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To the Committee on Graduate Study:

I submit herewith a thesis by Mr. Warner A. Dorsey, "Chemical Sterilization of Milk Utensils". I recommend that this thesis be accepted for eighteen quarter hours credit in fulfillment of the requirements of the degree of Master of Science in Agriculture.

L C Aylsie
Major Professor

At the request of the Committee on Graduate Study I have read this thesis and recommend its acceptance.

P. H. Shuey

Paul W Allen

Accepted by the Committee

R M Hamer
Chairman

CHEMICAL STERILIZATION
OF MILK UTENSILS

A THESIS

Submitted to the Graduate Committee

of the

University of Tennessee

in

Partial Fulfillment of the Requirements

for the degree of

Master of Science in Agriculture

WARNER ARNETT DORSEY

June 1931

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CHEMICAL STERILIZATION OF MILK UTENSILS

Introduction

It is a well known fact that the dairy utensils and the dairy plant equipment if not properly "sterilized" may add large numbers of bacteria to the milk and its products. Frequently the high bacterial content of the dairy product is due largely to the utensils.

The importance of the utensils as a source of bacteria has long been recognized in the dairy industry, for the modern dairy plant is built around the steam boiler. Milk as it comes from the cow is clean, containing few micro-organisms, but it may soon becomes highly contaminated. Many dairymen think washing a utensil visibly clean is sufficient. However, it is the invisible bacteria which cause many of the off-flavors and spoiling of milk.

Steam and hot water have been used for sterilizing dairy utensils. These have given good results but they have limitations. It is not always possible, on the average dairy farm, to have equipment for making steam or hot water in sufficient quantity to sterilize the utensils.

In the past few years hypochlorite solutions have come into widespread use as sterilizing agents. These solutions are becoming popular because of their simplicity of use, and reported efficiency in killing bacteria. Already many companies are making and selling these sterilizing solutions.

The purpose of this paper is to determine:

(1) The efficiency of a chemical sterilizer for milk utensils, and to find out those factors which make them desirable or undesirable for dairy use.

(2) To make a comparison between these and the more common methods of sterilization.

General Discussion and Survey of Literature

In the dairy industry sterilization is not spoken of in the strict bacteriological sense. A sterile object is a lifeless object, all bacteria and their spores being killed by steam under pressure. As commonly applied by dairymen, it means the destruction of bacteria as well as hot water, a steam jet, or a chlorine rinse solution will be efficient in killing them. The temperature which is used in these operations is often less than 212°F., and this for a very short time.

Spore forming bacteria are killed at temperatures higher than 284°F., if this temperature is maintained for three hours. As shown by Ayers' and Mudge's report, (22), dairy utensils heated to 230°F. for thirty minutes will be completely sterilized. This temperature is higher than many dairies can obtain, and the time is too long to permit many cans or bottles to be handled.

The oldest method for effective sterilization is the application of heat or steam under pressure. This method gives good results, but is really effective only in connection with dairy equipment which will receive and hold the steam. If the utensil to be sterilized will not hold the steam under pressure, then the method is incomplete and unsatisfactory. Many bacteria will remain on the wall of the container and inoculate the next batch of milk, causing it to sour. The very composition of milk

which makes it the ideal food for man invites and fosters bacterial growth.

While it is important to check the growth of bacteria in milk, it is more important to reduce the number of bacteria which contaminate the milk. Not less than 80% of the microbes ~~of germ life~~ seeded into milk comes from cans and other utensils. Any attempt to free cans from microbes by jet steaming leads to a consumption of time and steam to a degree which is commercially impracticable.

Hot water, as a means of reducing germ life, is the simplest method of sterilization. It is very effective when the utensils are completely immersed. The problem is to maintain temperature high enough to sterilize and at same time to dry the cans after removal. Johus (16) has shown that cans and pails which have been thoroughly washed, scalded, and appear perfectly clean, may add millions of bacteria to the milk at the next milking time, if traces of moisture are allowed to remain in them. This method is not practical under farm conditions because hot water cools very quickly. A teakettle from the kitchen stove cannot be expected to do the work of sterilizing very many cans or buckets.

Hot air has been suggested as a means of sterilizing but has never come into general practice. This method requires considerable heating and heat controlling equipment, such as thermostats, time switches, and high

temperature cut outs. It furnishes no hot water for washing purposes, and the temperature is variable within the steriliser. As far back as 1920 Ayers and Mudge (22) reported the method to be possible and ready for an engineer to develop satisfactory equipment. But in 1929, Farrell and Regan (23) were still finding need for improved equipment.

Sunlight

Sunlight is an active germicide which destroys spores as well as bacteria. Unfortunately, sunlight is so uncertain, the force of its rays so variable, and their disinfecting powers so superficial, that it cannot be depended upon as an aggressive means of killing the bacteria. The different rays of light have very different effects upon microbial life. Blue-violet and ultra-violet, the more refrangible chemical rays, are the only ones possessing germicidal power. The time required for these rays to destroy bacteria varies with their brightness, and with such conditions as moisture, temperature and time of day.

Steam

Steam is one of the most satisfactory sterilising agents we can use. It is reliable, quick, and may be depended upon to penetrate deeply if it is used with proper technique. Bacteria are killed instantly, and most spores in a reasonable time. Streaming steam or

steam under pressure are used in practical sterilisation. Streaming steam has the same disinfecting power as boiling water. Steam under pressure is a more powerful germicide than streaming steam, but it is not possible to secure very high pressure with common equipment around the dairy. The temperature is the most reliable guide to follow.

Electricity

It appears that electric currents have little germicidal action in themselves. The apparent effects noted are due either to the heat generated by the current or to electrolytic action. Fire is a great purifier but is not applicable to use as a direct sterilizing agent.

Chemicals Suited for Sterilising Dairy Utensils

In the past ten years , the use of chemicals as a means of sterilizing has come into common use. These chemical sterilizers are usually purchased in powder or liquid form and are used as a rinse solution. Not all of the solutions are desirable or effective in controlling bacterial life. These chemicals must be used while fresh, for they soon lose their strength. To effectively do its work, the solution must be of sufficient strength; it must be placed in contact long enough; and it must be used only when organic matter is absent.

The number of chemical compounds known as disinfectants, germicides, and sterilizers is large. Not all of them, however, are fit to be used in connection with the handling of food. The selection of chemicals is limited by a number of factors. The chemicals must be as odorless as possible to avoid tainting the milk; they must not be violent poisons, the residue of which might endanger human health; and they must have high bactericidal efficiency. At present, compounds depending upon chlorine for their action seem to be most effective in killing bacteria.

Chlorine Group of Sterilizers

The chlorine group of sterilizers includes a number of important substances such as chlorine itself, hypochlorous acid, its sodium and calcium salts, and organic "chloramine", that is, substances containing chlorine attached to nitrogen in form of the NCl groups. They are all characterized by marked instability, since in disinfection they react not only with cell constituents of microorganisms, but also with most other substances which are apt to accompany bacteria. In so reacting, the active chlorine is eventually converted either into inert chlorides or into inert organic substances in which the chlorine has become united with carbon. Thus, in using the chlorine germicides, as is also the case with other readily oxidizable substances, the process of disinfection will go on only as long as some of the active subetances remain undecomposed. The action is rapid and transitory.

These chlorine carriers may be classified by the method in which they are sold commercially:

1. Chlorine gas compressed in 150 pounds steel cylinder.
2. Hypochlorites
   a. Solid sodium hypochlorite. This compound is made by using 90 percent alkaline

sodium phosphate in the crystal, thus combining the cleaning and sterilising properties. These products are sold under the trade names of Diversol, Proven CX, Seezone, and Tri Sol.

b. Calcium hypochlorite, sold in powder form under the names of Brackett Chlorinated lime, N.T.H., etc.

c. Liquid sodium hypochlorite is sold in brown glass bottles the active ingredients of which are usually about three percent available chlorine. There are many companies selling this product; among these are B.K., D.B., Carthol, Chlorofectant, etc.

3. Organic, chlorine containing compounds.

a. Chloramine T. is sold in tablet and powder form under trade names like Santamine and Kleron.

b. Dichloramine T. is sold in powder form, but as it is not soluble in water, it is not suitable for dairy use.

Chlorinated Lime

Chlorinated lime, or bleaching powder, was used as a disinfectant and deodorant long before bacteriology was a science. The powder is soft, white, friable, and very unstable. It has great affinity for moisture, soon losing its strength unless it is stored in air tight containers.

The method of preparation is quite simple. By passing nascent chlorine gas over slightly moist calcium hydroxide, calcium oxychloride is formed. The dry powder should contain 35 per cent chlorine, according to the U. S. Pharmacopoeia, most commercial companies guarantee 24 per cent available cherine.

One fault of calcium hypochlorite sterilizers is that they deposit a film of lime on the utensil; this film gives a strong chlorine taste to the milk. This is more common when chloride of lime is used, and is rare when a commercial liquid hypochlorite is used. Tanner (31) has found that too much stirring when making the liquid solution is the cause of improper settling of the lime or sludge. This trouble is of little importance if the solution is made properly, as recommended by the manufacturer.

How to Prepare a Sterilising Solution from Chlorinated Lime

The most satisfactory method of preparation for use is to make a smooth watery paste of a 12 oz. can of the "bleach", first adding the water in very small quantities, and bringing the final volume of this stock solution to one gallon. This solution loses its strength rapidly, and should be kept tightly stoppered in a cool dark place; even then it should be renewed once every ten days. An earthenware jug is a most satisfactory container. One tablespoonful of thisstock solution to each gallon of wash or rinse water will make a disinfectant solution of effective strength, which will at the same time, not be so strong as to injure the skin of hands or udders.

Make up new solution every ten days, throwing away any of the old solution that is left.

Labaroque's Solution

Labaroque's solution, or Liquor Sodae Chlorenatae, is an aqueous solution of several chlorine compounds, chiefly sodium hypochlorite (NaOCl) and sodium chloride (NaCl). It is prepared by mixing hydrated sodium carbonate with chlorinated lime, so that there will be present at least 2.6 per cent of available chlorine by

weight, as determined by titration with sodium thiosulphate. The solution is clear and colorless when pure. This solution is more expensive than chlorinated lime and has no advantage over that compound.

Dakin's Solution

Dakin's solution (21) came to notice during the World War as a method of treating wounds. In reality it is only an improvement on Labarque's solution. The active ingredient is sodium hypochlorite. There are, at present, employed for preparing this solution, (24) several methods which are accepted as giving a generally satisfactory product:

A. Decomposing calcium hypochlorite with sodium carbonate.

B. Passing chlorine gas into a solution of sodium carbonate or hydrate.

C. Electrolysing a solution of sodium chloride.

The electric method has not yet come into common use. The other method, or a modification, is being used every day.

Antiformin

Antiformin consists of equal parts of liquor sodae chlorinate and a 15% solution of caustic soda. It has a strong germicidal action in weak solutions, killing

ordinary cocci and some bacilli rapidly. In this respect antiformin acts more rapidly and surely than either of its component parts used alone. It has, however, very slight action upon the tubercle bacillus and other organisms of the acid-fast group.

Antiformin is an almost colorless liquid; it has a strong odor of chlorine and is strongly alkaline. It keeps well, and has great power of penetration.

The germicidal properties are due to the energetic oxidizing properties of the chlorinated lime.

Gases

Chlorine as a gas is a germicide of considerable power. The germicidal action is due to its great affinity for hydrogen. So strong is this affinity that it combines with the hydrogen of water in the presence of light, liberating the oxygen in its nascent state. The germicidal action is, therefore, more one of oxidation than chlorination.

The gas may be obtained in cylinders or may be prepared by action of sulphuric acid on calcium hypochlorite. Another method is shown by the equation

$$2\ NaCl + MnO_2 + 3\ H_2SO_4 \longrightarrow$$

$$2\ NaHSO_4 + MnSO_4 + 2H_2O + Cl_2$$

The water and acid are mixed and then poured over the salt and manganese dioxid.

As a free gas chlorine is less useful than sulphur dioxid, because it is more difficult to control, more dangerous to manipulate, and more destructive in its effect. When it is added to rinse water there is formed some hydrochloric acid which is corrosive to metal. This makes the free gas undesirable as a sterilizer.

Some Other Sterilizing Compounds

Almost any chemical, under one condition or another, has the power to retard the development or destroy the activity of microbial life. Salt and sugar in sufficient concentration prevent fermentation. In weaker dilutions these substances, on the contrary, favor growth of almost all known bacteria. Only those substances which have proved their worth by scientific tests and have shown themselves to be trustworthy in actual practice will be discussed. All the following have one or more properties which makes them undesirable to use as sterilizer for milk utensils.

Metallic Salts

Many metallic salts have great germicidal activity, especially when acting on bacteria suspended in pure water. This powerful action is slightly reduced in the presence of organic matter. Bichloride of Mercury, $HgCl_2$, is one of the most valuable and potent germicides. It destroys all forms of microbial life in relatively weak solutions, killing both bacteria and their spores.

The disadvantage of bichloride of mercury is that it corrodes metals. This is enough to make it undesirable for sterilising dairy utensils. It is also very

poisonous and is never used by milk handlers to sterilize utensils. Silver nitrate, sulphate of copper, ferrous sulphate and chloride of zinc have good germicidal properties, but they, like bichloride of mercury, are not desirable sterilizers for milk utensils.

Coal Tar and its Products

Coal tar furnishes a number of germicides. Crude carbolic acid is the base from which most of them are obtained. Phenol, C_6H_5OH, is not a general germicide and cannot be depended upon to kill spores. Cresols have a higher germicidal value and are less poisonous. They do not have the power of penetration, since emulsions are lacking in that power. The cresols are insoluble in water, although very soluble in alcohol. The coal tar products are not desirable because they have many bad features; worst of which are that they have a pungent, penetrating odor and leave a deposit of coal tar oils.

Many germicides depend on the liberation of available oxygen. These are known as oxidizing agents. Hydrogen peroxide lime and potassium permanganate are the most important chemicals of this group. None of these are used in killing bacteria in milk utensils. They are reduced very quickly in the presence of excess organic matter, as shown by reduction of the rich purple color of

a solution of potassium permanganate. Hydrogen peroxide is the most feeble germicide of the two.

Lime

Lime is one of the best and cheapest disinfecting substances we have, especially if chlorine has been added. Quicklime is a very caustic substance used for the destruction of organic matter as well as germ life. It is one of the alkaline earths and is valuable because of its efficiency and cheapness. It is most effective as a watery solution. A 1% solution has been known to kill non-spore-bearing bacteria within a few hours, and a 3% solution to kill typhoid bacilli in one hour.

Lime is undesirable in sterilizing dairy utensils, because some of the solid which will be deposited on the surface of the utensils will be removed into the milk, giving a very disagreeable taste.

Formalin

Formalin is a very valuable disinfectant with a wide range of usefulness if its action is not seriously retarded by the presence of albuminous matter. It is a true deodorant and is not very poisonous. It is not corrosive to metal. It should not be stored in the milk-room

because it is very volatile and liberates the disagreeable gas formaldehyde.

Soaps

Soaps have limited disinfecting powers. Von Behring states "the germicidal power of soaps depends upon their alkalinity". Serafini says "The free alkali present, even in concentrated soap solutions, is so small in amount that it can exert no disinfecting action whatever, and that neither the alkali, the fatty acids, nor the combination of the two is an effective agent." The value of soap consists in the removal rather than the killing of germs, that is, the cleansing properties are more important than the germicidal action. In washing, all bacteria are not removed by soap and water. The exposure is not long enough, nor the concentration strong enough, to disinfect. Therefore, the washing must be followed by the use of an effective germicide in order to render the utensils sterile.

Medicated soaps are for the most part a snare and delusion, in so far as any increased germicidal action is concerned. Soaps are undesirable in that they leave a film on the utensil.

Strength of Solution

Chlorine sterilizers have one common property, namely, a certain amount of loosely combined chlorine in their molecules. This is directly concerned in the destruction of the germ life, and brings up the question of stability. Some solutions liberate the gas more readily than others, thus weakening the rinse water. The amount of organic matter present, and the temperature play an important part in the liberation of this gas. Also, the solution must be made of a concentration high enough to insure the presence of a high percentage of available chlorine.* Prucha (12) reports as low as 15 P.P.M. of available chlorine would be effective in killing B. coli but would recommend the strength to be more than 50 P.P.M. He found that when a small amount of milk was added the strength of the sterilizing solution had to be greater. When 5 per cent of milk was added to the solution having 50 P.P.M. of available chlorine, it practically destroyed all the sterilizing action of all the compounds. Wade, Archibald and Whittaker (5) working with calcium hypochlorite and chloramine on destruction of tubercle bacilli found that the solutions used were much too weak to kill

* Refers to the oxidizing value of the product and not to the actual amount of the element chlorine which it contains.

all of the germs. Calcium hypochlorite solution, testing even up to 500 P.P.M. can not be depended upon to destroy human tubercle bacilli. Chloramine in a strength of 93 to 95 P.P.M. of available chlorine for a period of three minutes is effective. In the presence of organic matter, the available chlorine disappeared faster in an alkaline solution. This shows that improperly washed utensils will tend to reduce the available chlorine in the sterilizing solution.

The dilution to use in making up the rinse solution should be the one recommended by the manufacturer. The federal government (17) requires the manufacturer to be responsible for all efficiency claims on his label. All such claims must be based on the results of adequate tests. It is impossible to give general directions which will be applicable under all conditions with various rinse solutions.

The U. S. Department of Insecticide Administration recommends a dilution of 200 P.P.M. of available chlorine. It will raise no objections, however, if the dilution falls as low as 100 P.P.M. There must not be too much organic matter present during use so as to weaken the solution. They also recommend two minutes for the disinfecting period.

How to Measure Strength of a Solution

The sterilizers, as a rule, are prepared by the manufacturer in a concentrated form, having 2.5 to 3.8 per cent available chlorine. This concentrated solution is then diluted with water in the proportion of one ounce sterilizer to five gallons water. They are readily soluble in water; and a solution of any strength can be prepared by simply adding the necessary amount of the sterilizer to the given amount of water. The amount to be added can be calculated as follows:

Divide the percentage of active chlorine in the commercial sterilizer by the number of parts of chlorine per million parts of water desired in the solution, then multiply the quotient by 10,000. The product obtained indicates the number of ounces of water to be used for each ounce of sterilizer. Any unit of weight can be substituted for the ounce.

To illustrate: A solution is to be prepared from 2.5% chlorine product, which will have 50 parts of chlorine in 1 million parts of water.

$$2.5 \div 50 = .05$$

$$.05 \times 10{,}000 = 500 \text{ ounces}$$

Hence, to make a solution the strength of which is to be 50 parts of chlorine in 1 million parts of water,

from a sterilizer containing 2.5 per cent of chlorine, it is necessary to use 1 ounce of the sterilizer in 500 ounces of water.

Testing for Available Chlorine

As has been shown, the rinse solution loses its strength very quickly. It is important to have the solution test at least 50 P.P.M. This test can be run very easily with a Diversey's Chlorine testing set or with the Nafe~~s~~ automatic chlorine test.

For determining chlorine in sterilizing a very reliable method is described by Olson (25). Essentially the method consists of acidifying a known amount of the chlorine solution with a weak acid; N/1 solution of hydrochloric acid can be used. Next, about 5 c.c. of a 10% solution of potassium iodide is added. The addition of this solution gives the sterilizing solution a yellow color which is caused by iodine. This is then titrated with a deci-normal solution of sodium thiosulphate. The latter is prepared by dissolving 24.8 grams of sodium thiosulphate in one liter of water. The titration is carried on until the yellow color disappears. To get an exact reading a few drops of boiled starch solution may be added to the solution. The chemical changes involved can be expressed as follows:

$$4\ NaClO + 4\ HCl = 4\ NaCl + 2\ H_2O + 2\ Cl_2 + O_2$$

$$2\ Cl_2 + 4KI = 4\ KCl + 2\ I_2$$

$$2\ I_2 + 4Na_2S_2O_3 + Starch =$$

$$- 2\ Na_2S_4O_6 + 4\ NaI$$

The starch reacts with the free iodine to form a deep blue color. When enough thiosulphate has been added no free iodine is present and the end point is a clear solution.

Proper Time to Sterilize Utensils

To be clean and sterile, the can should be sterilized just after it has been washed and again before it is to be used. This seems to be merely a repetition of work, but, according to the report of Prucha, (1) it would be worth the extra labor. He found, on examining fifty cans which were washed, steamed, and left thirty hours uncovered and inverted on a rack, that, if filled with milk, they would have added to the milk an average of 8 bacteria per cubic centimeter. Fifty cans handled similarly, except that the lids were left on, would have added to the milk an average of 1,816 bacteria per cubic centimeter.

Fifty cans handled similarly to the above, except that they were not steamed, would have added an average of 27,164, and, with the lids on, would have added 128,730 bacteria per cubic centimeter.

This experimental plan was also run using 154 bottles. The results check very closely to the average bacterial growth of the can experiment.

Fouts (8) concluded from his experiments that ordinary washing methods followed by a rinse of scalding water does not sterilize dairy equipment. He found sodium hypochlorite effective as a sterilizing agent for dairy equipment when used in proper strength. He recommends following the directions furnished by the manufacturers and providing a

minimum of 45 parts of active available chlorine per million parts of water. Most of the chemical sterilizers used in connection with the cleaning of dairy equipment depend for their sterilizing effect on the presence of active available chlorine. Since free chlorine is an active corrosive agent, these chemical sterilizers may constitute an important factor in the corrosion of the equipment. These facts emphasize the importance of selecting those solutions which will be effective in controlling bacteria, but which will not corrode the metals used in dairy utensils.

Hunziker and others, (33) working with solutions of sodium hypochlorite, Diversol, and Chloramine T. found Diversol to be the least corrosive to metals, and sodium hypochlorite to be the most corrosive. Chloramine T. was less corrosive than sodium hypochlorite, but its corrosive effect was somewhat greater than that of Diversol.

Allegheny metal and Enduro showed no visible corrosion with any of the chemical sterilizers. The attack on Ascoloy, nickel, Monel Metal, and nickel silver was very slight.

Chemical sterilizers are active chemical compounds, not only in killing bacteria, but also in attacking other substances. Stained, tarnished, corroded, or pitted surfaces of utensils are not desirable for handling milk. They are much harder to sterilize and may affect the flavor of the milk by the production of metallic salts. That a great

deal of harm may be, and is, done to the equipment by the use of too strong a rinse solution is unquestioned.

Clark (26) in a report on treating city water of Nashville, Tennessee, said "Rusting increased with increase in chlorine content, and corrosion increased in same order."

Lothian and Ward (27) found that raw water acting on new zinc lined tanks, dissolved 4 P.P.M. of zinc in 18 hours. Chlorinated water dissolved 20 parts in 24 hours, but after three weeks use only two parts, owing to the formation of a protective layer of zinc oxide. Rusting occurs in distilled water because of the presence of dissolved oxygen, which is present in a greater quantity than in water containing dissolved electrolytes. In the presence of chlorine, the most active agent of hypochlorite, disappears first from the solution. There is no question but that the rust is formed rapidly during the disappearnace of Hypochlorous acid, and then practically is stopped when the concentration of HCl becomes constant. $HCl + HOCl \rightleftarrows H_2O + Cl_2$

Clark (26) has shown that the reaction,

$H_2O + Cl_2 \rightleftarrows HOCl + HCl$, proceeds only very slowly and comes to an equilibrium, the constant of which has been roughly determined. It has farther been shown that iron has an apparent catalytic action on the reaction, resulting in the disappearance of both chlorine and hypochlorous acid.

This has been verified by the very recent work of Olson on the same reaction, carried out at 91°C. so that

$HClO_3$ would be formed. It is pointed out in that work that, in order to act as a catalyst, the iron must, of course, exist in two stages of oxidation, that Fe ++ must reduce ClO- ion faster than Cl - does, and that Fe +++ must be reduced quickly by the Cl- ion in order to maintain an effective concentration of Fe ++, In deciding whether or not the iron has actually acted as a catalyst in materially hastening the final attainment of equilibrium.

It is at once apparent in the presence of chloride, the iron is almost completely in the form of the ferric ion, and hence the effective concentration of ferrous ion which reacts with ClO- is negligible. The effect is almost chemical rather than catalytic in nature, since the equilibrium is entirely destroyed and two of the members disappear.

The testing of corrosion properties of these solutions is done more in theory than in an actuality.

Rawdon (28) says accelerated corrosion tests are intended to obtain results, within a relatively short time, which would only be obtained in normal service over a longer period. Such tests are chiefly valuable for what they indicate rather than for what they prove, since direct correlation of service results with those obtained by such tests has not yet been made.

Prucha (13), in testing by accelerated corrosion tests, found that solutions of about 35 P.P.M. of active chlorine sterilizers did practically no harm. Solutions

of 100 P.P.M. of active chlorine from liquid sodium hypochlorites became harmful to all metals except Allegheny metal. Solutions of 500 P.P.M. became harmful to the Allegheny metal, when that metal was not properly polished. Solutions of calcium and sodium hypochlorite were equally corrosive. Chloromine T solutions were not so destructive on most metals as were the solutions of hypochlorites. Diversol was least corrosive of all chemical sterilizers, some of the metals used remaining shiny under the surface of the water.

Because of the corrosive nature of the solutions used it is best to sterilize just before using the utensils.

Methods of Applying Sterilizing Solutions

The greatest difficulty encountered in sterilizing utensils is to keep the solution on the surface for a sufficient length of time to kill the bacteria. It is practically impossible to submerge all bottles in such a way as to expose all parts to the solution. Many of the bottles, when dropped into the tank, trap air which prevents their being filled with the solution.

The most common means is to use two wash tanks, one in which to clean the utensil, the other in which to sterilize the bottle by a soaking process. For a cooler and for large vats a great quantity of water must be used to secure proper time of contact.

Methods of treating the tanks for the killing of bacteria consist of steaming and the use of chemicals. Steam, if turned into the tank long enough, will accomplish the desired result; but where fleets of tanks are used, unloading is retarded or trucks are held up on the wash floor because of the time required for steaming each tank. Then, too, it requires time for steamed tanks to cool. Where health departments permit it, chemical treatment of tanks is satisfactory. This should be done by spraying, with a small pressure sprayer, the entire inner surface of the tanks. Care should be taken to spray the edges of all

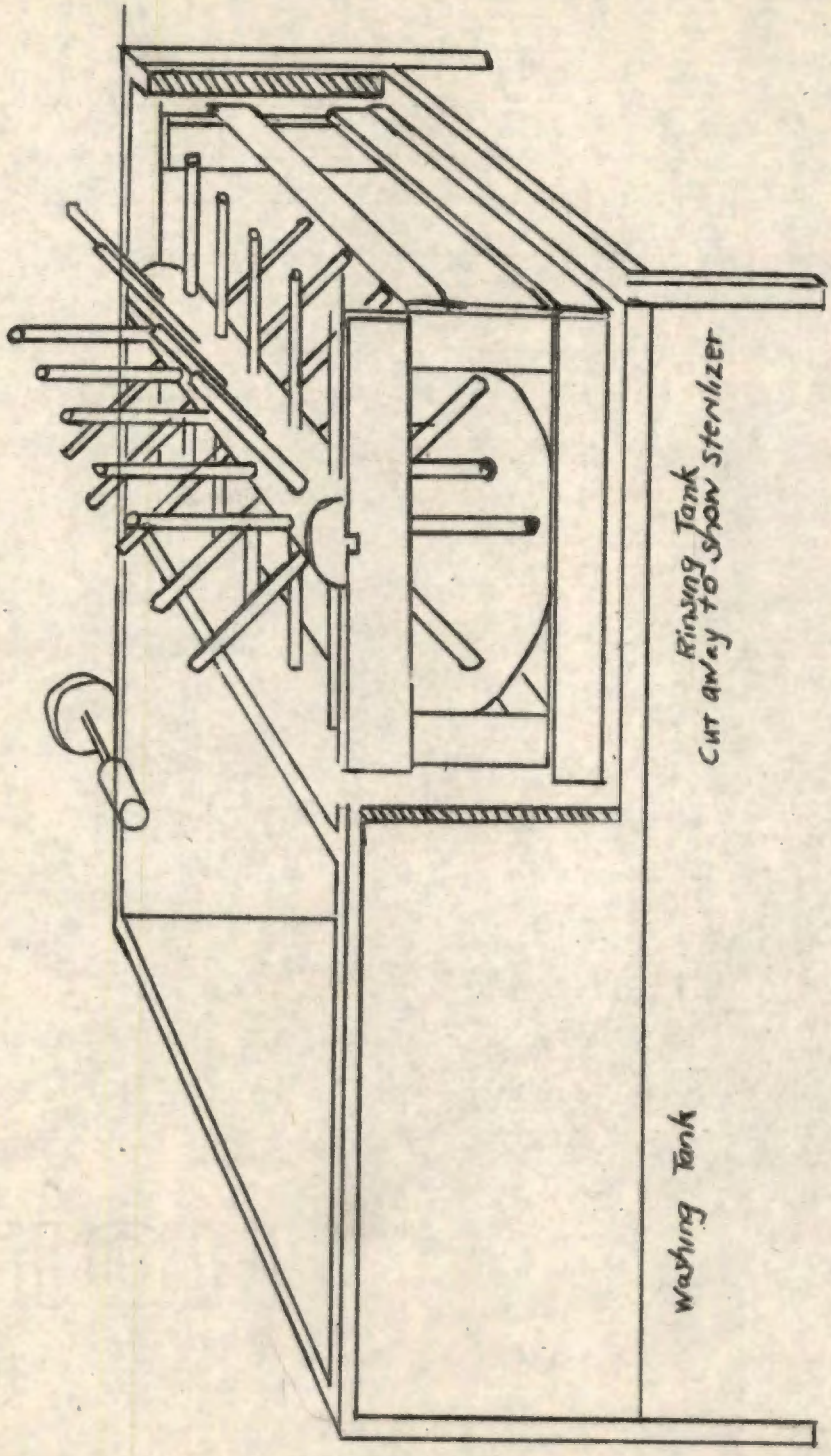
openings, caps of the openings, and the valve and valve parts. A strength of at least 200 parts available chlorine per million parts* of water should be used.

In the pressure washers, a jet of chlorine solution is sprayed up into each bottle. The Ladd's pressure bottle washer is equipped with a small brine coil, in the chlorine tank, to be used when necessary to keep the sterilizing solution below 120°F. By the use of this attachment, a cold sterile bottle is delivered to the bottle filler.

Whittaker and Archibald (29) constructed and tested the efficiency of a wooden roller (figure one and two apparatus). The apparatus consists of a cylindrical block of wood carrying eight rows of wooden pegs which are properly spaced to permit the bottles to be placed on the pegs and passed through the solution. This wheel is suspended in a wooden rack and provided with a spring catch to prevent the wheel from revolving except when moved by the operator. A sheet of metal is attached to the wooden rack in the form of a semi-circle and prevents the bottles from slipping off the pegs while they are passing down through the solution. They found the device to be very efficient and practical to use in connection with the hand washing and immersing of milk bottles.

In summarizing the results of examining over a hundred bottles before and after installation, they report

* Henceforth Parts per million will be abbreviated to P.P.M.



Minnesota State Board of Health
MILK BOTTLE STERILIZER

Figure I.

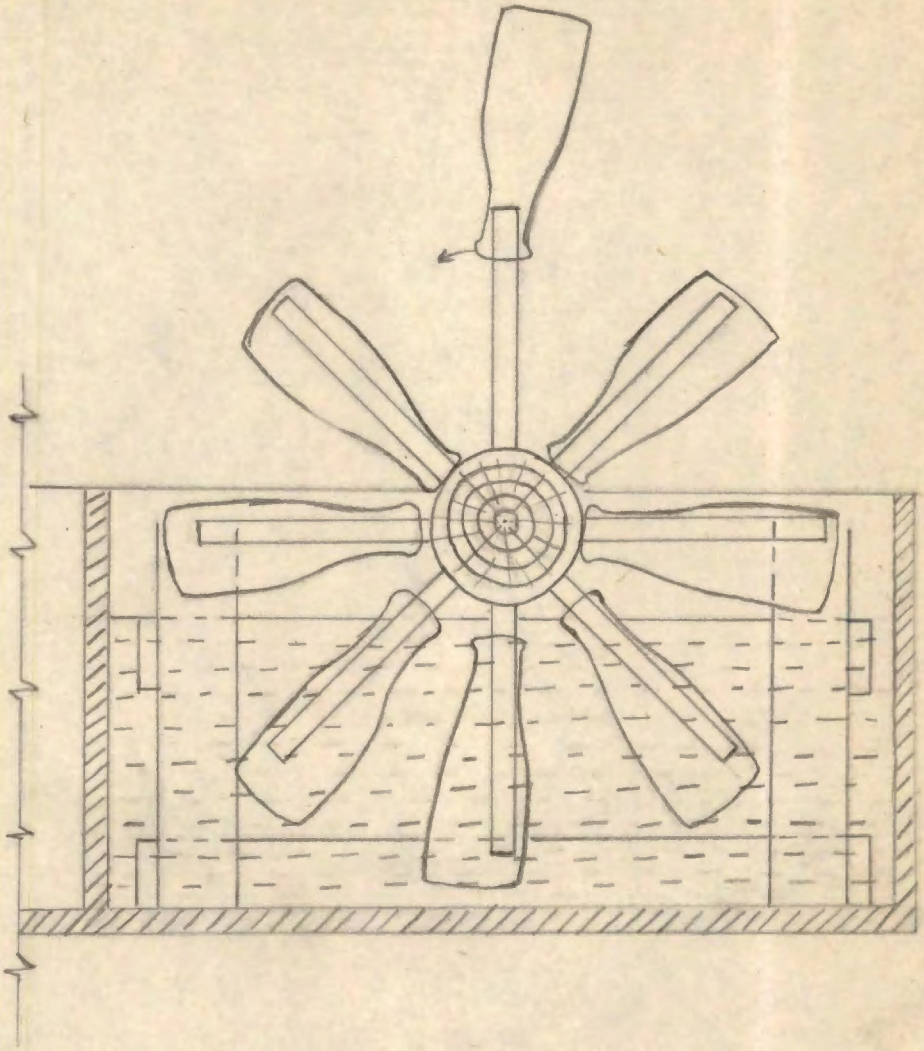


Figure II.

Hand Milk Bottle Sterilizer

in Operation.

the following data:

Table 1. Summary of Bacteriological Results, Before and After Installation of Sterilizing Apparatus.

Before Installation		After Installation	
No. of Bottles Examined	Average Bacterial Count	No. of Bottles Examined	Average Bacterial Count
60	578,000	54	100

Table one shows how important it is to get each bottle immersed in the sterilizing solution. Each bottle was adding 578,000 bacteria to that amount of milk because the bottles were not properly immersed.

There are other ingenious devices in use for the filling of milk bottles with a sterilizing rinse solution.

Stability of Sterilizer in the Presence of Organic Matter

When a sterilizing solution is subjected to continuous use in rinsing cans and bottles, it is expected that traces of milk, dirt, and some washing powder may get into the solution. What effect this will have on the available chlorine, and consequently on the sterilization efficiency, has been studied by Prucha (12). He reports that the solutions lost none or very little of the chlorine when they were exposed for thirty minutes, at temperatures ranging from 80 to 160 degrees F. The addition of small amounts of milk promptly caused a reduction in the amount of the available chlorine. As the amount of milk was increased from 0.1% to 5%, the reduction in chlorine became greater. In a similar manner, as the temperature of the solution was increased, the reduction became greater and faster, especially with increasing amounts of the milk. Thus sodium hypochlorite solution, having about 200 P.P.M. of the available chorine to which 5% of milk was added, lost about 43% of the available chlorine after it was held 30 minutes at 80°F. When a similar solution was exposed to 160°F. it promptly lost all the chlorine.

The effect of alkali on the available chlorine was interesting. In the absence of organic matter, the

presence of the alkali tended to make the solution stable. In the presence of organic matter, however, the available chlorine disappeared faster.

Ivan (34) testing for stability added 1 cubic centimeter of milk to 500 cubic centimeters of rinse solution, testing 200 P.P.M. available chlorine. He tested for the loss of chlorine at different temperatures and times.

Table 2. Stability of Sterilizers.

Temperature	Steriliser	Loss of Chorine P.P.M.		
		½ hour	1 hour	1½ hours
75.4°F.	Sodium Hypo-chlorite	31.2	40.8	50.7
109.4°F.	" "	68.0	100.0	----
145.0°F.	" "	152.	183.3	186.0

From the data given in table 2, it appears that the rate of deterioration due to increase of temperature is progressive. At a temperature of 109.4°F., 68 P.P.M. of available chlorine were lost in half an hour and 100 P.P.M. were lost in one hour. At a temperature of 145°F., 152 P.P.M. of available chlorine were lost in half an hour, and 183.3 P.P.M. were lost in one hour.

The importance of maintaining relatively low temperatures during the sterilization seems obvious. It is also evident that improperly washed utensils will tend to reduce the available chlorine in the solution with which they are being sterilized.

What Some Operators Say About Use of Chemical Sterilizers

Not all operators of milk plants are convinced of the desirability of using a chemical as a means of sterilization. Mortensen[40] says hypochlorite of lime tends to discourage thorough cleaning. For that reason he does not recommend its use in a milk plant.

The production manager of City Dairies of St. Louis has found sodium hypochlorite to be best suited to their needs. They are able to buy it there at a very reasonable price. In other places it may be more desirable to make your own solution.

The production manager of Avondale Farm Creamery of Knoxville, Tennessee, who has used Diversol for some time, finds it rather expensive as compared to the liquid solution which he now is using.

The Chief Sanitary Engineer of the State Board of Health of Florida reports that he has examined a number of hypochlorite solutions to be used for sterilizing utensils. He says they were all effective in killing bacteria and in such a convenient form that they are to be recommended for daily use.

Hunziker (32) has found chemical disinfectants to be incapable of penetrating the pores of the wood of a churn. He does not recommend its use in the sterilizing of a churn in place of hot water and steam.

Mr. J. Heart, a milk producer, reports that he found it necessary to buy new cans after using D.B. The old cans were corroded very badly and had to be discarded.

The manager of Grey Von Allman Milk plant in Louisville, Kentucky is using H.T.H. under the close supervision of the manufacturers. He is very much interested in saving of money for the farmer by the use of this product.

Detecting Presence of Chlorine in Milk

In years past the producers of sweet milk have sought for a means to prevent the growth of bacteria. They had to have something which was simple and easy to use. The chlorine sterilizers offered just what they needed, and there is no doubt that some producers have added it direct to the milk for purpose of preventing growth of bacteria.

The addition of certain chemicals to milk will retard the growth of bacteria, has been proven. While the keeping quality of milk may be materially increased, their use has been opposed by health authorities (3) because it is contrary to the pure food laws.

When hypochlorites are added to milk, the products of the reaction are mostly sodium chloride with a small amount of chlorinated casein formed. Hypochlorites are bactericidal to milk only in such concentrations that the amount of chlorinated casein formed will exert a killing action upon the milk flora. This influence is noticeable at concentrations of one part of hypochlorite to 100 parts of milk and increases with increased concentrations. However, in the concentrations stated above, the milk turns a light pinkish tint and has a medicinal like taste, making the milk unpalatable and unsaleable. Thus, hypochlorites cannot be successfully used for reducing bacterial counts of milk and we do not recommend that it be used in this manner, because the amount added, which cannot be detected by taste or smell, has no effect on the bacterial life present.

The Diversey Company ran an experiment with their product, Diversol, to determine if it would prevent growth of bacteria. They used milk originally containing 480,000 bacteria per c.c. This milk was treated with quantities of Diversol, measured so as to add successively 3, 30, 300 and 3,000 parts available chlorine P.P.M. of milk. The results were as follows:

Table 3. Does Chlorine Added to Milk Prevent Growth of Bacteria?

Sample	Bacteria per c.c.	% Diversol added	P.P.M. Available Chlorine	Odor	Color
Original	480,000	None	None	OK	OK
3 P.P.M.	450,000	.01%	3	OK	OK
30 P.P.M.	325,000	.10%	30	Slight Chlorine	OK
300 P.P.M.	253,000	1.00%	300	Chlorine	Thin blue white milk
3,000 P.P.M.	320	10.00%	3,000	Chlorine	Light coffee brown

Table 3 shows that only in the case of the sample that was treated with 3,000 P.P.M. of available chlorine was there an appreciable reduction in the bacterial count. When this high concentration of Diversol was added it was noted that the milk, upon standing was noticeably affected in appearance, flavor and odor. The casein was precipitated in the flocculent state in less than one hour, and a light coffee brown, watery liquid was formed.

It was noted that where the first slight reduction in bacteria took place, i.e. in samples containing 30 P.P.M. available chlorine, the milk itself was affected because of its chlorine odor. These experiments definitely show that if sodium hypochlorite is added to milk so as to appreciably affect its bacterial count, it simultaneously and materially affects the flavor and color of the milk. This is conclusive

evidence that chlorine cannot be added to milk for the purpose of reducing the bacterial count.

Johns (40) finds little or no advantages to be gained by the addition of chlorine compounds to milk, if the milk is promptly cooled to a temperature below 60°F. and stored for 18 hours. Consequently, there appears to be little possibility that chlorine compounds will take the place of prompt and thorough cooling as a milk preservative.

It is necessary, however, to have a means to determine if some ignorant person will persist to add hypochlorite to the can of milk.

Rupp (6) has outlined a method of detecting the presence of a hypochlorite added to milk or cream. It is rather difficult to determine the presence of chlorine because it combines with the protein in the milk and is not easily liberated.

If the chlorine is liberated in the presence of potassium iodide it displaces the iodin of the iodid, which then combines with the protein. This reaction gives rise to a yellow-colored compound, the shade of the color depending on the amount of iodin liberated.

The amount of chlorine can be detected even up to a dilution of 1 part sodium hypochlorite to 100,000 parts of milk.

Table 4. A Test for Sodium Hypochlorite Added to Milk.

Outline of Test	Available Chlorine with Different Color Reactions					
	Dilutions					
	1:1,000	1:2,500	1:5,000	1:10,000	1:25,000	1:50,000
Take 5 c.c. milk	Reddish color	Slightly discolored				
Add 1.5 c.c. Iodid Sol. milk appears	Yellow Brown	Deep Yellow	Pale Yellow which fades			
Add 4 c.c. HCl - Curd Appears	Yellowish Brown	Deep Yellow	Light yellow			
Heat to 85°C. and cool. Curd & Liquid below Appear	Yellowish Brown	Deep Yellow	Yellow	Yellow	Pale Yellow	Yellowish
Add 0.5 c.c. Starch Sol. Liquid below Curd Appear	Blue Purple	Blue Purple	Blue Purple	Dark Red Purple	Red Purple	Pale Red Purple

Table 4 gives an outline for the method and results which L. A. Rogers, Chief, Division of Dairy Research, U. S. Department of Agriculture, thinks is entirely reliable as a means of determining the presence of chlorine in milk. He says this test, run in presence of copper, might give a positive reaction. The test is simple to run. As the various parts of the test are performed, there appear various color reactions which indicate the amount of chlorine present. In a dilution of 1 part of chlorine to 1,000 parts of milk, the milk will have a reddish color. When the entire procedure of the test is performed on this dilution, the milk will have a

blue purple color. In a dilution of 1 to 10,000 parts the milk does not have any noticeable change in color at the start of the test, but on completion the sample changes to a dark red purple. In a dilution of 1 to 50,000 parts, a pale red purple is formed, which indicates that there is little chlorine present.

Comparison of Steam and Chemicals as a Means of Sterilizing

Health authorities everywhere are recommending chlorine solutions for sterilizing milking and dairy utensils, both on farms and in the dairies. The effectiveness of chlorine has been demonstrated by the Minnesota State Board of Health (4), which passed rules in 1917 requiring pasteurization plants to sterilize all milk bottles. The following summary - table 5 of investigations shows the extreme need for sterilization and the remarkable effectiveness of chlorine solutions correctly used.

Table 5. Method of Sterilization	Av. Bact Count per c.c.
None attempted	542,000
Steam through single perforated plate	347,000
Steam through a series of plates in power washer	5,425
Steam oven	2,000
Hand submerging in Chlorine rinse	6,200
Machine submerging in Chlorine rinse	247
Power washer, chlorine rinse water sprayed into bottle	56

From the data of table 5, it is remarkable the great reduction of bacteria which was secured. Bottles which would have added 542,000 bacteria per cubic centimeter were sterilized by spraying chlorine rinse water into the bottle. By this method the number of bacteria was reduced to 56 per cubic centimeter. Steam has not proven so effective; 5,425 bacteria per cubic centimeter were left when steam was sprayed through a series of plates. This proves that chlorine is a very useful means of reducing the number of bacteria in milk utensils. The effectiveness of this method was studied at two milk plants where a power driven washer and sterilizer of spray type were in operation. The following results (table 6) show that chlorine solutions are more dependable as a sterilizing agent than steam.

Table 6. Steam vs. Chlorine as Means of Killing Bacteria.

	Steam	Chlorine
Number of examinations	28	28
Maximum bacterial count	4,400	70
Minimum bacterial count	15	0
Average bacterial count	525	25

Table 6 shows chlorine to be twenty times as efficient in killing bacteria as steam.

Germicidal Power of Sodium Hypochlorite

To know how efficient a sterilizing solution is in killing bacteria, it is necessary to test the germ killing power on particular organisms. The handlers of milk are interested in killing those pathogenic organisms which might be carried by milk. These organisms are the cause of typhoid fever, diphtheria, scarlet fever, septic sore throat, tuberculosis, summer complaint of children, and undulant fever.

Tonney (39), working on the problem of minimal chlorine death point of bacteria, reports that many of the organisms which a dirty milk bottle might carry are killed in a few seconds by rather small doses of free chlorine, the utensil being exposed in solution of distilled water. He found that vegetative cells were killed in 15 to 30 seconds by the following percentages of chlorine:

Chlorine 0.1 P.P.M.

B. typhosus

B. dysenteriae

B. enteriditis

B. proteus

Brucella melitensis and abortus

Strepto coccus albus

Chlorine 0.15 P.P.M.

C. diphtheriae

B. coli (fecal)

S. scartabinae

S. aureus

S. morbili

Chlorine 0.20 P.P.M.

Pneumococcus

B. coli

Chlorine 0.25 P.P.M.

S. hemolyticus

B. coli

On the whole, the results furnish a satisfactory basis for the current practice of relying on the consistent destruction of B. coli in water as an index bacteria. Its acceptance has been based on the analogy of its greater resistance to heat and longer survival than the common pathogens which may be present. The destruction of this organism may be an index to a higher efficiency in killing bacteria present in milk utensils.

General Laboratories (37) made some tests to demonstrate the germ killing power of sodium hypochlorite. They reported as follows:

B. typhosus - killed at once. Dilution, one part to 1,500 parts of water.

B. dysenteriae - killed in less than one minute. Dilution, one part to 1,000 parts of water.

B. cholera - killed in less than one minute. Dilution, one part to 1,200 parts of water.

B. coli - killed in less than one minute.
Dilution, one part to 1,200 parts of water.
B. streptococcus - killed in less than one minute.
Dilution, one part to 700 parts of water.
B. abortus - killed in 30 seconds. Dilution,
one part to 1,000 parts of water.

They also report sodium hypochlorite to be more powerful than carbolic acid, formaldehyde or cresol in killing bacteria.

Prucha (12), working with B. coli, found that solutions of chlorinated water, calcium hypochlorite, B.K. and Diversol having 5 P.P.M. of available chlorine, destroyed the bacteria in 10 minutes of exposure. The solutions having ten parts of available chlorine destroyed the bacteria in less than five minutes, and the solutions having twenty parts of available chlorine in less than one minute. Chloramine T also destroys bacteria, but it requires a longer exposure and stronger solutions. The addition of small amounts of milk retarded the sterilizing action.

Wade, Archibald and Whittaker, (38) working with fresh sputum from tubercular patients, report some valuable data. Calcium hypochlorite did not appear to be effective in dilutions commonly recommended for milk plants. Rinse solutions even as strong as 500 P.P.M. available chlorine can not be depended upon to destroy the tubercle bacilli. Chloramine T, in a dilution of 93 to 95 P.P.M. available chlorine, for an exposure of three minutes, is effective.

Guinea pigs were inoculated with the sputum after the chlorine treatment. The summary of three trials showed almost every pig to have extensive lesions of tuberculosis.

The city water plants all over the country secure safe drinking water by the use of less than 2 P.P.M. of available chlorine.

From these data, it would seem that bacteria are killed by a rather small dose of available chlorine.

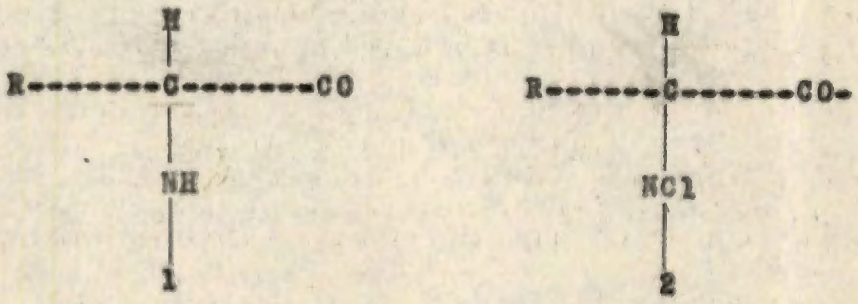
How Bacteria are Killed

The chlorine compounds have loosely combined chlorine in their molecules. By an oxidation process this chlorine combines with hydrogen to form free oxygen.

$2\ HClO = 2\ HCl + O_2$ which acts on the bacteria by oxidation process killing it in short time. Rohm (30) says in explanation, "The action of a poison upon the cell is generally considered an action upon the protoplasm. The poison is supposed to combine chemically with the cell plasma, producing compounds which interfere with the cell plasma which interfere with the continuation of the life processes and thus causes death. Vegetative cells are killed quicker than spores because more water is present."

Dakin (21) says the cardinal points of efficient disinfection are concentration, time of action, period of

contact, and temperature. The action of a poison on bacterial cells is more thorough if there is freedom of contamination, as in distilled water. He thinks that killing of bacteria is the chlorination of the bacterial protein. All proteins contain large numbers of amino-acid groups which may be represented as shown below:



These groups are liable to attack by substances containing active chlorine. The attack operates in such a way that the hydrogen attached to the nitrogen atom is replaced by the chlorine. The compound thus formed contains the (NCl) group and hence belongs to the class of chlormines. In the chloramines, the chlorine is still active and they form active germicides.

PART II

EXPERIMENTAL STUDY

EXPERIMENTAL INVESTIGATION

The operators of many dairy farms and milk plants are attempting to sterilize their equipment with steam or small amounts of hot water. These methods, however, have been unreliable in many cases resulting in large amounts of spoiled milk.

The purpose of this experiment was to investigate 1. The efficiency of sterilization of milk utensils by means of steam, and by means of some commercial hypochlorite solutions. 2. Stability of chemical sterilizers. 3. Corrosion of milk utensils by chemical sterilizers. 4. Cost of chemical rinse solution.

The commercial solutions used in these tests were those which are being commonly sold by dealers of dairy supplies in this section. They are known by the trade names of B.K., Carthol, Chlorofectant, D.B., H.T.H., Kloron, and Diversol.*

* B.K. - General Laboratories, Madison, Wis.

Chlorofectant - American Oil & Disinfecting Corporation, New York City.

D.B. - L. G. Duggar, Montgomery, Ala.

H.T.H. - Mathison Alkali Works, New York City.

Kleron - J. I. Holcomb Mfg. Co., Indianapolis, Ind.

Diversol - Diversey Mfg. Co., Chicago, Ill.

Carthol - Cabel Chemical Co., Huntington, W. Va.

Steam Versus Chemicals as a Means of Sterilizing Dairy Utensils.

It has been stated that steam is less efficient than some chemicals in dairy sterilization. The purpose of this test was to find how steam compares with Diversol, H T H, B. K. and D. B. In performing this test, twenty pint milk bottles were washed. Fifty cubic centimeters of sterile water were added to each bottle, and then each bottle was shaken ten times. A small amount of this water was taken in a sterile test tube and analyzed to find average number of bacteria in the bottles. Ten of these bottles were steamed over a perforated steam plate for two minutes. Water was again added and samples taken. The other ten bottles were immersed in chlorine rinse water for two minutes and then carefully drained. Samples were taken as before. This procedure was used in taking samples from five gallon milk and cream cans. The cans were steamed for two minutes over a steam jet and then dried.

These samples were then iced and taken to the laboratory for analysis by the plate count method. They were plated as recommended by the Standard Methods of Milk Analyses. Dilution of 1/2000 and 1/20,000 was used.

Controls and duplicates were run in each case. The poured plates were incubated in a control box at a temperature of 37.5°C. for forty-eight hours. Readings were made and recorded as shown in Table 7.

The strength of the rinse water was determined by means of the sodium thiosulphate test just after use. This water was made to test over 75 P. P. M. of available chlorine. The chlorine treated utensils were always carefully drained. Very little rinse water should remain which might be carried onto the agar plate and lower the bacterial count. Three trials were run for each commercial solution tested.

Table 7. Steam Versus Sodium Hypochlorite Solutions: Efficiency in Killing Bacteria in Milk Bottles, Milk Cans and Cream Cans.

Utensils	Solution Used	P.P.M. Available chlorine	Bacteria per C.C. Sterilizing Method		
			Washed	Steamed	Chlorine Treated
Bottles	Diversol	80	3,500	1,400	1,400
Milk Cans	"	85	6,200	6,100	400
Cream Cans	"	70	20,170	4,660	6,165
Bottles	H T H	76	5,270	1,070	2,270
Milk Cans	"	55	15,000	14,000	2,600
Cream Cans	"	75	666,222	48,600	5,000
Bottles	B. K.	95	3,000	3,066	1,733
Milk Cans	"	83	6,500	2,150	2,150
Cream Cans	"	85	46,000	16,045	9,000
Bottles	D. B.	98	8,400	2,900	1,300
Milk Cans	"	81	3,125	910	800
Cream Cans	"	101	11,889	2,707	82
	Averages		66,272	8,634	2,738
Average per cent reduction				86.83	95.70

From data given in table 7 the number of bacteria is reduced by steaming and treating with a chlorine solution. The average bacterial count of the washed utensils was 66,272. By use of steam this number was re-

duced to 8,634, and by the use of chlorine the count was reduced to 2,738. The average per cent reduction of bacteria by use of chlorine is 8.87 per cent higher than by use of a steam jet. The data of Table 7 show that the chemicals used, of which chlorine was the active agent, sterilized more efficiently than did steam. Moreover, the chemicals are less difficult to use.

Substances Introduced into Milk by Use of Hypochlorite Rinses.

It is possible, in the sterilizing of milk utensils, that some of the chlorine will remain in the utensil and be carried into the milk. This might cause a lower bacterial count. ~~In performing this test,~~ A lower count for chlorine rinse utensils might be due to this. This phase of the problem was studied as follows:

1. Some colonies of the common milk bacteria were grown on an agar plate.
2. Several of these colonies were scraped into a bottle of sterile water.
3. This water was plated to determine the average number of bacteria per cubic centimeter.
4. One cubic centimeter of this culture was added to 100 cubic centimeters of sterile water.

5. A bottle was rinsed with a strong solution of Chlorofectant. The bottle was drained and 100 cubic centimeters of sterile water was added. To this was added 1 cubic centimeter of the bacterial culture and plated as before.

This test was run in duplicate with results as shown in Table 8.

Table 8. Chlorine Treated and Untreated Utensils

Treatment	Bacteria per C. C. Test #1	Test #2	Average
Original Bacteria per c. c.	5,500,000	5,180,000	5,340,000
Chlorine Treated	54,000	56,900	55,450
No Treatment	55,000	58,000	56,500

The data of table 8 show that very little difference is due to the rinsing of a bottle with a strong hypochlorite solution. It is true there was a slightly lower count, but there is not enough difference to be significant. Neither is there enough difference between the steam and chlorine count to indicate that chlorine ~~is~~ was carried to the agar plate. Therefore, it is not likely that enough chlorine be carried into a can of milk to affect the count or to give sweet milk an off or chlorine flavor.

Careful weighing and calculations with Diversol under plant conditions have shown that the maximum quantity of liquid left in a milk bottle after rinsing and draining is less than 1 cubic centimeter in a quart milk bottle. A cubic centimeter of solution in dilutions of 1/3 oz. per gallon introduces into a quart of

milk 1/12,000 of an ounce of alkaline sodium phosphate, or expressed in parts per million, 1 part of anhydrous alkaline phosphate per 1,000,000 parts of milk.

Stability of Chemical Sterilizers.

The buyers for milk plants are confronted with confusing problems in deciding upon buying a sterilizing solution. One of the problems they have to solve is: will the concentrated solution be stable during storage? Light and high temperature will soon cause a liberation of the chlorine. They also want to know how quickly the chlorine will be liberated in the presence of organic matter.

Tests were run in order to determine:

1. Stability over a period of time.
2. The amount of chlorine lost through the average daily use.
3. The stability of chlorine under various conditions of storage.
4. The effect of adding a small amount of milk at various temperatures.

1. Stability over a Period of Time

It is known that rinse water is not changed often enough in the routine practice of sterilizing milk utensils. Usually the operator does not have facilities at hand to make an accurate test for available chlorine. There should be high enough concentration of available chlorine to kill bacteria. To find how various commercial solutions will act over a period of time, solutions of Diversol, B.K., Kloron, Carthol and Chlorofectant were made

up and tested. The amount of each concentrated solution used was that recommended by the manufacturer of the product.

These solutions were tested by thiosulphate test at the beginning and at end of each week for four weeks. The bottles were exposed to a subdued light at room temperature. The parts per million of available chlorine were found to be reduced as follows:

Table 9. Stability Test

P.P.M.

Solution	Date 1-1-30	1-7-30	1-15-30	1-22-30	Per cent Reduction
B.K.	145	110	105	104	28.2
Chloro-fectant	75	57	52	49	34.6
Kloron	61	58	56	56	8.0
Carthol	130	110	105	103	28.4
Diversol	52	28	26	26	57.7

Table 10. Stability Test P. P. M.

Solution	Date 3-23-30	Date 3-30-30	Date 4-9-30	End 4-15-30	Per Cent Reduction
D. B.	161.7	98.1	8.8	4.4	96.6
B. K.	131.5	113.1	15.0	10.5	90.8
Chloro-fectant	121.8	90.3	11.6	4.9	95.9
H T H	236.0	214.9	31.5	24.3	89.7
Kloron	139.0	135.0	108.0	99.0	28.7
Diversol	149.5	66.4	19.9	14.4	90.3

The data of tables 9 and 10 show an outstanding stable sterilizer. Kloron was found to be 25 per cent more stable than any of the other sterilizers. This stability is to be expected as it is a Chloramine T. product. Of the liquid hypochlorites, H T H and B. K., were almost equal in per cent reduction of available chlorine. Chlorofectant and D. B. were less stable than any of the others. Diversol appeared to be readily available in liberating chlorin in the first trial but in the second it had average qualities of stability. The other sterilizers, except Kloron and Carthol, lost a higher percentage of chlorine than did Diversol. This shows Chlorine to be freely liberated from a fresh solution of Diversol. After four weeks time the rate

of liberation is not as great as the liberation from the other hypochlorite solutions.

2. Chlorine Lost by Average Daily Use.

When a chlorine rinse solution has organic matter present, the chlorine is liberated much more quickly. To find how much chlorine is liberated during daily use a test was run using one quart of a 2% H T H solution to 100 gallons of water. A test was made for available chlorine just as soon as the H T H was added. The rinse water was then pumped from a coil vat over the cooler through a long pipe line and into the bowl of the bottling machine in the University Creamery. A second sample of rinse water was then taken and tested for available chlorine. The per cent reduction was computed for the average of all tests run.

Table 11. Stability in Daily Use.

Date	P. P. M. Available Chlorine	
	Before Use	After Use
3/30/30	42.5	37.6
4/1/30	51.0	40.0
4/2/30	42.3	37.1
4/4/30	42.3	36.0
4/6/30	29.3	23.2
4/8/30	27.7	21.1
4/12/30	32.2	24.9
4/18/30	22.1	12.7
4/19/30	30.4	21.0
4/30/30	30.4	27.7
5/15/30	29.3	23.2
Average	35.0	28.1
Per Cent Reduction		19.6

From results of table 11, H T H is shown to be a stable sterilizer in actual plant use. Only 19.6 per cent available chlorine was lost by daily use in the plant. This shows that H T H is very stable, especially when you consider the amount of

milk stone present and remember that from one-half hour to an hour elapsed during the sterilizing operation.

None of the other products were studied by this test. The liquid hypochlorite solution would have a similar per cent reduction and Diversol would have a greater per cent reduction as shown in date of table 13.

(3) Stability of Chemical Sterilizer Under Various Storage Conditions.

The object of this part of the experiment is to see if it is necessary to have a cool dark place to store a chlorine solution. This problem was investigated by making up a solution of B. K., M T H, D. B., Diversol, and Kloron. Each of these solutions were divided into three parts and placed in different storage conditions. One set was placed in the milk room and held at temperature of 45°F. A second set was placed in general storage room, a dark room with a temperature of 70°F. The third set was placed in the sunlight on the sill of a window at temperature variation of from 78° to 100°F.

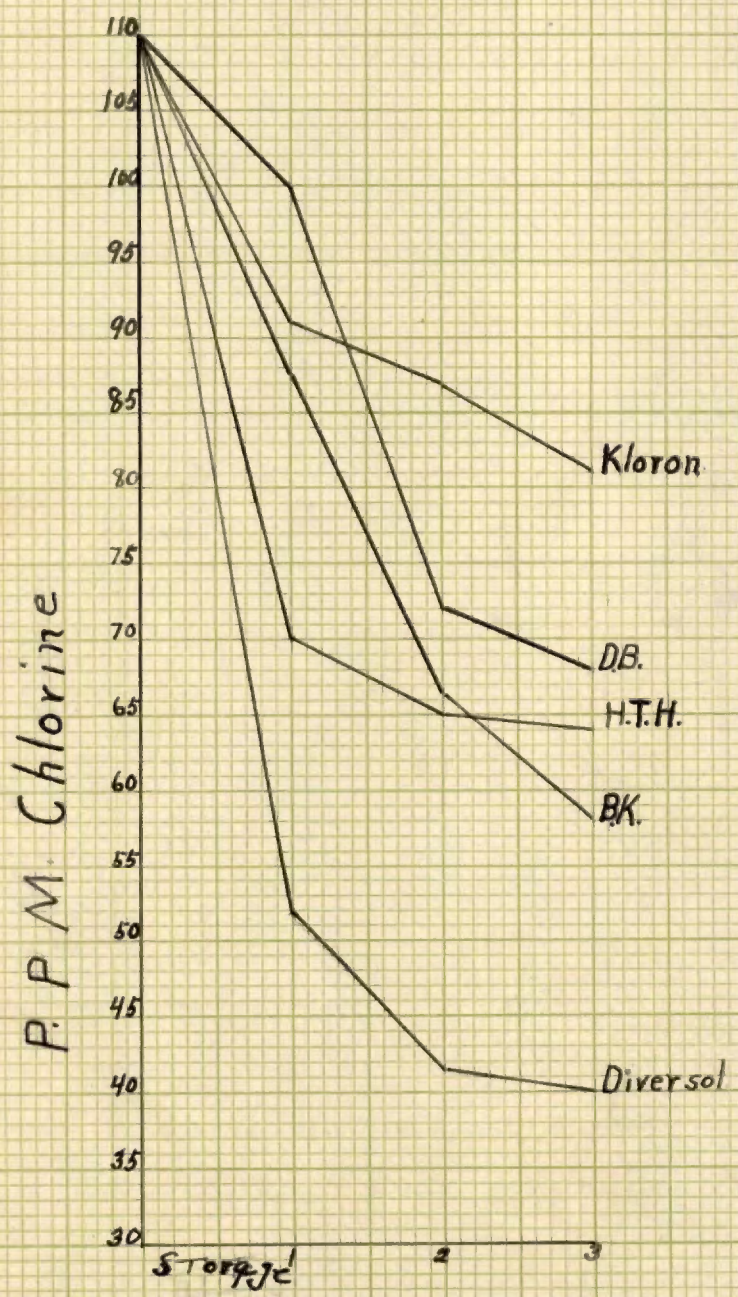
These bottles were tested for available chlorine by the sodium thiosulphate test at the end of each week for three weeks.

Table 12. Stability of Chemical Sterilizers under Various Storage Conditions.

Storage	Dates Tested 7/21/30	7/28/30	8/4/30	8/11/30
	D. B. P. P. M.			
Milk Room	110	107.2	103.8	103.0
General Storage	110	103.2	102.7	101.6
West Window	110	100.6	11.0	0.1
	H T H P. P. M.			
Milk Room	110	100.1	99.4	99.0
General Storage	110	97.9	95.7	93.5
West Window	110	12.6	0.05	Trace
	B. K. P. P. M.			
Milk Room	110	96.2	93.5	88.0
General Storage	110	96.2	93.5	83.6
West Window	110	66.0	0.1	Trace
	Diversol P. P. M.			
Milk Room	110	84.0	83.0	82.5
General Storage	110	60.8	41.0	40.0
West Window	110	11.5	0.3	None
	Kloron P. P. M.			
Milk Room	110	98.0	100.0	98.0
General Storage	110	98.0	100.0	101.0
West Window	110	77.0	61.0	48.4

Graph #1

Average Stability under Various Storage Conditions



The data of table 12 show the sodium hypochlorite to be apparently unstable when exposed to light, losing most of the chlorine in less than two weeks. Kloron is stable, as shown by the sodium theosulphate test, because it does not depend upon available chlorine for its sterilizing strength. The liquid hypochlorites are more stable than Diversol, as shown by this test. Diversol is the least stable of compounds tested by this method. See Graph number one.

This test indicates that a dark cool place is best for the storage of sodium hypochlorite. A temperature of 40°F. is desirable but not necessary. Wherever the solution is stored, it is necessary to avoid the direct rays of the sun.

(4) Stability in Presence of Milk.

It is generally recognized that the available chlorine is the agent of destruction of germ life. Hence, the sterilizing strength of these compounds is measured by the amount of such chlorine.

When a sterilizing solution is used for thirty or more minutes, it is expected that traces of milk will be left from each can. Since it is known that

milk, an organic matter, will cause a quick liberation of chlorine, there is the danger that the rinse solution will become so weak that the bacteria will not be killed.

In this experiment the object is to find what effect the addition of a small per cent of skim milk would have on the liberation of P. P. M. of available chlorine. Temperature also plays a very important part in the liberation of chlorine; so the temperatures of 80, 100 and 120°F. were used. Readings of the amount of available chlorine remaining were made at the end of 1, 10, and 30 minutes.

Table 13. Effect of Temperature, Milk, and Time on the Reduction of Available Chlorine of Commercial Chlorine Sterilizers.

Diversol

Per cent of Milk Added

Time	0.0%	0.1%	0.25%	1.0%
	P. P. M.			
80° Farenheit				
Start	54.15	44.32	41.55	33.24
1	53.73	44.87	37.12	33.20
10	53.00	43.21	30.47	24.93
30	52.00	35.46	20.50	17.17
100° Farenheit				
Start	49.25	44.32	41.55	33.24
1	48.75	43.21	33.52	27.70
10	48.25	42.10	29.36	14.95
30	46.00	26.59	22.16	11.63
120° Farenheit				
Start	56.00	55.5	46.75	22.0
1	55.00	50.5	38.50	18.15
10	54.20	42.9	35.75	16.50
30	54.00	39.6	20.90	13.75

Table 13. Effect of Temperature, Milk, and Time, on the Reduction of Available Chlorine of Commercial Chlorine Sterilizers.

D. B.

Per cent of Milk Added

0.0% 0.1% 0.25% 1.0%

80° Farenheit

Time	P. P. M.			
Start	58.8	58.3	57.7	56.4
1	58.8	58.0	57.2	50.1
10	58.5	57.5	55.5	35.0
30	58.0	55.1	38.4	21.0
100 ° Farenheit				
Start	73.9	70.2	69.6	53.4
1	72.0	67.5	66.4	46.9
10	71.0	64.8	54.4	27.0
30	70.2	63.7	51.3	16.2
120 ° Farenheit				
Start	56.7	55.3	48.6	35.1
1	56.0	52.3	46.9	29.7
10	54.7	46.9	36.1	17.2
30	53.7	44.2	32.4	11.8

Table 13 (Continued)

H T H

Per cent of Milk Added

0.0% 0.1% 0.25% 1.0%

80° Farenheit

Time	P. P. M			
Start	52.6	44.32	44.30	32.13
1	52.0	43.76	40.97	30.47
10	52.0	38.78	29.97	26.59
30	51.0	34.90	27.70	23.82
100° Farenheit				
Start	58.00	57.75	53.9	39.60
1	58.00	55.55	48.4	37.95
10	57.50	48.95	35.75	30.25
30	57.00	40.15	28.6	22.0
120° Farenheit				
Start	56.00	46.2	43.35	27.50
1	56.00	44.0	35.75	16.50
10	55.50	38.75	24.75	19.25
30	53.75	16.50	11.00	13.75

It is shown in table 13 that the solution, when no milk was present, lost very little of the chlorine when exposed for one, ten, and thirty minutes, at temperatures of 80°, 100°, and 120°F. Adding 0.1 per cent of milk caused a great reduction in the amount of available chlorine to take place. As the amount of milk was increased from 0.1 to 0.25 and to 1.0 per cent, the reduction of chlorine became faster. Thus, H T H solution, having 58 P. P. M. at 100°F, was reduced to 56 P. P. M. by heating to 120°F, which by the adding of 1 per cent of milk it was reduced to 39.6 P. P. M.

All of the different solutions behaved in a similar manner. None of them were outstandingly stable. Diversol was less stable than the others. These date indicate that all milk utensils should be carefully washed before attempting to sterilize them.

Corrosion of Milk Utensils.

The sterilizers used in killing bacteria are active chemicals capable of attacking metals. It is undesirable to have tarnished and corroded utensils with which milk comes in contact. Such utensils are hard to clean and sterilize. It was shown that the salts and oxides of certain metals have distinct toxic properties rendering milk unsafe for consumption. It was, therefore, deemed advisable to determine to what extent chemical sterilizers will corrode the equipment.

Realizing the importance of this question, experiments were run to determine the relative corrosiveness of D. B., B. K., Chlorofectant, H T H, Kloron and Diversol. Three trials were run using can metal strips, cheap syrup cans, and eight-quart milk cans. These commercial solutions, it was thought, would produce some evident corrosiveness and tarnishing on the metals.

The metal strips used were heavily tinned steel strips, 4 inches long, and 3/4 inch wide. These were placed in a rinse solution so that half of the strip was immersed in the solution and the rest was

exposed to the moist atmosphere, in a covered half-pint milk bottle.

The object of this experiment was to determine the effects on the air line, and to observe tarnishing and other visible changes that the solution might have upon the metal strip. The visible effects were noted each day, and the amount of available chlorine was determined at the end of each week for four weeks.

At the end of each trial the rusty water left in the half-pint milk bottle was evaporated to dryness, and the residue was weighed and recorded (see table 14). Pictures were made to secure a permanent record of results obtained.

The syrup can test was run to see how a cheaply tinned surface would compare to the better can metal surface. Friction top gallon cans were employed (plates 2-6). The solution used was the same as in the second trial of can metal strips. The cans were filled half full and set in a cool place so the chlorine would not be liberated too quickly.

In the third trial eight-quart milk buckets were used to check the results of the can metal strips (plates 3-6). They were Lisk extra-heavy-tinned,

small-top buckets. The results secured in this test should be representative of utensils commonly used in handling milk. The cans were filled half full of the solution and kept covered. They were observed daily to ascertain the effect of corrosion both above and below the air line.

The can metal strips in the half-pint milk bottles were observed daily and a picture was made showing the results at the end of the experiment. D. B. was found to be most corrosive, followed by B. K., Chlorofectant, H T H, Water, Kloron and Diversol, in the order of their decreasing corrosiveness (plates 2a and 3a). The strip placed in water showed rusting where the edge was not properly tinned. No corrosion and very little tarnishing took place on the tinned surface. This shows that water may not be as corrosive as the hypochlorite solutions. Kloron and Diversol were observed to be outstandingly the least corrosive sterilizers.

Table 14 gives the record of grams of residue from the metal strips. This represents the amount of metal lost as iron oxide and salt residue from the metal strip. Diversol had an average of .47 gram residue. As this product contains a large amount

of tri-sodium phosphate, it is likely that this is the reason for the high weight of the residue. The amount of residue indicates the rate of corrosiveness. B. K. and D. B. had more than .7 gram residue and were observed to be corroded the worst. H T H had less residue than the other liquid sterilizers; therefore it is considered to be least corrosive.

The cans showed corrosiveness in the same order as the metal strips. There was a marked rusting on the lids, showing that a moist atmosphere in presence of chlorine gas is as corrosive as the rinse solution in the bottom of the can.

In discussing the results of these experiments one should bear in mind that the metal strips and cans were exposed to the solution for four weeks. The sterilizing of the equipment with the chlorine sterilizer ordinarily takes only a few minutes a day. Hence, to expose the utensils under the usual operations in the milk handling to the same length of time as was done in the experiment would take many months or years.

It is difficult to describe or even show by a picture the intensity, nature of tarnishing,

sediment deposition, and pitting of the metals. Diversol and Kloron were not nearly as corrosive as the other sterilizers. Diversol contains trisodium phosphate to which may be attributed its non-corrosiveness. Diversol left a greater residue in the half-pint milk bottle (table 14) because it carried this alkali in solution. D. B. is the most corrosive of the solutions tested. It is followed closely by B. K., Carthol, Chlorofectant and H T H. Water is about as equally corrosive as sodium hypochlorite solutions. This would indicate that too much stress has been placed upon the importance of corrosion by chlorine sterilizers. If metal utensils are not properly drained and dried, the use of a sodium hypochlorite rinse solution will cause serious difficulty in keeping cans clean and shining.

Table 14. Corrosion of Metal Strip by Chemical Sterilizers.

Date	1/30/30	4/28/30	8/18/30	
	Weight in Grams of Residue			Average
Solutions	Trial 1	Trial 2	Trial 3	
Diversol	.12	.70	.60	.47
Kloron	.14	.70	.10	.31
Chlorofectant	.18	1.30	Not run	.49
H T H	Not run	.70	.15	.42
B. K.	.22	1.30	.10	.71
D. B.	Not run	1.25	.20	.72

The problem now is to determine why the solution varied in amount of corrosion. The chemical nature of the city water might have some bearing on this. For this reason a test was run on the city water.

Corrosion Test.

Plate 2-a Can Metal Strips Trial # 2.



D.B. B.K. Chloro-fectant H.T.H. H_2O Kloron Diversol

Plate 2-b Syrup Can Trial # 2.



D.B. B.K. Chloro-fectant H.T.H. Kloron Diversol

Corrosion Test.

Third Trial

Plate 3-a Can Metal Strips

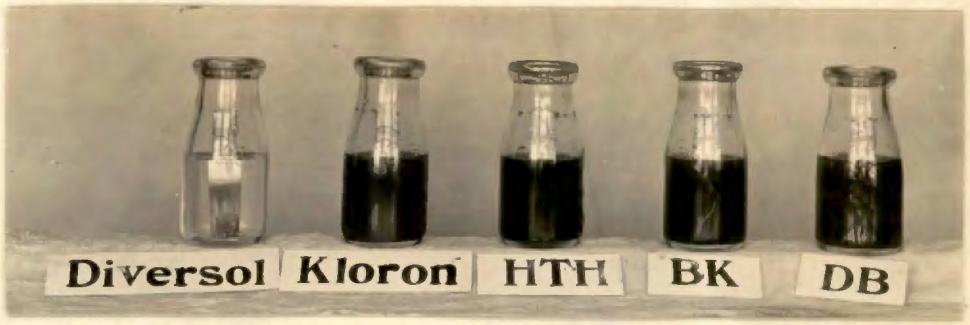
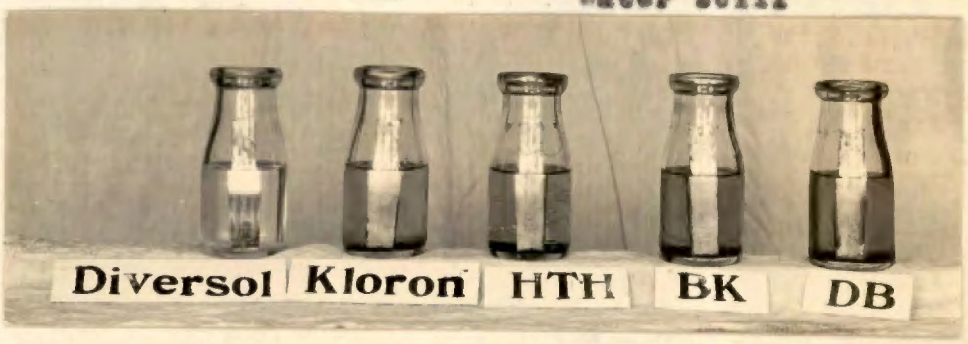


Plate 3-b

Water still



Lisk Heavily Tinned Milk Buckets



Summary of Corrosion Tests.

Three Trials



Plate 1

Plate 2a

Plate 3b

Water Analysis Report.

The chemical analysis of water effluent from Knoxville filtration plant averaged for April, 1930, as follows:

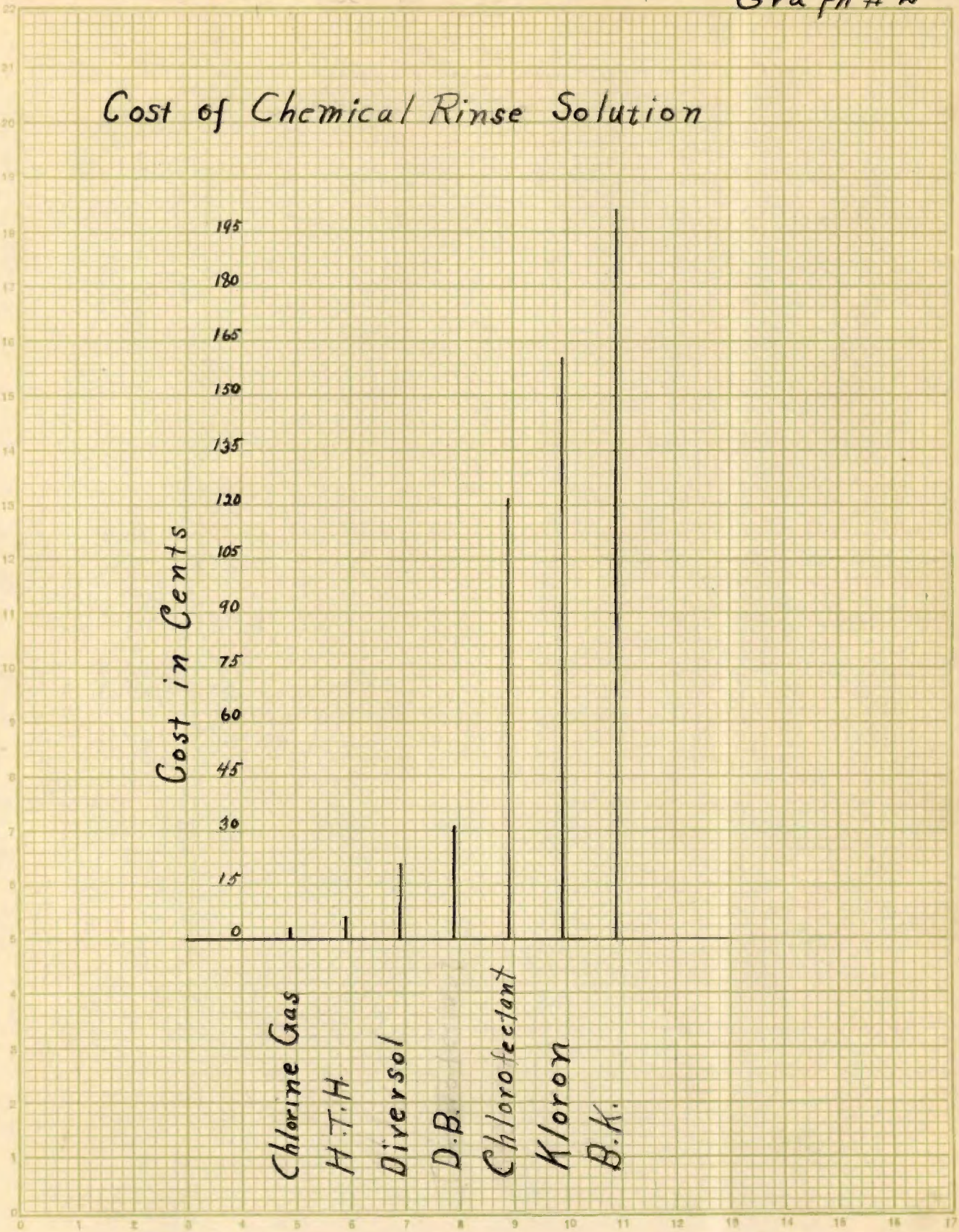
Hardness	85	Parts	Per	Million
P. H.	7.3	"	"	"
CO_2	5	"	"	"
Alkalinity	67	"	"	"
Chloride	21	"	"	"

A picture was made of all the metal strips. The close observation of the cleaned strip shows the same results as the pictures of strips in the bottles. This picture, however, shows a non-tarnished surface as a shiny surface. It is evident that the moist atmosphere is not as corrosive as the surface in water because the upper end is shiny. In test number one Diversol and Kleron are about equally tarnished. B. K., Carthol and Chlorofectant treated strips show a distinct mark at the air line and a very evident tarnished surface, both above and below the water. The B. K. treated strip is tarnished more than the others, showing a large rust spot on the side.

In the second and third tests, about the same results were secured as in the first one. D. B. was used in place of Carthol. It proved to be the most corrosive, exceeding even B. K.

Water showed up in plates 2-a to be almost as corrosive as a sodium hypochlorite sterilizer. In the second test the strip shows a shiny surface similar to a check strip, proving that water is non-corrosive to the heavily tinned surface.

Graph #2


Cost of Chemical Rinse Solution
Cost in Cents
195
180
165
150
135
120
105
90
75
60
45
30
15
0
Chlorine Gas
H.T.H.
Diversol
D.B.
Chlorofectant
Kloron
B.K.

Cost of a Chemical Rinse Solution.

It has been shown that the value of a chemical sterilizer depends upon many factors. The solution must be soluble in water, quick in action, have power of penetration, be stable, and non-corrosive. However, the cost of making a quantity of rinse water is the most important factor. The object of this study is to find that sterilizer, which will be desirable for use but cost the least to make rinse solution testing 100 P.P.M. of available chlorine. These will be calculated as the manufacturer recommends the dilution.

The cost of chemicals sold under the trade names, D. B., B. K., Diversol, Chlorofectant, Kloron and H T H was studied with results as follows:

Table 15. Cost to Make 100 Gallons Rinse Water.

Solution	Cost per 100 gallon	Commercial Price	Recommended Strength
B. K.	$1.98	$3.00 Gal.	2 oz. to 3 gal.
Kloron	1.60	2¢ tablet	2 tab. to 2½ gal.
Chloro-fectant	1.21	1.60 Gal.	1 oz. to 1 gal.
D. B.	.31	1.25 Gal.	1 oz. to 4 gal.
Diversol	.23	.23 lb.	1 # to 100 gal.
H T H	.058	.174 Gal.	1/3 gal. to 100 gal.
Chlorine Gas	.00075	.07½¢ lb.	1 # to 10,000 gal.

In table 15 it is shown that B. K. is, of all the sterilizers, the most expensive to make 100 gallons of rinse solution. Kloron is less expensive and is followed by Chlorofectant, D. B., Diversol, H T H and Chlorine Gas.

Chlorine gas is by far the cheapest sterilizer, but it is unsuitable for use in milk utensils because it is very corrosive and hard to handle. H T H is the cheapest sterilizer which can be used in small milk plants. It must be made in rather large quantities.

Therefore, it is suited only for a milk plant and not the farm dairy. The plant in turn could make and furnish H T H to the milk producers free of charge. The only close competitor of H T H is Diversol. Chlorofectant, Kloron and B. K. are more expensive to make a given amount than the other solutions studied.

Detection of Chlorine Added to Milk and Cream.

Chlorine is a good means of reducing the original bacterial contamination of milk. Therefore, all milk handlers should have some on their farms for this purpose. The temptation is so great that some will also try to reduce the bacteria count by directly adding chlorine to the cans of milk. It is very necessary, therefore, that the milk buyers have an accurate means of finding out if chlorine has been added to the sweet milk.

The presence of small amounts of chlorine can be detected easily in water. It can not be detected so easily in milk because the chlorine combines with milk protein and is not liberated readily at room temperature.

There is a good method, however, for detecting the presence of chlorine in milk. By this method the chlorine is liberated in the presence of potassium iodide, which displaces the iodin of the iodide; the latter in turn combines with the protein, giving rise to a yellow-colored compound, the shade of the color depending on the amount of iodin liberated. This makes it possible to detect very weak dilution of chlorine added to the milk. As little as one part of chlorine added to 100,000 parts of milk, can be detected.

It has been a practice of farmers to add as much as two table spoons of a 3% commercial sterilizer to a ten-gallon can of milk. This gives a dilution of one part hypochlorite to 1,260 parts milk.

The object in this experiment is to try out this test using known dilutions of milk and cream. Dilutions were made up as follows:

1 part	chlorine	to	1000	parts	milk
1 "	"	"	5,000	"	"
1 "	"	"	10,000	"	"
1 "	"	"	50,000	"	"
1 "	"	"	75,000	"	"

Each of the dilutions were run in duplicate. Sodium hypochlorite, sold under trade name of B. K. was used.

The reagents used in the experiment were made as follows:

1. Seven grams potassium iodide were dissolved in 100 c. c. of distilled water.
2. 200 c. c. of distilled water were added to 100 c. c. of concentrated hydrochloric acid.
3. 1 gram of starch was boiled in 100 c. c. of water.

The Test.

(1) To 5 c. c. of milk add 1.5 c. c. of iodid sol. Mix thoroughly by shaking, and observe the color of the milk.

(2) If unaltered, add 4 c. c. of HCl, mix with glass rod flattened at one end. Note the color of the curd.

(3) Place tubes in water bath heated to 85°C. (185°F.) and allow to remain 10 minutes. During this interval the curd will rise to the surface.

(4) Cool rapidly and examine the curd and liquid below.

(5) Finally, add 0.5 to 1 c. c. of starch solution to liquid below the curd and note results.

Table 16. Determination of Sodium Hypochlorite Added to Milk.

Outline of Test	Dilutions of Available Chlorine with Different Color Reactions.					
	1:1000	1:5000	1:50,000	1:75,000	Cream 1 to 1:5000	50,000
(1) Take 5 c.c. Milk - Cream	Reddish color	slight discolor	No change	No change	very slight discolor	No change
(2) Add 1.5 c.c. Iodid sol. (Milk appears)	light yellow	deep yellow	No change	No change	yellow	No change
(3) Add 4 c. c. HCl (Curd appears)	yellow brown	deep yellow	very light yellow	No change	light yellow	No change
(4) Heat to 85°C. and cool. Curd & Liquid appear	Blue Purple	light purple	yellow	very light yellow	yellow	No change
(5) Add 0.5 c. c. starch. Liquid below curd appears	Blue Purple	purple	Dark Straw	straw	Dark straw	pale red color

As table 16 shows, there were various color reactions on the addition of the different strength of sterilizing solution in the test. In parts 1 and 2, it is hard to detect a color change; and parts 3, 4, and 5 show a color change from the natural milk color through various shades of yellow to bluish purple.

Holding milk and cream to which chlorine has been added does not change the results of this test.

Although this test is subject to error, it furnishes a good means of determining whether chlorine is the cause of off-flavor in milk. If the color changes are carefully observed, they furhish a reliable guide to

the amount of chlorine added to a can of milk.

Summary

During the last ten years many methods have been tried to make milk keep for a longer time. One source of trouble is improperly sterilized utensils. Hot water and steam have been used for a long time with varying success. These have their limitations in that they are not always available at the time of use, and it is not possible to maintain high enough temperature to kill bacteria. Chemicals have been tried, such as mercuric chloride, various coal tar products, and formalin. All of these chemicals are poisonous and should not be used on surfaces coming in contact with milk. Sodium hypochlorite is the one most commonly used, because chlorine liberated readily destroys bacteria and the chlorine solution is not poisonous.

The strength of this solution must be great enough to kill the bacteria in a very short time. As low as 15 P.P. M. of available chlorine has been found effective in killing bacteria. The strength of the solution to be used depends on the amount of dirt or organic matter present.

To secure proper sterilization in the presence of dirt or organic matter, a larger amount of chlorine is required. A strength of from 50 to 200 P.P.M. is usually recommended where utensils are dipped, and 500 P.P.M. where a spray system is used. There should be a reliable test available at all plants to measure the amount of chlorine present.

Chlorine will combine with hydrogen and form an acid which is corrosive to metals. For this reason chlorine treated cans and buckets should be placed on a rack in such a position as to secure drainage. As a means of preventing corrosion, it is a good plan to use chemical sterilizers just before the milk is to come in contact with the metal.

Sodium hypochlorite solutions are active germicides killing vegetative cells in fifteen seconds. However, they cannot be added to whole milk for the purpose of reducing the bacterial count. The milk is given a medicinal taste long before there has been enough added to kill any bacteria. Dairymen are getting away from the practice of adding hypochlorite directly to the milk. The sterilizing solution will keep the milk from souring by preventing the original contamination

from the utensils. All milk utensils should be carefully rinsed with some hypochlorite.

The common pathogenic organisms are killed by a rather small dilution of available chlorine. B. coli is considered as an index organism being harder to kill than the organisms which cause disease. Two tenths of 1 P. P. M. available chlorine will kill this organism very quickly in sterile water. These bacteria are killed by the action of compounds produced which act on the cell plasma.

Experimental Study

A study was made to find the desirable and undesirable features of some of the common chemical sterilizers. Diversol, H T H, B. K. and D. B., were compared with steam for efficiency in reducing the number of bacteria remaining in milk utensils. Any of these solutions is more effective than steam in sterilizing milk bottles and cans. Steam is more difficult to use. Each of these four solutions were found to be about equally effective in reducing the number of bacteria. There is not enough water left in a chlorine treated can or bottle to cause a reduction

in an agar plate count. By calculation it was shown that less than one cubic centimeter of rinse water would remain in a bottle. If this small amount of water is diluted into a bottle of milk very little change of flavor will result.

A chemical sterilizer must be capable of holding some chlorine in the solution which will be available during the entire period of use. The liquid hypochlorite solution is not stable loosing all the chlorine. The rinse solution must be changed as soon as the available chlorine falls below 100 parts per million, if a reliable job of sterilizing is to be done. Kloron, a Chloramine T. product, was found to be more stable than any of the other compounds tested. B. K., Carthol, and Chlorofectant were about equally stable. H T H was found in daily plant use to loose only 19.6 per cent of the available chlorine which indicates that it is sufficiently stable.

Light and high temperature were found to cause a liberation of chlorine very rapidly. The concentrated solution should be stored in a dark and cool place. Presence of milk or organic matter will also cause a quick liberation of chlorine. When much dirt

is carried into the rinse water it is necessary to change water more often. Diversol proved to be less stable in the presence of organic matter than did D.B. and H.T.H. At a high temperature the chlorine is lost much more rapidly.

Chlorine acting in a moist atmosphere attacked and corroded a metal surface. It is impossible to use the rinse water at high enough temperature for the heat absorbed by the metal to dry the utensil. This is not a serious difficulty if the sterilizer is used as a rinse just before milk comes in contact with the metal. In all trials testing for corrosion, Diversol was outstandingly non-corrosive. It was followed by Kloron. Chlorofectant, B.K. and D.B. were more corrosive than H.T.H. Water proved to be corrosive showing that it is very important to place all metal utensils in such a position as to secure good drainage.

One of the most important factors in selecting a sterilizer is the cost of making a strong, safe rinse solution. Chlorine gas figures much cheaper than any of the hypochlorite solutions. As it requires expensive apparatus to handle, it is not in common use in the smaller milk plants. Based on chlorine content H.T.H. costs one-fourth as much as Diversol. D.B. is more expensive than Diversol, but much less expensive than Chlorofectant, Kloron and B.K.

Conclusions

1. The results of these experiments indicate that chemical sterilization of milk utensils is effective, practical and simple in application if properly used.

2. For small dairies chemical sterilization is more practical than steam sterilization.

3. A few cents worth of hypochlorite solution will sterilize the usual number of utensils on the average farm.

4. Of the compounds studied sodium hypochlorite is the one most common in use and is very easy to use.

5. Chloramine T compounds have not come into as common a use as they do not quickly go into solution.

6. Chlorine gas for sterilizing bottles is finding increased use in the larger milk plants.

7. The commercial chlorine preparations studied are safe and reliable if they are used as directed by the manufacturer.

8. Sterilizing solutions should be made in strength of 100 parts per million of available chlorine. Solutions of this strength have a good margin of safety, providing the utensil is properly cleaned. There are simple tests for checking the strength of the rinse water.

9. Each of the solutions studied has advantages as well as disadvantages.

10. Diversol is non-corrosive which makes it valuable to use in sterilizing expensive equipment.

11. Chlorine gas is cheap but corrosive to metals. It can be safely used in sterilizing bottles.

12. H.T.H. is stable, cheap, and can be made non-corrosive by use of soda ash.

13. The most important factor which should be investigated is the question of alkalinity. The higher the alkalinity, the more stable is the solution, but the slower the action.

14. Chemicals are finding increased use in addition to the steam boiler, for sterilizing dairy utensils.

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