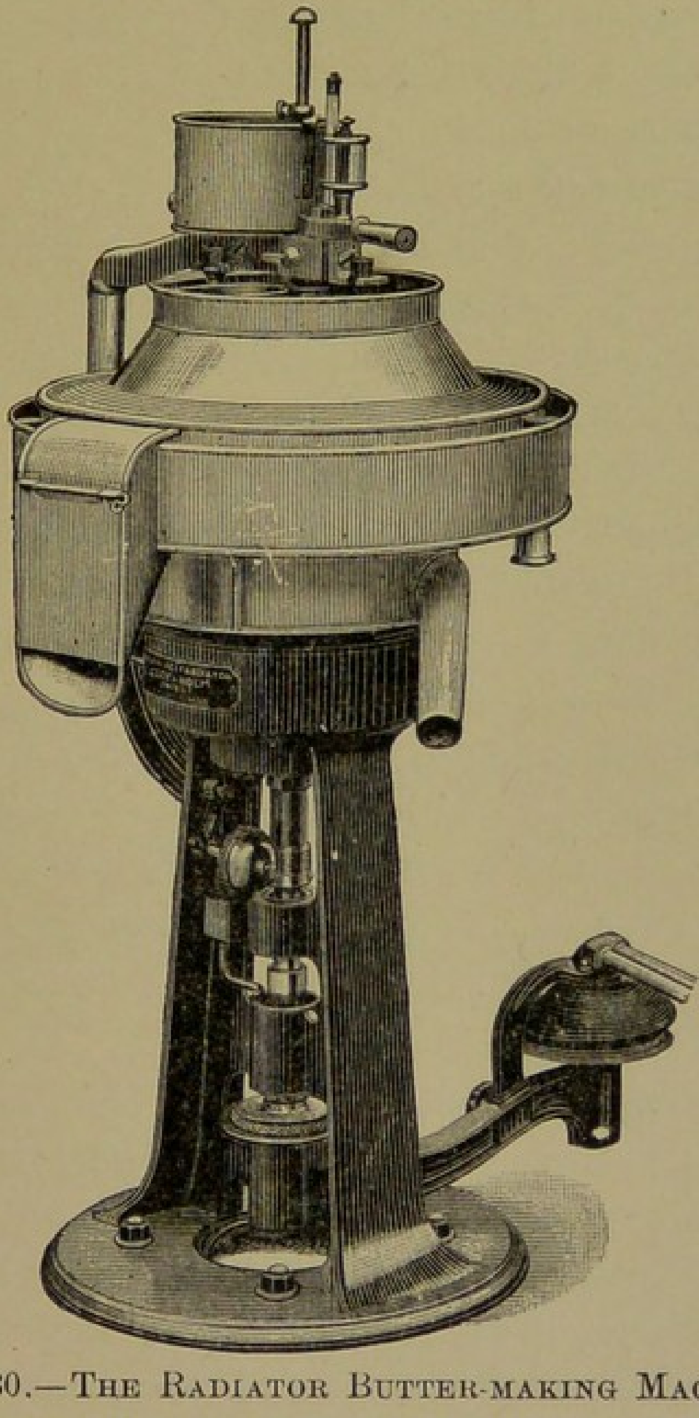

Fig. 30.—The Radiator Butter-making Machine.

drops from the apparatus may easily be worked in the ordinary manner.*

Preservation of Butter.—Butter being an expensive and very delicate article of food, it has of course been the object of adulteration and admixtures of preservatives.

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* Neither this machine, nor others devised for the manufacture of butter direct from milk, have come up to expectations. So far as is known, none of these machines are on the market at the present time (1902).—W.

Manetti in Milano has made lengthy experiments to preserve the butter by exhausting the air from it. It was very difficult to apply the method to practical conditions, and the butter assumed a spongy consistency, greatly injuring its commercial value.

Musso and Manetti in Lodi state that an admixture of one gram salicylic acid to one kilogram of butter is able to check the butyric-acid fermentation without changing the taste and appearance of the butter, and they direct to add the acid in washing the butter. According to Bersch a salicylic-acid solution of two to three grams salicyclic acid per liter is preferable to common water for washing the butter. He even recommends keeping the butter in such a solution. Boracic acid and borax have also been recommended for increasing the keeping quality of butter, but they seem to give it a bitter taste.

An admixture of such antiseptics must, however, as previously shown (p. 145), be considered an adulteration, especially if it takes place without the knowledge of the buyer.*

The salting of the butter is an entirely different matter; the fact of its being used is not disclosed for the public, and each buyer may easily satisfy himself concerning its presence. The great majority of people, moreover, demand salt in their butter. [The same applies to the use of butter color during the greater portion of the year.—W.]

Canning Butter.—Rather than applying special antiseptics, as salicylic and boracic acid, etc., for the preservation of butter, it may be preserved by being hermetically

* As is the case in ninety-nine cases out of a hundred under present conditions. Concerning the admixture of preservatives to food articles, see p. 146, foot-note.—W.

sealed—a method which has long been practised, especially in case of butter intended for exportation to the tropics. Only butter of the very best quality can be used for this purpose, as only such will pay for the additional expense incurred by this method, and only such butter can stand the influence of the long transportation. Both sour- and sweet-cream butter are used for canning.*

* More than four million pounds of this kind of butter was exported from Denmark alone during the year 1892–93.—W.

CHAPTER III.

DISEASES OF BUTTER.

It has been and still is a general opinion among dairymen that a great many of the various diseases of butter are attributable to a faulty feeding of the cows. But it has been proved by bacteriological investigations that many diseases are due to an infection of the milk, cream, or butter with one or more forms of bacteria producing abnormal fermentations in the same. The feeding of the cows certainly influences the quality of the butter, as has been shown in a large number of older experiments. Other conditions are also of importance in this regard. Several butter faults, like white-specked butter (arising from an excess of buttermilk remaining in the butter), or striped butter (the salt being unevenly divided), or butter showing an uneven color in the tub, etc., arise as a result of faulty processes of manufacture. A smoky smell or taste, which is sometimes found, especially in butter from small, poorly-conducted dairies, is caused by keeping the milk or cream in impure air. Wood taste in the butter arises when butter is kept in tubs either made from an unfit kind of wood or not properly cleaned, etc.

On the other hand, more recent investigations, especially by the Danes Storch and Jensen, show that a great many of the most common butter diseases have their origin in an infection of the milk or cream by all kinds of bacteria.

C. O. Jensen, who has been very successful in his studies of all kinds of butter diseases, separates these diseases into two different groups. First, diseases caused by the presence of several forms of bacteria, which, each one by itself, is harmless. Second, diseases caused by the presence of a single definite injurious form of bacteria.

"Off Flavor" in Butter.—To Group I the butter disease characterized by the expression an "off" flavor and taste of the butter first of all belong. This disease springs from lack of cleanliness in the treatment of the milk and the cream. Jensen is correct in stating that the fact that a great many forms of bacteria and a multitude of each of them are formed during the ripening of the cream is often in itself a sufficient reason for the poor quality of butter. A sample of butter examined by Jensen, which was described as bitter, unclean, dry, and soft, contained an immense number of forms of bacteria and many of each form. The disease could not be ascribed to any distinct form of bacteria present. The numerous foreign bacteria prevented the normal lactic-acid fermentation, and i is also possible that other decompositions arose in the cream by the simultaneous presence of so many different bacteria forms than those produced by the single bacteria forms themselves.

Among the diseases of Group II the following have been investigated at the present time.

1. **Tallowy Butter.**—In his investigations and experiments as to the ripening of cream Storch found a lactic-acid bacterium to which he ascribed the origin of this disease. This bacterium is not very different from most other lactic-acid bacterium, as far as size and form go; but if allowed to grow luxuriantly in cream during its ripening it will produce a most disagreeable tallowy taste in the butter

made from it, so as to make it unpalatable to the least particular palate.

2. **Oily Butter.**—This disease is characterized by a disagreeable taste and smell in the butter, reminding one of ordinary lubricating oils. Faulty methods of working the butter or of feeding (as regards the composition or the quality of the fodder) are often given as causes. Jensen's investigations which are not yet finished show, however, that the disease is caused by a small oval bacterium belonging to the lactic-acid bacteria, which produced a firm white coagulum in the milk within 12–24 hours. This at the same time assumed a disagreeable, oily odor. The bacteria thrived best at about 77° F. (25° C.); at ordinary room temperature it developed somewhat more slowly.

3. **Root-taste (Turnip-taste).**—As is natural, this disease was long believed to be due to a too liberal feeding of roots; but Jensen has shown conclusively that the appearance of disease does not stand in any relation to the method or system of feeding, but is caused by one or more forms of bacteria which develop in the milk before or during the ripening of the cream. In a sample of butter suffering from this disease, Jensen isolated a staff-like bacteria possessing locomotive power; this sample originated from cows that were not fed any roots. When the bacteria was inoculated into milk or cream it caused "a disagreeable, very bitter taste, reminding of turnips or rutabagas."

4. **Rotten Taste.**—This very troublesome disease was mentioned already in the introductory chapter (see p. 20). It appeared in 1888 at Dueland and neighboring farms (Denmark), and is caused by a bacterium carefully studied by Jensen, and by him named *bacillus fœtidus lactis.*

According to Jensen's investigations this common disease seems to be produced through the activity of several distinct bacteria; first among these a small oval bacteria appearing in groups of two single bacteria. Inoculated into milk it did not change its appearance, but within sixteen to twenty-four hours caused a distinct, somewhat sweetish, and at the same time burnt taste and flavor.

6. **Bitter Butter.**—This disease seems to be caused by several different bacteria. Conn* isolated a micrococcus of bitter milk in an American sample of milk; Weigmann in Germany speaks of a bacillus of bitter milk which causes a bitter butter, but does not injure the cheese made from the milk. A third bacterium of a veritable putrefactive form has in my experiments shown a tendency to make both milk and butter bitter. It seems to thrive surprisingly well in butter; the experiments every time ended with the butter practically rotting away.

7. **Dappled Butter.**—This disease appears rather frequently in farm butter during the summer, the butter being dappled by grayish, more or less extended, pale spots. Danish dairy experience tells us that this condition is caused by contamination of the milk in the stable, the dairy, or during the milking. This is correct as far as the location of the trouble is concerned; but the inner cause of the disease seems, according to my investigations, to lie in the activity of a bacterium possessing a high locomotory power, which develops in the butter, spreading in all directions from small separate centres, thereby giving the butter a mottled appearance. It seems to possess a smaller vital power the farther it is removed from this

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* Storrs' Agr. Experiment Station Report, 1891, p. 158.

center, and the gray color will gradually disappear, until it is entirely gone. This bacteria will therefore hardly be able to spoil larger quantities of butter. Neither is there any difficulty in keeping it away from the milk, it being unable to stand even a heating to 130° F.

8. **Blue Butter.**—This disease has so far only been found in Central Europe. It appears in butter made from the abnormal milk called bluish milk, and is caused by a bacterium (*Bacillus cyanogenus*).* The Germans Haubner and Fürstenberg and the Frenchman Reiset state that they have frequently met with such blue butter. Haubner says, however, that if the butter was well prepared and carefully washed the blue milk would not produce diseased butter, but only in case of a greater quantity of buttermilk remaining in the butter. I have also been in position to investigate this subject and have corroborated Haubner's results.

9. **Moldy Butter.**—Butter may assume a moldy taste and flavor also in other cases than when very old. I have found it in rather fresh butter which had small white specks both on its surface and in the inner portion of the mass. By microscopic examination the specks proved to be mold-fungi. The fungus did not grow on any of the nutritive substances on hand at that time, so it could not be further studied. Segelcke met with moldy, green-colored butter in 1879.

It may be clear from the preceding accounts of the main studies and investigations at hand concerning the production and keeping of milk and other dairy products

* See, further, "Saprophytic Micro-organisms in Cow's Milk," p. 63.

that dairying in our days is no more a single trade, but is a very complicated industry, requiring intelligent workers, not only fully familiar with the manipulations of the dairy, but well grounded in their underlying principles.

The fact alone that the raw material with which we have to deal is so delicate and easily changed calls into play one's highest efforts of cleanliness; there are so many chances of harmful bacterial infection in the various manipulations that thoughtfulness, good judgment, and well-developed power of observation are essentials for any dairyman.

The demands made on farmers and dairymen as well as all dealers in dairy goods for high-quality products have greatly increased of late years; more of thorough knowledge and intelligent understanding is required than ever before; automatic work, no matter how faithfully performed, is no longer in keeping with the greater demands. The words spoken by Professor Segelcke more than ten years ago are even truer to-day: In dairying the standard is constantly being raised higher and higher.

PART V.*

CHEESE.

CHAPTER I.

BACTERIA AND CHEESE-MAKING.

CHEESE is pressed curd which has undergone certain processes of fermentation. Without fermentations no cheese; without bacteria no fermentations; therefore without bacteria no cheese. The bacteria make cheese out of the curd and give it the characteristic flavor desired in each case. We owe the proof of the correctness of these statements to the bacteriological investigations conducted during late years. Before 1875 it was believed that the ripening of the cheese was a chemical process. Cohn first maintained that this view was incorrect, and that the ripening is attributable to the vital processes of all kinds of bacteria. Decisive proofs have later been furnished by Duclaux, Schaffer, Bondzynski, and by Adametz.

The processes of fermentation which occur in the

* Author's addition to American translation.

ripening of cheese differ in various kinds of cheese and are caused by different forms of micro-organisms. The intensity and duration of the fermentations are also different in the various kinds. The soft kinds of cheese undergo violent and radical fermentations, while certain kinds of English cheese ferment only slightly and very slowly. We find a smaller number of bacteria in the latter kinds than in the former. Swiss cheese seems to stand nearer the soft cheeses as regards the number of bacteria contained in it and the intensity of the fermentations, but it requires a rather long time for perfect ripening.

What dairy science at the present time knows of the bacteriology of cheese-making is due above all to the investigations of Duclaux, Adametz, Weigmann, and v. Freudenreich.* The following account is based mainly on the

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* The following references include the main investigations of the relation of bacteria to cheese-making published up to date:

ADAMETZ. Ripening of Emmenthal and Cottage Cheese. *Landw. Jahrb.*, **18** (1893), p. 227.

—— The Causes of Abnormal Ripening Processes in Cheese. *Milch-Zeitung*, 1891, pp. 237–248; 1892, pp. 205–223.

BAUMANN. Studies in the Ripening of Cheese. Inaug. Dissert. Univ. Königsberg, 1893; *Landw. Versuchs.-Stat.*, **42**, pp. 181–214; *Exp. Sta. Record*, **5**, p. 249.

BENECKE. On the Causes of the Changes in Emmenthal Cheese during Ripening. *Landw. Jahrb.*, **16**, p. 359.

CAMPBELL. Pure Cultures for Cheddar Cheese Making. *Trans. Highl. and Agr. Soc. of Scotl.*, 1898, p. 181.

CONN. Isolation of Rennet from Bacteria-cultures. Storrs School Experiment Station Report, 1892, pp. 106–126.

DUCLAUX. Manufacture, Ripening, and Diseases of Cantal Cheese. Paris, 1878.

—— Mémoires sur le Lait, I–III. Paris, 1880–84.

—— Microbes and Fat. *Ann. de l'Inst. Past.*, **7** (1893), pp. 305–324.

FREUDENREICH. Ripening of Emmenthal Cheese. *Landw. Jahrb. d. Schweiz*, **4**, p. 17; **5**, p. 16; *Centralbl. f. Bakt.*, **12**, p. 335.

results of their researches, and also on original investigations by the author.

In the manufacture of cheese the casein is precipitated in two different ways, viz.:

1. By means of certain bacteria producing a ferment which coagulates the casein, or

2. By means of rennet.

FREUDENREICH. Bacteria causing Formation of Holes in Cheese. *Ann. d. Microgr.*, **2** (1890), p. 353; for other investigations in this line by F., see recent volumes of *Ldw. Jahrb. d. Schweiz*; *Chem. Centr.*, 1893, No. 5; and *Fühling's Ldw. Zeit.*, **43** (1894), p. 361.

GRAEFF. Useful and Injurious Bacteria in the Manufacture of Dutch Cheese. *Molk.-Zeit.*, **5**, p. 183.

HENRICI. Contributions to the Bacteriology of Cheese. *Centralbl. f. Bakt.* II, 1895, p. 40.

KLECKI. On Curing of Cheese. *Ibid.* II., Part II., p. 21.

LEPIERRE. Examination of a Spoilt Cheese. *Comptes Rendus*, 1894, p. 476.

LLOYD. Reports published in recent volumes of *Journ. Bath and W. of Eng. Soc.*

MCFADYEAN. Chem. Bact. Investigation of a Bacterium Causing Inflammation of the Udder and Formation of Holes in Cheese, *Landw. Jahrb. d. Schw.*, 1890, p. 64.

MALENCHINI. On Ptomaines in Cheese. *Zeitschr. f. Nahrungsmittel Unters.*, **7** (1893), p. 7.

MANETTI and MUSSO. On the Composition and Ripening of Parmesan Cheese. *Landw. Vers.-Stat.*, **21** (1878), p. 224.

PAMMEL. An Aromatic Bacillus of Cheese. Ia. Exp. Sta. Bull. 21.

—— Ripening of Cheese. *Ibid.*

WEIGMANN. Formation of Holes in Cheese. *Milch-Ztg.*, 1890, p. 741; *Landw. Jahrb.*, **20** (1890), suppl. 1. Action of Rennet-producing and Peptonizing Bacteria in the Ripening of Cheese. *Molk.-Zeit.*, **7**, p. 479.

The important researches of phenomena connected with the curing of cheddar cheese, by Babcock and Russell were begun in 1894, and are reported in the publications of the Wis. Exp. Station for this and following years, which also see for accounts of bacteriological cheese investigations by Russell.—W.

Sour-milk Cheese.—The former method is mainly applied in the manufacture of so-called *sour-milk cheese* ("Dutch cheese"), prepared by the spontaneous souring of milk and subsequent heating, by which processes the casein is completely coagulated. In the making of this cheese the lactic-acid bacteria are offered as favorable conditions as possible. When the casein is precipitated the cheese is pressed, and it is then often considered ready for consumption. At some places the pressed cheese is allowed to ripen for a few days, during which time all kinds of fermentations arise. The office which the bacteria fill in the manufacture of this cheese is then twofold: (1) the casein is precipitated and (2) the cheese is ripened by them. In the former work only lactic-acid bacteria take part; in the latter such bacteria appear as use the casein as fermentation material. The former decompose the milk-sugar and precipitate the casein by the ferment which they produce; the latter decompose the precipitated casein. The latter group of bacteria are usually only allowed to develop to a limited extent, there being otherwise a danger that the fermentation processes will progress too far under the very favorable conditions present, in which case the bacteria would give rise to harmful or undesirable fermentations, producing a bad flavor and taste in the cheese. This kind of cheese will therefore only keep for a short period.

The sour-milk cheese is the oldest kind of cheese in Finland (as in most other dairy countries), and forms an important and rich article of food on the table of most farmers. Among other kinds of cheese in the making of which the lactic-acid bacteria play an important part, may be mentioned green Swiss cheese, cottage cheese, etc.

Cheese Prepared by Means of Rennet.—Considering next the cheese made by means of rennet, we may first mention that *rennet* forms an animal ferment prepared in special glands in the third stomach of calves. In the coagulation of the casein by means of rennet, bacteria as it seems, play only an insignificant part.* Rennet acts best at 95°–104° F. (35°–45° C.). In adding the rennet the milk is heated to a higher or lower temperature according to the time in which the coagulation of the milk is to take place.

Among the kinds of cheese belonging to this group we may distinguish between two subdivisions:

1. *The firm cheeses*, requiring a long ripening period, in the curing of which bacteria play the main part.

2. *The soft cheeses*, requiring a short period of ripening, the curing of which is effected not only by bacteria, but by mold fungi.

The manufacture of the firm cheese is very complicated as now practised in cheese-factories; as we shall see, the methods followed have been developed from experience. Let us take a glance at the various processes in order to ascertain what part the bacteria play in these.

Methods of Manufacture of Firm Cheese.—Milk used in the manufacture of full cream cheese is usually recently drawn and fresh. Its bacterial content is as a rule rather low, but it is of course by far not germ-free. Macroscopic as well as microscopic impurities will always be found in

* The small number of bacteria added in the rennet in proportion to those already present in the milk was first called attention to by Baumann (Inaug. Dissert. Univ. Königsberg, 1893). He found that under ordinary conditions the rennet added would supply only one bacterium for every two thousand already present in the milk. See also Pammel, Bull. 21, Iowa Experiment Station, p. 799.—W.

it. Concerning the macroscopic impurities of milk, see p. 31. The microscopic impurities are numerous and indicate contamination of dust or dung-particles in the stable. In the making of certain kinds of Dutch cheese it is considered of primary importance that the milk be removed from the stable as quickly as possible, and that it be coagulated while still warm from the cow. Those acquainted with the care and cleanliness maintained in Dutch stables will know that these cheeses are prepared from a comparatively pure milk.

Rennet and cheese-color are first added to the milk. The former coagulates the casein, entangling in it all macroscopic impurities along with microscopic ones adhering to them, and also retaining the bacteria suspended in the milk. The bacteria thus inclosed in the coagulated casein come from three different sources, viz.: (1) from the milk and its impurities; (2) from the rennet—which, especially if prepared from calves' stomachs at the cheese-factory, usually contains an immense number of bacteria (rennet extract contains a small number of bacteria*); and (3) from the cheese-vat and the air. In the beginning these bacteria seem to play an insignificant part, and in some kinds of cheese the increase takes place but slowly. We

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* The number of bacteria in rennet extract has been determined by Baumann and Pammel. The former (loc. cit.) found in two samples of rennet tablets 39,250 bacteria per cc. (strength 1 : 200,000) and 32,400 bacteria per cc. (strength 1 : 32,000) ; a sample of Danish fluid extract contained 1,407,600 bacteria per cc. (strength 1 : 5000). Pammel and students working with him found in five determinations of the bacteria content of fluid rennet extracts from 409,500 to 4,019,200 bacteria per cubic centimeter.—W.

shall see directly, however, that they soon make their presence felt. In some kinds of cheese it is considered important that the coagulation takes place rather slowly, in 40 to 50 minutes, and the temperature during the same is increased from about 86° to 104°–131° F., a temperature especially favorable to certain forms of bacteria. It is then cut and run through a curd-mill, and the whey is removed.

Some kinds of cheese require that the curd be kept warm continually, so that it will rapidly turn acid, by which means it assumes a distinct sour taste and flavor; it is often also considered advantageous to continue the heating even in the press. In this way highly-favorable conditions of temperature are for several hours offered the bacteria in the curd. There is plenty of moisture, and the casein as well as the milk-sugar are excellent nutritive substances for bacteria; these therefore multiply rapidly in the curd. The action of the bacteria is shown from the fact that in nearly all kinds of cheese we observe during the first twenty-four hours small holes throughout its mass. In some kinds the holes soon disappear; in others they remain and sometimes even grow larger. They arise on account of a gas generation (especially carbonic-acid gas*) caused by certain bacteria, butyric- and lactic-acid bacteria being the main ones. This fermentation generally belongs to the normal changes in the cheese. If the desirable forms of bacteria are not present, or are present in

* According to Baumann the gases causing holes in cheese consist mainly of carbonic acid (63 per cent) and hydrogen, and also small quantities of other gases, but no hydrocarbons. (*Landw. Vers. Stat.*, **42**, p. 214). See also Adametz, *Milch-Zeitung*, 1893, p. 220.—W.

too small a number compared with the others, troublesome cheese-diseases may arise even in the first stages of the manufacture. Freudenreich thus isolated a bacteria which caused irregular cracks in Swiss cheese (*geblähter Käse*) or else an immense number of irregular holes (*Nissler Käse*), giving the cheese a different appearance than that produced by the desired regular holes. He states that if this micro-organism is inoculated into the milk, and cheese at once made from it, the comparatively few bacteria will cause the appearance of large irregular holes (the first-mentioned disease); but if the bacteria are allowed to multiply in the milk, i.e., if it is left to coagulate slowly, the second form of the disease will arise.

In some kinds of cheese, e.g. certain English cheese where a slow fermentation and a solid, closed cheese is wanted, the curd is salted. Besides checking the growth of the bacteria this gives to the cheese the salt taste desired. In other kinds, e.g. Swiss cheese, the first fermentation is left to continue unchecked, and the salting does not take place until the cheese has been pressed.

Curing of Cheese.—After having been put into molds and pressed, the cheese is ready for the curing process in which it is to assume the flavor desired. For this purpose the cheese is brought either into the curing-room or directly into the cheese-cellar, according to the demands in each case. The cheese in the former case is allowed to dry out somewhat in the fairly dry, pure air of the curing-room and is then transferred to the cheese-cellar, where the curing proper will take place. The most important work which the bacteria have to perform in the cheese then begins.

The curing consists of a series of different fermentations which succeed one another and are caused by different kinds of bacteria appearing one after the other. Duclaux first gave a scientific account of this phenomenon in his in several respects remarkable work on milk entitled "Le Lait, Études Chimiques et Microbiologiques." In the Cantal cheese, manufactured in southern France, he found not less than ten different kinds of bacteria during its period of curing, seven of which were aerobic and three anaerobic. The statement made of the action of the different bacteria is briefly as follows: Some of the bacteria produce both a rennet-like substance, the object of which is unknown, and a ferment which changes the casein to a soft consistency characteristic of the ripe cheese. Other bacteria continue the work of the curing and give rise to strong-smelling, often sharp fermentation products, which finally may be still further changed by other bacteria and decomposed into leucin, ammonia, etc. Weigmann has also isolated this ferment (*casease*) and shown its great importance in the curing of the cheese.*

Adametz investigated Swiss cheese (*Emmenthaler*) and Swiss cottage cheese (*Hauskäse*), and found in both of them an enormous number of bacteria, of nineteen different forms, which he refers to three separate groups. The bacteria of the first group are not able to dissolve the casein, but change it to a characteristic jelly-like consistency which later is easily attacked by other bacteria and subjected to farther changes. Micro-organisms of the second group continue where the first group left off and

* New light has recently been thrown on the problems of cheese-ripening by the investigations of Babcock and Russell (Wis. Exp. Station Rep. 14 *et seq.*). For a brief account of the present status of the theory of cheese-ripening, see Russell, Dairy Bacteriology.—W.

are unable to attack the original curd. The bacteria of the third group are indifferent. In the curing of the Roquefort cheese certain molds play an important part.*

The number of bacteria contained in cheese increases immensely during the curing process. At its beginning Adametz found 90,000 bacteria in one gram of Swiss cheese, but when the fermentation was at its highest as many as 850,000 were found in it. By adding small quantities of disinfectants to the cheese, Adametz prevented the bacteria in the cheese from increasing, and at the same time the curing process of the cheese was completely checked.†

Method of Manufacture of Soft Cheese.—In most of the firm kinds of cheese spoken of in the preceding, the curing process takes place very slowly; in some it lasts for a year, in others for several years. In the soft kinds of cheese, on the other hand, the curing has a much more rapid course. The coagulated and molded curd is highly infected by placing the green cheese on straw mats previously used, in a room where molds, etc., are plentiful. Before long the cheeses will be spotted with brown mold colonies which gradually spread to a white downy cover. At the same time the bacteria in the cheese have started their fermentations, but the relatively low temperature

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*Roquefort cheese is made in the department of Aveyron, southern France, from sheep's milk. Carefully-prepared molded bread is introduced in the forms between the layers of curd, and the cheese is ripened in mountain-caves, where the temperature is very low and varies but little (39°–46° F.), while the air is kept exceedingly moist by small streams of water running down the walls of the caves (relative humidity about 60°).—W.

† See also Pammel (Ia. Exp. Sta. b. 21), Baumann (*loc. cit.*), Freudenreich (*Ldw. Jahrb. d. Schweiz*, 4, p. 17; 5, p. 16), Lloyd (*Journ. B. and W. Engl. Soc.*, 2, p. 180), and Russell (Wis. Exp. Sta. Rep. 13).—W.

retards their progress, while molds thrive and act on the cheese. After some time the mold vegetation assumes a bluish color, and the color of the cheese turns reddish yellow. If the air grows too moist, these molds will die and the putrefactive bacteria will take their place, thus spoiling the cheese. If sunlight strikes the molds, they will also die and fermentations are stopped. After some time—e.g., with the Camembert cheese in twenty-five days—the cheese is brought from the curing-room into the cheese-cellar, which is usually built half underground and so arranged that its temperature will remain fairly constant at 54°–57° F. (12°–14° C.), and that direct sunlight and draught are avoided. The activities of the molds are here soon checked and the work of the bacteria proper begins. These are now in position to multiply immensely. Adametz found the usual bacteria content of Swiss cottage cheese (*Hauskäse*) 2–5 millions per gram.

At the present stage of our knowledge of the action of bacteria in the curing of cheese it would hardly be advisable to give a more detailed account of the morphology and other characteristics of the separate cheese-bacteria which have so far been identified. There are still many points in the complicated processes of manufacture, and especially in the curing of cheese, which are not yet worked out, and the nature of several of the bacteria isolated have not been sufficiently studied in detail. About fifty different forms are at the present included among the so-called cheese-bacteria, and this number will doubtless be considerably increased when further study has been made. In the curing of different kinds of cheese different forms of bacteria are evidently at work. Of the ten forms of bacteria which Duclaux found active in the curing of

Cantal cheese, not a single form is present in Swiss cheese, as shown by Adametz's investigations. In my work with Swiss cheese made in Finland I have found but very few of the bacteria which the latter scientist gives as typical for this cheese.

All the methods of cheese-manufacture so far described are characterized by the fact that although the bacteria play a most important part in the making and curing of the cheese in each case, no special care is taken that the desired bacteria are really introduced. It is left to chance whether they take part or not. Often, however, the outcome is different than was expected, the cheese produced having a different flavor and being of a different appearance than that desired. I shall only mention that the Swiss scientist Freudenreich states that 40 per cent of *Emmenthal* cheese is not cured in the proper manner, and that we still more rarely find the correct flavor and taste in imitation Swiss cheese. The same is true in case of the soft French cheeses. Outside of their native country they only exceptionally obtain the genuine flavor and appearance.

CHAPTER II.

OLD-METHOD CHEESE-MAKING.

It has always been considered a maxim in dairying that the manufacture of cheese differs from butter-making in this respect, that while cleanliness is the fundamental rule in the latter, it may safely be left out of sight in the former. Lack of cleanliness has even by some people been considered an essential point in the management of cheese-factories, and the mountain factories of the Swiss have been offered as proof of the correctness of this statement. Everywhere in these cheese-factories, as I have had occasion to personally ascertain, conditions incompatible with cleanliness are met with, although not to the same extent in the large new cheese-factories as in the small Alp factories. At the latter the barn usually directly adjoins the cheese building; a calf-stable may even be found in the cheese building, with calves in it; both the walls and the ceiling of the room are black and dirty; only dirt floors are usually found, and frequently the fireplace lacks a good chimney and the smoke finds its way out wherever it can, through cracks in the walls and ceiling. Similar conditions are found in the curing-room and the intense smell in the latter plainly indicates that numerous fermentations take place there.

Neither is special cleanliness observed in the manufacture of soft French cheeses, as may easily be ascertained.

Molds thrive luxuriously on the shelves and walls in the curing-room, and are not removed therefrom ; no care and neatness are observed in the milking and the early treatment of the milk. And in spite of all lack of cleanliness excellent cheese is made.

In case of English or Dutch cheeses a somewhat different practice is followed. Cleanliness is observed at least in the manufacture of the cheese, although not even here is it always considered absolutely essential in order to obtain good products. Especially in the curing-room or cellar it is often preferred that certain molds attack the cheese.

It may furthermore be noted as characteristic of the manufacture of cheese that its theory has only to a small extent been worked out. It has been an art in which it has been necessary in the main features to blindly "follow the steps of our forefathers," without knowing why it is done this and not that way. In the manufacture of certain kinds of cheese, as, e.g., the Swiss cheese, the experience of centuries has accumulated from generation to generation. One has not deviated a hair's breadth from the paternal inheritance, for otherwise "the cheese would not be good." No other explanation was given or can be given.

The old-method cheese-making is in many ways analogous to the old-method butter-making. In both we act according to old custom; in both the fermentations are started without knowing their nature or without any certainty of the outcome. The fermentations in the former, being less radical and far less complicated, are more easily reached. In the old-method cheese-manufacture, on the other hand, much more complicated processes of fermentation take place, and we cannot therefore make use of such simple means as in butter-making. To reach the desired changes in the cheese, it was necessary, where these are rather energetic, to give up cleanliness, and a more intense infection with fermentation bacteria was thus secured. Where less thorough changes are needed, as, e.g., in the making of English or Dutch cheeses, greater cleanliness can be observed, but cleanliness is not even here observed to any similar extent, as we have seen, as is necessary in the manufacture of butter.

It is but natural that successful results are often not obtained when, as is often the case, several kinds of cheese are made in the same factory and kept in the same curing-room. We saw that the different kinds of cheese need different bacteria for their proper curing, and different degrees of moisture and temperature, etc., and still they are made to cure in the same room and it is expected that each will develop its characteristic flavor. The result usually is that the different kinds are all failures.

If we compare such cheese-factories with those in Switzerland, we find at once that the old method of cheese-manufacture in the latter country is on a considerably firmer basis than that elsewhere. Only one kind of cheese is usually made in Switzerland, and it has been manufactured through centuries. All curing-rooms, cheese-factories, and perhaps also farm-houses have been infected with the very bacteria favorable to the curing of this cheese, and it is therefore almost a certainty that the correct bacteria will appear to ripen the cheese in the manner desired.* In the same way every section of France makes

* Baumann (*Landw. Vers. Stat.*, **42**, p. 214) states that the fact that genuine Emmenthal cheese, i.e., such made in Switzerland it-

mainly one kind of cheese, and it is natural that the bacteria useful in each case under such conditions must gradually obtain the upper hand.

We may in this connection mention a practice which I have been informed has been followed at a German cheese-factory in order to start the correct fermentation in the soft "French cheese." When the factory was opened, some green cheese guaranteed to be genuine, was imported from France. The whole factory was then infected with this cheese, the cheese-room and the vats, the curing-room, cellar, and especially the shelves in the rooms, etc. When cheese was later carefully made according to the directions given, the curing process desired, and an excellent quality was secured in the product. Such a method of mass-infection is a step toward new-method cheese-making—toward the cheese-making of the future.

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self, is better than that made elsewhere, is due not so much to the aromatic feed which the cows find in the mountain pastures or in a higher fat content of the Swiss milk, as to the number of different forms of bacteria in the milk being subject to smaller changes, and the process of manufacture followed being better suited to the mixture of bacteria in the milk, than is elsewhere the case.—W.

CHAPTER III.

NEW-METHOD CHEESE-MAKING.

THE fact that fermentations will always take place in the cheese no matter what the method of manufacture followed, would at first thought seem to indicate that there can hardly be any improvement in conducting the cheese-making on a systematic basis. "Fermentation-starters are found everywhere, and we cannot force forward the fermentation wanted"—these are the arguments with which old-method cheese-makers try to silence the efforts of improvement. Several facts are, however, now known which throw a doubt on the correctness of these assertions. The example just given of the mass-infection introduced at the German cheese-factory shows the possibility of a rational system of cheese-making. The same objections were offered against the use of pure cultures in other fermentation industries, and these have here been shown entirely feasible. In the making of sour-cream butter the old method of spontaneous ripening of the cream had to yield to modern methods of using starters or pure cultures, and in the manufacture of beer the progress made by the introduction of modern methods has been equally pronounced. We cannot overlook the fact that the manufacture of cheese is considerably more complicated than the industries just mentioned, but, on the other hand, practical laboratory experiments have already shown that the case is not hopeless.

Instead of following the method of controlling the fermentation processes in the cheese through a "mass-infection," another may be practised which leads to a more successful result, viz., the introduction of pure cultures, the milk being pasteurized and strict cleanliness being observed throughout the manufacture. The main points in this method of manufacture, which we may call new-method cheese-making, are considered in the following.

1. **Pure, Clean Milk.**—Such milk is obtained through a careful observation of the directions given in the early part of this work as to cleanliness in the stable and in the hauling of the milk, and by pasteurization of the same. If the milk has not become highly infected with bacteria in the stable, even a slight heating may be of service for the annihilation of the bacteria. Freudenreich has by practical experiments shown the great benefit of pasteurization in the manufacture of cheese. The cheese made from pasteurized milk did not cure on account of the small number of bacteria contained in it; not until the milk was inoculated with certain bacteria could the curing take place. The pasteurized milk demands special methods for the making of cheese, as cooling after the heating, use of larger quantity of rennet extract, etc.

2. **Exclusion of Injurious Infection from the Surroundings.**—The main condition for the exclusion of harmful infection from the surroundings is cleanliness in the factory and in the factory men. If the objects surrounding the milk are kept sufficiently clean, there will be no danger in this direction. There is no need of entire exclusion of all infection, as any small number of harmful

bacteria possibly present in the cheese may easily be overpowered by the larger number of bacteria added in the direct infection. The milk is coagulated in carefully-cleaned vats, and the cutting of the curd, the milking, pressing, and other processes in the manufacture take place as rapidly and in as cleanly manner as possible. The Dutch and English cheese-factories in many respects come up to the demands made in the preceding.

3. **Direct Infection.**—Experiments have been made by several scientists for the preparation of pure cultures for curing of cheese, but so far with only partial success. The difficulties met with in this case are considerable. We do not here have only one or two kinds of bacteria in pure cultures, as is the case in the brewing of beer or in the manufacture of sour-cream butter, but as the assistance of several kinds of bacteria are necessary in the making of cheese, we must obtain pure cultures of several forms to obtain a proper curing of the cheese. This part of new-method cheese-making is yet at the stage of experimentation, but the investigations at hand at the present give certain hope of the solution of the problem. We shall not here go farther into a discussion of this question or explain the practical methods for the applications of such pure cultures, as these are still not sufficiently worked out, or have not yet been subjected to tests in practical operations.

4. **Clean Cheese-cellar.**—By cleanliness in the cheese-cellar we do not understand the same as is usually meant by the work in modern dairying. It is not so much a question of having a cellar where no bacteria are found as a cellar where only those favorable for the curing of cheese are found. To reach this, both disinfection and infection must be practised; the former in order to destroy the

harmful bacteria possibly present in the cellar, and the latter to introduce the useful ones.

The new method of cheese-making still lacks a good many accessories and is but little tried in practice, but it is in several respects beginning to break its way. All kinds of publications and specific laboratory experiments and even smaller cheese-factory experiments give promise that the necessary accessories and methods will not be long in coming.* It is also doubtless a fact that definite systematic methods of cheese-making are absolutely neces-

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* Detailed accounts of the various kinds of cheese and more or less complete directions for their manufacture will be found in the following works, which include our best literature on the subject of cheese-making:

KLENZE. Handbuch d. Käserei-Technik. Bremen, 1884. 643 pp.

EUGLING. Kleines Handbuch d. prakt. Käserei. Bremen, 1892. 252 pp.

DECKER-WOLL. Cheese Making, Cheddar, Swiss, Brick, etc. Fifth rev. ed. Madison, Wis., 1909. 214 pp.

MARTINY. Die Milch, II. Danzig, 1871. pp. 200–281.

BAUMEISTER. Milch- u. Molkereiproducte. Leipzig, 1895. pp. 224–328.

MONRAD. A B C in Cheese-making. Winnetka, Ill., 1894. 68 pp.

WING. Milk and Its Products. Rev. ed. New York, 1912.

RICHMOND. Dairy Chemistry. New ed. Philadelphia, 1912. 384 pp.

SHELDON. Dairy Farming. Cassell & Co., London. pp. 196–283.

FLEISCHMANN. Das Molkereiwesen. Braunschweig, 1876. pp. 735–1027.

—— Lehrbuch d. Milchwirtschaft. 3d ed. Leipzig, 1901. pp. 261–372.

—— The Book of the Dairy, tr. by Aikman & Wright. London, 1896.

STOHMANN. Die Milch- und Molkereiprodukte. Braunschweig, 1898. pp. 778–997.

KIRCHNER. Handbuch d. Milchwirtshaft. 3d ed. Berlin, 1891. pp. 389–501.

OTTO. Die Milch und ihre Produkte. Berlin, 1892. pp. 127–169.

DUCLAUX. Le Lait. Paris, 1887. pp. 63–311.

—— Principes de Laiterie. Paris. pp. 269–361.

LEZE. Les Industries du Lait. Paris, 1891. pp. 429–633.—W.

sary in our dairy practice. The great uncertainty in the present methods and their varying results makes the manufacture of cheese a risky and expensive industry. By the introduction of more rational methods good results will be obtained with greater certainty; the cheese will be forced into exactly the desired fermentations, thereby decreasing the number of unsuccessful cheeses manufactured and making the cheese produced both cheaper and of a better quality.

INDEX.

CIVIL ENGINEERING—*Continued*

5e Highways; Municipal Engineering; Sanitary Engineering; Water Supply. **Forestry. Horticulture, Botany and Landscape Gardening.**

6—Design. Decoration. Drawing: General; Descriptive Geometry; Kinematics; Mechanical.

ELECTRICAL ENGINEERING—PHYSICS

7—General and Unclassified; Batteries; Central Station Practice; Distribution and Transmission; Dynamo-Electro Machinery; Electro-Chemistry and Metallurgy; Measuring Instruments and Miscellaneous Apparatus.

8—Astronomy. Meteorology. Explosives. Marine and Naval Engineering. Military. Miscellaneous Books.

MATHEMATICS

9—General; Algebra; Analytic and Plane Geometry; Calculus; Trigonometry; Vector Analysis.

MECHANICAL ENGINEERING

10a General and Unclassified; Foundry Practice; Shop Practice.

10b Gas Power and Internal Combustion Engines; Heating and Ventilation; Refrigeration.

10c Machine Design and Mechanism; Power Transmission; Steam Power and Power Plants; Thermodynamics and Heat Power.

11—Mechanics.

12—Medicine. Pharmacy. Medical and Pharmaceutical Chemistry. Sanitary Science and Engineering. Bacteriology and Biology.

MINING ENGINEERING

13—General; Assaying; Excavation, Earthwork, Tunneling, Etc.; Explosives; Geology; Metallurgy; Mineralogy; Prospecting; Ventilation.