# Churn Contamination as a Source of Yeasts and Molds in Butter

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YEAST and mold counts on butter have been of value in indicating the efficiency of pasteurization of the cream and the sanitary condition of the equipment—vats, pipe lines and churns—in which the pasteurized cream and the butter are handled. That yeasts and molds do not play a significant part in determining the flavor score and keeping quality of butter of medium or high salt content has been shown by several investigators. Thus, Grimes (3) graded and examined 135 samples of butter for total bacterial count, yeasts and molds but found no correlation between the flavor score of the butter when two weeks old and the results of any of the microbiological examinations.

Macy, Coulter and Combs (10) reported that the flavor of salted butter stored for one month at 35° F. was uniformly good and that the majority of samples showed decreasing counts of bacteria, yeasts and molds during storage. For unsalted butter, however, these investigators reported an entirely different situation; there was a noticeable tendency for the bacterial, yeast and mold counts to increase during storage, accompanied by serious deterioration in flavor. The possibility of a relationship between this deterioration and the increases in counts is pointed out. Olson and Hammer (13) found no significant differences in keeping qualities of salted (2.5%) butter from clean and from contaminated churns.

The importance of churn sanitation in the manufacture of unsalted butter and butter of low salt content has, however, been fully recognized. Thus, Olson and Hammer (13) showed that unsalted butter from clean churns possessed keeping qualitity at 45° F. distinctly superior to that of unsalted butter from contaminated churns. Experience of the author in commercial manufacture of unsalted butter from cream ripened to 0.40 percent acidity has amply demonstrated the necessity of low yeast and

mold counts if the butter is to have good keeping quality throughout the ordinary holding period in fresh consumption channels.

The influence of the churn as a source of contamination of the butter has been studied by a number of investigators. Gregory (2), Lund (8), Hood and White (5) and Brown (1) presented some of the early results pointing to the churn as an important source of yeasts and molds in butter. Hunziker (6) states that the churn is the most difficult piece of equipment to sterilize and recommends the use of boiling water. Macy and Combs (9) made a survey of commercial creameries in 1925 and 1926 to investigate sources of mold in butter and found that the churn was one of the principal sources of contamination from equipment. James (7) used both boiling water and chlorine compounds in attempting to sterilize churns and discovered that molds and yeasts were worked from the churns (into a sterile water rinse) after extreme exposures to hot water and to chemicals.

Macy, Combs and Morrison (11) showed that the churn may be an important source of mold in butter. Morrison, Macy and Combs (12) studied the effects of hot water, steam and chlorine compounds on the microflora in churns and found that the hot water treatment was most effective but that it must be administered daily to prevent the churn from becoming a serious source of contamination. Chlorine compounds were not found effective.

Olson and Hammer (13), however, found that treating highly contaminated churns regularly with either sodium hypochlorite or a chloramine preparation resulted in large reductions in the numbers of organisms present. Using either the rinse or agar disc method of judging results, hot water effected "striking" reductions in the numbers of organisms, yeasts and molds being largely eliminated.

The agar disc method for studying contamination from churns, developed and reported by Hammer and Olson (4), consists of allowing a small amount of an agar medium to solidify in contact with the wood of the churn and transferring it to a sterile petri dish for incubation.

While in some cases the type of churn used was not reported in the literature, apparently most, if not all, of the work has been done with churns of the combined churn-and-worker type, with the workers permanently installed in the churn. The present work was done (1) to study the yeast and mold content of butter made in Simplex churns, which have a set of workers to be run into the churn only for the working of the butter, and (2) to determine if some sterilizing treatment could be devised which would leave the churn and workers in satisfactory condition from a bacteriological point of view. This work received impetus from the practical necessity of reducing churn contamination to the point which would permit the manufacture of unsalted butter possessed of keeping quality—that is, the retention of the desired culture flavor and aroma throughout its life in the hands of the consumer.

## METHODS

All work herein reported was done in a commercial creamery equipped with 1,000-gallon Jensen vertical-coil vats and No. 12 Simplex churns, the average churning being approximately 1,000 pounds of butter. A common method for determining the extent of contamination left in a churn after a "sterilizing" treatment has been to rinse the churn with sterile water and to make plate counts on the water after agitation in the churn. Inasmuch as the present work was done with commercial creamery equipment, it was not possible to prepare the quantities of sterile water necessary to adequately rinse a churn of the size employed. Ordinary city water, therefore, was used. While bacterial and yeast and mold counts were made on the water after rinsing the churn, and in a number of cases on the water entering the churn also, it was thought highly desirable to follow through and determine the yeast and mold count of the cream in the churn after a short run and of the finished butter. In a number of cases counts were made from the start—the pasteurized cream in the vat—through the several stages to the finished butter.

While it is recognized that there would be some breaking up of clumps of cells in the agitation of cream in the churn, the comparatively low yeast and mold counts secured on the cream after a 10-minute run in the adequately treated churn are believed to indicate that the breaking up of clumps was of minor importance as compared with contamination from the churn barrel in accounting for the increase in yeast and mold count from the cream in the vat to the cream in the churn. In a few preliminary trials, in which a small, sterile, enameled churn was used in the laboratory for churning 1,500-gram quantities of cream, it was not possible to demonstrate by increased plate counts any definite breaking up of clumps of yeast and mold cells. After a churning period of 10 minutes the counts showed slight decreases in two cases and a slight increase in another, the average for the three trials being 52 colonies before churning and 50 colonies after.

Comparisons were made between various churn treatments, each of two churns receiving a different "sterilizing" treatment in any one experiment. Cream from the same vat was used for the two churns so that the butter from them was directly comparable. Yeast and mold counts were made on whey agar with 1 ml. of 1 percent tartaric acid per plate in the early part of the work, and on potato dextrose agar adjusted to pH 3.5 with tartaric acid in the later experiments. All counts reported are the average of duplicate plates. Incubation was for 5 days at 20° to 25° C.

## EXPERIMENTAL

At the beginning of the experimental work the churns had been in service for two years, during which time they had received a routine treatment which will be designated as "ordinary" hot water and which consisted of the following:

1. In afternoon after butter was removed.
   a. 50 gallons (approximately) hot water, 150° F., with Wyandotte Cleaner and Cleanser, or tri-sodium-phosphate. Churn run 5 minutes with workers in.
   b. 150 gallons (approximately) water at 210° F. Churn run 15 minutes, workers in.
2. Next morning.
   a. 50 gallons cold water, churn run 5 minutes with workers in.

That this treatment was not efficient in the destruction of germ life in the churns and workers and in the production of butter with a low yeast and mold count had been known. A series of bacterial and yeast and mold counts on the cold churn-rinse water in the morning and yeast and mold counts on the butter was made at the beginning of the experimental work, and it was found that the cold rinse water had a plate count of 12,000 to 50,000 bacterial colonies per ml. and a yeast and mold count varying from 200 to 1,000 per ml. Expressed on another basis, the 50 gallons of rinse water removed from 2,270,000,000 to 9,460,000,000 bacteria and from 37,800,000 to 189,200,000 yeasts and molds (plate counts) from the churns. The yeast and mold count of the butter churned in such churns varied from 100 to 700 per ml. While it was not possible to use sterile water for the routine rinse of 50 gallons of cold water, the bacterial and mold counts on the water used were always very low as shown by numerous check determinations on samples of the water taken as it was going into the churn. The average bacterial count of 47 per ml. by the plate method for 14 determinations on separate days is believed to warrant the assumption that the bacterial content of the water going into the churn was unimportant as a source of the large numbers of organisms found in the same water coming out. The high yeast and mold counts of the water after rinsing the churns were essentially yeast counts, since the yeasts usually greatly outnumbered the molds. Yeasts were never found in the water going into the churns.

### VIGOROUS HOT WATER TREATMENT

It seemed likely that the poor results secured with the "ordinary" hot water treatment were to be attributed to the fact that the last rinse of boiling water was used with the workers in the churn, causing a rapid drop in temperature and the loss of a good portion of the water in the first five minutes' run. Table 1 gives a record of the temperatures observed.

The rapid drop in temperature of the water from the boiling point to around 150° F. in five minutes and to only 125° F. in fifteen minutes easily explains the survival and growth of enormous numbers of bacteria, yeasts and molds as revealed by the counts on the cold rinse water the following morning.

TABLE 1. *Decrease in temperature of churn wash water*
Temperatures (degrees F.) on separate days

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Water in tank | 206 | 210 | 210 | 210 | 210 | 210 |
| Water in churn | 185 | ..... | 183 | 187 | ..... | ..... |
| Water after 6 revolutions | ..... | 182 | ..... | ..... | ..... | ..... |
| Water after 5 min. run (½ water lost) | ..... | 158 | 148 | 146 | ..... | ..... |
| Water after 15 min. run (very little water left) | 125 | 132 | 125 | 122 | 124 | 126 |

It was accordingly decided to try the boiling water rinse (150 gallons) at night in a closed churn and attempt to give the workers treatment outside of the churn with scalding water after they had received the alkali rinse in the churn. A daily comparison was made between two churns, one having the "ordinary" hot water treatment and the other the so-called "vigorous" hot water treatment. Both churns were given only a cold rinse of about 50 gallons of water in the morning before cream was pumped in. One vat of cream was used for each pair of churnings so that the butter counts were directly comparable. The results of this comparison are given in table 2.

TABLE 2. *"Ordinary" treatment vs. "vigorous" hot water treatment*

| | Ordinary—workers in | | | Boiling water (150 gal.) in closed churn, run 15 or 30 minutes | | |
|---|---|---|---|---|---|---|
| | Plate count—colonies per ml. | | | Plate count—colonies per ml. | | |
| | Cold A. M. rinse | | Butter— | Cold A. M. rinse | | Butter— |
| Exp. No. | Bacteria | Yeasts & molds | yeasts & molds | Bacteria | Yeasts & molds | yeasts & molds |
| 4 | 3,800 | 500 | ..... | 4,300 | 400 | ..... |
| 5 | 6,500 | 400 | ..... | 9,000 | 450 | ..... |
| 6 | 49,500 | 550 | ..... | 9,200 | 400 | ..... |
| 9 | 54,000 | 760 | ..... | 810 | 16 | ..... |
| 10[1] | 8,700 | 390 | 92 | 45 | 29 | 15 |
| 11 | 9,000 | 220 | 200 | 86 | 60 | 86 |
| 12 | 11,800 | 680 | 180 | 10,500 | 40 | 8 |
| 13 | 18,000 | 1,060 | 340 | 1,050 | 36 | 9 |
| 14 | 20,800 | 1,500 | 530 | 1,620 | 79 | 31 |
| 15 | 13,200 | 510 | 330 | 11,000 | 53 | 100 |
| 16 | 21,100 | 1,190 | 600 | 5,600 | 68 | 89 |
| 17 | 21,200 | 1,070 | 380 | 9,300 | 165 | 49 |
| 18 | 29,000 | 700 | 710 | 3,000 | 59 | 1,470 |
| Ave. | 20,507 | 733 | 373 | 5,038 | 143 | 206 |

[1] In experiments 10 to 18, inclusive, cold morning rinse was in closed churn.

The bacterial counts on the cold rinse water in the morning varied from 3,800 to 54,000 per ml. for the "ordinary" hot water treatment and averaged 20,507, compared with limits of 45 and 11,000 and an average of 5,038 per ml. for the "vigorous" treatment. Yeast and mold counts on the rinse water averaged 373 per ml. for the "ordinary" treatment and 143 per ml. for the "vigorous." The yeast and mold counts on the butter showed decidedly the advantage of the closed-churn treatment. Eight of the nine churnings in the direct comparison had a count of 100 per ml. or less and averaged 48. The one high count of 1,470 brought the average up to 206 per ml. On the other hand, the butter from the same cream (each pair from the same vat) but churned in the churn that received the "ordinary" treatment had only one out of nine churnings below 100 per ml. in yeast and mold count, the others varying from 180 to 710 per ml. and averaging 373.

Thus, a definite improvement in the bacteriological condition of the butter was brought about by using a boiling water rinse in a closed churn at night and scalding the workers outside of the churn. In this way the churn barrel itself received the full benefit of the hot water, although the bacterial counts on the cold rinse water left much to be desired in the approach toward sterility. The average bacterial plate count of 5,038 colonies per ml. of cold rinse water in the morning meant that over 950,000,000 cells and clumps were removed from the churn by the 50 gallons of rinse water. This treatment, it was recognized, left the workers as a rather important source of contamination of the butter since it is impossible to secure adequate treatment of the wood through scalding water or steam. Undoubtedly the condition of the workers was responsible for the one high count of 1,470 yeasts and molds per ml. among the "vigorous" treatment counts.

## USE OF CHLORINE STERILIZERS

### A. *Sodium Hypochlorite*

Because of economic reasons—the large amount of steam required to prepare adequate quantities of water for the boiling water treatment for all churns and the time element involved—it was thought desirable to determine the efficiency of chlorine sterilizers. Accordingly, a number of comparisons were made between hot water and sodium hypochlorite, one churn receiving a hot water treatment for a series of days and another the chlorine rinse in addition to the hot water. The hot water treatment consisted of a final rinse of 50 gallons of boiling water at night and the same in the morning followed by cold water; the sodium hypochlorite rinse (75 p.p.m.) was used either night or morning, or both. When used at night it followed the boiling water, and when used in the morning it was in place of the hot rinse and followed by the cold. Thus, when used in the morning only, there was a direct comparison between hot water

TABLE 3. *Effect of sodium hypochlorite rinse in addition to hot water treatment*

| | Boiling hot water (50 gal.) P.M. & A.M. | | | | Sodium hypochlorite rinse (75 p.p.m. av. chlorine) after boiling water | | |
|---|---|---|---|---|---|---|---|
| | | Cold A.M. rinse | | Butter | | Cream in churn after 10 min. run | Butter |
| Exp. No. | Workers in or out | Bacteria col. per ml. | Y. & M. col. per ml. | Y. & M. col. per ml. | Rinse in closed churn | Y. & M. col. per ml. | Y. & M. col. per ml. |
| 24 | In | 5,200 | 940 | 1,010 | A.M. only | ..... | 900 |
| 25 | In | 3,800 | 830 | 650 | P.M. & A.M. | 380 | 610 |
| 26 | Out | 3,650 | 620 | 550 | P.M. & A.M. | 1,150 | 500 |
| 27 | Out | 2,020 | 490 | 570 | P.M. only | 690 | 970 |
| 33 | Out | 400 | 107 | 630 | A.M. only | 360 | 210 |
| 34 | Out | 1,350 | 280 | 1,100 | A.M. only | 188 | 340 |
| 48 | Out | ..... | ..... | 450 | A.M. only | 450 | 420 |
| 50 | In | ..... | ..... | 71 | A.M. only | 200 | 34 |
| Ave. | | 2,732 | 544 | 629 | | 482 | 498 |

and sodium hypochlorite since other items in the treatment of the two churns were identical.

Table 3 gives the results obtained. The yeast and mold counts of the butter from the churn which received the hot water treatment varied from 71 to 1,100 and averaged 629 per ml., while the butter from the same vat of cream but from the churn which received the chlorine rinse varied from 34 to 970 yeasts and molds per ml. and averaged 498. In every comparison except one the chlorine rinse resulted in a lower yeast and mold count in the butter, and in that one the chlorine rinse had been used at night only. Apparently the chlorine rinse was more effective when used in the morning, although it by no means resulted in a sterile churn. Yeast and mold counts were made on the cream in the churn after a 10-minute run, and it was found that they varied from 188 to 1,150 per ml. and averaged 482. A churn responsible for such contamination could not be said to be in satisfactory bacteriological condition.

The condition of the cream before its entrance into the churns was checked by making yeast and mold counts on samples out of the 1,000-gallon vats. Through a sterile tube the cream was removed from below the surface into sterile wide-mouth glass-stoppered bottles. The counts varied from 0 to 18 and averaged 6 per ml. for the series of determinations. The entire pasteurizing and cooling system was sterilized with steam and flushed with 190° F. water previous to circulation of the cream, and the sanitary lines between the holding vats and churns were also steamed and flushed. The cream was flashed at 160° F. into a holding vat, where pasteurization was completed by holding it for a period of 20 minutes at a temperature ranging from 150° to 155° F. The cream was then

pumped through an internal tubular cooler and into a 1,000-gallon holding vat of the glass-enamel, vertical-coil type. The holding vat was previously steamed for a period of 15 minutes. The efficiency of this vat treatment was studied by rinsing sides and coils with one gallon of sterile, distilled water. It was found that the vat was not sterile. The plate method on the rinse water showed a bacterial count of 20 colonies per ml. The finding of yeast and *Oospora lactis* cells in the cream in the vat was undoubtedly a result of contamination from pipe lines, connections, pumps and vats which was not eliminated even with the procedures employed.

B. *Diversol*

In a series of trials with Diversol, a chlorine-carrying cleaning compound, essentially the same results were secured as with sodium hypochlorite. The same concentration of chlorine (75 p.p.m.) was used in a rinse both night and morning after a rinse of boiling water. The yeast and mold count of the butter varied from 210 to 380 per ml. in four trials and averaged 275, as compared with an average of 520 per ml. for churnings from the same vats of cream but made in churns which received the "ordinary" hot water treatment night and morning. Counts on the latter butter varied from 360 to 680 per ml. In one case both the churn and the workers were thoroughly scrubbed with the Diversol solution after the alkali rinse; in addition the churn was run closed for 10 minutes with the Diversol rinse of 50 gallons of warm water containing 75 p.p.m. available chlorine. In the morning the churn received a hot rinse of 50 gallons of 210° F. water followed by another Diversol rinse like the first. Two cold rinses were given the churn, the first to wash out the traces of chlorine and the second for sampling. The latter gave a bacterial count of 120 colonies per ml. and a yeast and mold count of 130 per ml., showing that over 22,500,000 bacterial cells and clumps and over 24,500,000 yeasts and molds were removed from the churn by the second cold rinse in spite of the thorough treatment with hot water and chlorine solution and the mechanical removal effected by the several rinses. The cream that went into this churn had a yeast and mold count of 5 per ml. in the vat, but contained 114 yeasts per ml. after it had been run in the churn for 10 minutes; the butter had a yeast and mold count of 280 per ml. The results of two other trials in which the Diversol was used only in rinse water after the hot water rinse night and morning are summarized as follows:

*Yeast and mold counts per ml.*

| Cream in vat | Cream in churn after 10-min. run | Finished butter |
|---|---|---|
| 9 | 180 | 230 |
| 8 | 275 | 380 |

The use of Diversol in churn treatment, while it reduced the yeast and mold count of the butter as compared with the "ordinary" hot water treatment, was not successful in lowering the count below 200 per ml.

C. *Chlorinated Lime*

The efficiency of chlorinated lime (bleaching powder) in the destruction of germ life in churns was investigated in a limited way. The "ordinary" hot water treatment, supplemented by a rinse of 50 gallons of boiling water in the morning before the cold rinse, was used on one churn; on another churn the same treatment was employed with the addition of chlorinated lime rinse at night after the hot rinse, 1 pound of the powder being added to 50 gallons of water at 120° F., giving an available chlorine content of approximately 800 p.p.m. This is considerably in excess of usual strengths employed in the sterilization of utensils, pipe lines and vats, but it was thought desirable to use extreme measures in attempting to secure efficiency in churn sterilization. In view of the relative cheapness of chlorinated lime, the use of high concentrations of available chlorine would not be impractical from an economic standpoint if they were found to be effective.

As before, cream from the same vat was used for each comparison between the churns representing the two different treatments. Table 4 gives the data secured. They show that the use of the chlorinated rinse resulted in lower bacterial and yeast and mold counts on the cold morning rinse water, and lower yeast and mold counts on the butter, the only exception to this being the yeast and mold count on the rinse water in experiment 19. The butter in the case of the "ordinary" hot water treatment averaged 1,255 yeasts and molds per ml., while the butter from the same cream but churned in the chlorine-treated churn averaged 420 per ml. While this was an improvement, the latter figure represents considerable contamination and is evidence of the difficulties to be met in at-

TABLE 4. *Effect of a chlorinated lime rinse in addition to "ordinary" hot water treatment*

| | "Ordinary" hot water[1], workers in churn | | | "Ordinary"[1] plus final $CaOCl_2$ rinse in P.M. (800 p.p.m. av. chlorine) | | |
|---|---|---|---|---|---|---|
| | Plate count—colonies per ml. | | | Plate count—colonies per ml. | | |
| | Cold A. M. rinse | | Butter | Cold A. M. rinse | | Butter |
| Exp. No. | Bacteria | Y. & M. | Y. & M. | Bacteria | Y. & M. | Y. & M. |
| 19 | 3,400 | 200 | 1,000 | 2,800 | 530 | 400 |
| 20 | 24,300 | 1,500 | 1,600 | 8,300 | 740 | 480 |
| 21 | ..... | ..... | 1,700 | ..... | ..... | 500 |
| 22 | 24,000 | 1,200 | 720 | 3,300 | 540 | 300 |
| Ave. | 17,233 | 966 | 1,255 | 4,800 | 603 | 420 |

[1] Supplemented by a rinse of 50 gallons of boiling water in morning before cold rinse.

tempting to sterilize churns even with extremely high chlorine contents in the sterilizing rinse.

The above results were secured with the butter workers in the churn and receiving all sterilizing rinses—both hot water and chlorinated lime—as well as the cold water rinse. Further trials were made in which the churn was run closed for all rinses except the preliminary hot alkali rinse after the butter was removed, the workers then being treated with scalding water outside of the churn. In one comparison the chlorinated rinse was used in the morning in place of hot water; the churn was run closed for 10 minutes followed by the usual cold rinse. The cream in the vat had a plate count of 4 yeasts and molds per ml.; the cream in the chlorine-treated churn after a 10-minute run had a count of 64 per ml.; and the count on the finished butter was 240. The butter from the same cream but in the churn that received the hot water treatment, however, had a plate count of 1,160 yeasts and molds per ml.

In another comparison with churns run closed for the sterilizing rinses, the chlorinated lime rinse was used both night and morning. In this case the cream in the vat had a plate count of 3 yeasts and molds per ml., while in the chlorine-treated churn after a 10-minute run the count was 170. Thus, a chlorinated lime rinse of excessively high chlorine content was unable to sterilize the churn barrel even when used both in the afternoon as a final rinse and in the morning before the cream was pumped into the churn. The churn barrel still yielded contaminating organisms to the cream.

D. *Chloramine-T*

The more stable nature of the organic form of a chlorine compound and its prolonged action over a period of time suggested the desirability of employing it for the sterilization of churns. The commercial product Santamine was used in a series of trials, either in the final rinse water at night or as a spray after the hot water rinse. When used in the rinse water, the recommended strength of 1 ounce per 30 gallons of water was employed (approximately 35 p.p.m. available chlorine based on a chlorine content in the chloramine-T of 13 percent). When used as a spray, the "standard" Santamine solution of 8 ounces dry powder per gallon of water was sprayed directly into the churn without dilution. While the use of a solution of such a strength would be impractical from an economic point of view because of the cost of the product, it was deemed advisable to determine what results could be obtained when extreme measures were taken. The counts on the cold rinse water and on the butter are given in table 5. In experiment 2 the chloramine was used in the final rinse of warm water, the workers being in the churn for all rinses. The counts on the cold rinse water in the morning and on the butter show no essential difference in churn contamination. Final yeast and mold counts on the

TABLE 5. *Chloramine-T treatment—rinse or spray—after ordinary hot water treatment*

| Exp. No. | Ordinary hot water treatment—workers in | | | Chloramine-T treatment in P.M. in addition to hot water | | |
|---|---|---|---|---|---|---|
| | Plate count—colonies per ml. | | | Plate count—colonies per ml. | | |
| | Cold A. M. rinse water | | Butter | Cold A. M. rinse water | | Butter |
| | Bacteria | Y. & M. | Y. & M. | Bacteria | Y. & M. | Y. & M. |
| 2 | 56,000 | 170 | 480 | 40,000 | 640 | 560 |
| 3 | 11,600 | 180 | 39 | 2,120 | 270 | 220 |
| 4 | 3,800 | 500 | ..... | 3,700 | 310 | ..... |
| 5 | 6,500 | 400 | ..... | 11,600 | 220 | ..... |
| 6 | 49,500 | 550 | ..... | 30,000 | 630 | ..... |
| | 2nd rinse | | | | | |
| 6 | 9,000 | 300 | ..... | ..... | ..... | ..... |
| 7 | 6,300 | 120 | 430 | 9,500 | 310 | 280 |
| Ave. | 22,283 | 317 | 310 | 16,153 | 397 | 353 |

butter were 480 and 560 per ml. for the ordinary hot water and the chloramine treatment, respectively. The cream, as usual, was from the same vat.

When the chloramine solution was used as a spray, the counts on the cold rinse water were both higher and lower than those for the ordinary hot water treatment. In experiments 6 and 7 the churn was held closed after the spraying for 15 and 35 minutes, respectively, to delay the drying out and to prolong the time of action of the chloramine. This was apparently of no benefit as judged by the counts on the cold rinse water and on the butter. In experiment 7 the butter in the chloramine-treated churn had a final count of 280 yeasts and molds per ml.

The use of chlorine compounds did not prove effective in the methods employed for the sterilization of the churns. The high yeast and mold counts secured on the cream in the churn after a short period of agitation suggest that the chlorine treatments were not effective in eliminating the churn barrel itself as a source of contamination, even though the barrel was exposed to the action of the chlorine solution during a run when the churn was kept closed and worker contamination was not a part of the problem.

### USE OF FORMALIN

In a few trials formalin was added to the rinse water (1 quart in 30 gallons of water at 70° F.) after the hot water treatment both night and morning. Results are shown in table 6. While the finished butter churned in the formalin-treated churn showed a lower yeast and mold count than butter from the same vat of cream churned in the hot-water-treated churn, two of the counts were over 200 per ml.; the counts on the cream after a 10-minute run in the churn indicate definite contamination from the bar-

TABLE 6. *Effect of formalin rinse in addition to hot water treatment*

| Exp. No. | Cream in vat | Boiling water (50 gal.) in closed churn P. M. & A. M. | | | Formalin rinse (1 qt. in 30 gal. water) P. M. and A. M. after hot water | |
|---|---|---|---|---|---|---|
| | | Plate count—col. per ml. | | | Plate count—col. per ml. | |
| | | Cold A. M. rinse | | Butter | Cream in churn after 10 min. run | Butter |
| | Y. & M. | Bacteria | Y. & M. | Y. & M. | Y. & M. | Y. & M. |
| 28 | 0 | 1,590 | 40 | 670 | 220 | 210 |
| 29 | 3 | ..... | ..... | 470 | 61 | 50 |
| 30 | 9 | 980 | 240 | 380 | 99 | 210 |
| Ave. | 4 | 1,285 | 140 | 506 | 126 | 156 |

rel. The formalin rinse both night and morning was not effective to the desired degree.

### USE OF STEAM

It was recognized that in most of the above trials in which hot water was used as a "check" treatment the quantity used was insufficient to produce any great destruction of microorganisms. As indicated in table 2, best results with hot water were secured with 150 gallons of boiling water in a closed churn. Since steam had been used by several investigators, it seemed desirable to determine what could be accomplished with it in the Simplex churn. While its use would not be expected to offer any advantage in economy as compared with the use of adequate quantities of hot water for each churn, the use of steam would be time-saving, especially if it could be used after the alkali rinse without a rinse of clear hot water. In the first trials one churn was closed up and steamed for 15 minutes each night by means of a hose inserted in the churn-gate. This was done after the churn received the usual boiling water rinse of 50 gallons, run closed for 15 minutes. In the morning the hot water rinse was repeated, followed by a cold rinse. Yeast and mold counts on the butter are given in table 7 and show that in 7 out of 10 trials the steamed churn yielded butter with a lower count than the churn which received the hot water treatment only, the butter again coming from the same cream. The average for the steam treatment was 526 yeasts and molds per ml. and for the hot water 706. In experiment 38 the yeast and mold count on the cream in the steam-treated churn after a 10-minute run was 58 per ml., the count on the cream in the vat having been 5 per ml.

In another series of trials a steaming period of 30 minutes or longer was employed, usually without the boiling water rinse at night, the churn

TABLE 7. *Effect of steaming in addition to hot water treatment*

| Exp. No. | Boiling water (50 gal.) in closed churn P. M. & A. M. | Steam for 15 min. at night in addition to boiling water treatment |
|---|---|---|
| | Plate count—colonies per ml. Butter, Y. & M. | Plate count—colonies per ml. Butter, Y. & M. |
| 38 | 1,050 | 500 |
| 39 | 870 | 300 |
| 40 | 460 | 210 |
| 41 | 750 | 390 |
| 42 | 760 | 410 |
| 43 | 1,200 | 420 |
| 44 | 620 | 1,550 |
| 45 | 240 | 420 |
| 46 | 390 | 160 |
| 47 | 720 | 900 |
| Ave. | 706 | 526 |

being flushed out with the hose after the alkali rinse and then steamed. The morning treatment was a 50-gallon rinse of boiling water, churn run closed for 10 minutes, followed by a cold rinse. The workers were scalded outside of the churn both night and morning. This treatment was compared with the "ordinary" hot water treatment received by another churn—a rinse of boiling water at night with the workers in—but supplemented by a hot rinse in the morning before the cold. The impression was growing that the workers were a serious source of contamination; in order to secure information regarding this, yeast and mold counts were made in some cases on the butter both before and after washing, as well as on the finished butter. Counts on the butter after washing would show the extent of contamination up to the entry of the workers, while the finished butter counts would include that from the workers also. Table 8 gives the data secured.

The yeast and mold counts on the cream in the churn after a 10-minute run show the extent of contamination from the churn barrel in the case of the steam treatment and demonstrate that the treatment was reasonably effective compared with previous treatments tried. The counts, together with the counts on the cream in the vat, are evidence that the large increases observed with previous treatments after a 10-minute run were not increases resulting merely from a breaking-up of clumps but, instead, definite increases brought about through contamination from the churn barrel. The steam treatment was so effective that the average yeast and mold count on the cream in the churn after 10 minutes was only 22 per ml. The average counts before and after washing were 15 and 13, respectively; thus, the butter ready for working was

TABLE 8. *Steam treatment compared with "ordinary" hot water treatment*
Plate counts—yeasts and molds per ml.

| Exp. No. | Cream in vat | Ordinary hot water—boiling water P. M. & A. M.—workers in Finished butter | Churn steamed at night | | | | |
|---|---|---|---|---|---|---|---|
| | | | Period of steaming | Cream in churn after 10-min. run | Butter granules Before washing | Butter granules After washing | Finished butter |
| 52 | | 570 | 30′ | | | | 220 |
| 53 | | 900 | 30′ | | | | 370 |
| 54 | | 800 | 45′ | 10 | | | 390 |
| 55 | 0 | 450 | 30′ | 17 | | | 520 |
| 56 | 5 | 460 | 30′ | 48 | | | 660 |
| 57 | 14 | 590 | 30′ | 21 | | | 590 |
| 58 | | 1,050 | 30′ | 13 | | | 450 |
| 59 | | 1,160 | 30′ | 51 | | | 1,150 |
| 60 | 1 | 300 | 60′ | 18 | 10 | 6 | 60 |
| 61 | | 120 | 30′ | | 9 | 13 | 26 |
| 62 | | 1,080 | 60′ | | 12 | 12 | 800 |
| 63 | 14 | 1,150 | 45′ | 11 | 35 | 9 | 510 |
| 64 | 5 | 680 | 45′ | 19 | | | 320 |
| 65 | | 320 | 45′ | 13 | 12 | 10 | 320 |
| 66 | | 480 | 30′ | | 11 | 11 | 410 |
| 67 | | 850 | 30′ | | 14 | 9 | 440 |
| 68 | | 480 | 30′ | | 22 | 32 | 290 |
| 69 | | 1,600 | 30′ | | 13 | 16 | 360 |
| Ave. | 7 | 724 | | 22 | 15 | 13 | 438 |

fairly low in yeast and mold content, yet the counts on the finished butter averaged 438 per ml., only two churnings out of 18 being below 200 and the balance ranging from 220 to 1,150 per ml.

This pointed definitely to heavy contamination from the workers. In experiment 69 the workers received a flush of scalding water both night and morning as well as a strong sodium hypochlorite solution in the morning, yet the yeast and mold count of the butter increased from 16 per ml. after washing to 360 in the finished butter. While this churning was being worked, a sample of the brine dripping from the shelves, before complete incorporation, was taken. This was plated, with a resulting count of 3,800 yeast and mold colonies per ml. With such contamination coming from the workers, the high yeast and mold counts secured in the finished butter throughout the entire series of trials are readily understandable. In the

series of 18 comparisons between the steam and "ordinary" hot water treatments shown in table 8, the cream in each comparison coming from the same vat, the steam treatment resulted in a lower yeast and mold count in 14 cases, a slightly higher one in 2, and the counts were the same in the other 2. For the steam treatment the average was 438 yeasts and molds per ml. in the finished butter, as compared with 724 for the hot water.

### INFLUENCE OF TYPE OF CHURN

The influence of the workers in contaminating the product was shown in a final experiment in which a 60-pound portion of butter was removed from the Simplex churn after washing and worked up to the finished moisture content in a small laboratory churn of the combined churn-and-worker type. The latter had been kept in satisfactory condition by a boiling water treatment, and was given a rinse of boiling water followed by a cold one preparatory to the working of the butter. The Simplex churn had received the 30-minute steam treatment at night with a rinse of boiling water followed by cold water in the morning. The butter granules after washing gave a plate count of 19 yeasts and molds per ml.; the 60-pound portion of butter worked in the laboratory churn gave a final count of 31 per ml. The same butter worked in the Simplex churn gave a final count of 220 yeasts and molds per ml. (unsalted butter).

A sample of the water taken from the Simplex churn early in the working process gave a plate count of 3,900 yeasts and molds per ml., showing essentially the same condition as the brine sample in experiment 69. A sample of the water-buttermilk mixture which drained from the 60-pound portion of butter removed from the churn after washing gave a plate count of only 8 yeasts and molds per ml., showing the condition previous to the entry of the workers.

The work reported above was all done in one commercial creamery. In the replacement of old churns in a second creamery in another state the opportunity presented itself to secure a direct comparison between the Simplex churn and the combined churn-and-worker type on the yeast and mold content of butter. In these comparisons cream from the same vat was pumped into the two churns, which were both receiving a routine treatment of 150 gallons of boiling water at night (Simplex closed with workers scalded outside) and a boiling water rinse of 50 gallons in the morning before the cold rinse. Results are shown in table 9. Yeast and mold counts were made on potato dextrose agar adjusted to pH 3.5.

While the bacterial counts on the butter were higher for the Simplex churn in five cases out of seven, the yeast and mold counts showed the pronounced difference between the two types of churns, the heavy contamination in the Simplex undoubtedly resulting from the workers. The highest yeast and mold count on butter from the combined churn-and-worker was 57 per ml., while the counts on butter from the Simplex

TABLE 9. *Comparative plate counts on butter from two types of churns*

| | Combined churn and worker type | | | Simplex churn | | |
|---|---|---|---|---|---|---|
| Vat of cream | Lot No. | Bacteria col. per ml. | Yeasts & molds col. per ml. | Lot No. | Bacteria col. per ml. | Yeasts & molds col. per ml. |
| 1 | 348 | 16,000 | 20 | 349 | 74,000 | 900 |
| 2 | 354 | 34,000 | 16 | 355 | 110,000 | 137 |
| 3 | 356 | 33,000 | 15 | 357 | 27,000 | 520 |
| 4 | 360 | 10,700 | 23 | 361 | 24,000 | 620 |
| 5 | 363 | 10,900 | 57 | 364 | 13,800 | 1,010 |
| 6 | 365 | 380,000 | 45 | 366 | 109,000 | 1,400 |
| 7 | 367 | 23,000 | 39 | 368 | 56,000 | 1,170 |
| Ave. | | 72,514 | 31 | | 59,114 | 822 |

churn varied from 137 to 1,400 per ml.; averages were 31 and 822, respectively.

Such differences are of definite significance in the manufacture of unsalted butter. That the contamination from the workers is of importance also from the standpoint of the bacterial content of the butter has been demonstrated by the bottle test in this laboratory in several instances in the examination of butter for development of surface taint.

The high yeast and mold counts obtained on the finished butter in the Simplex churns throughout the entire series of experiments demonstrate the inadequacy of all treatments in the attempted sterilization of the workers, and they prove the futility of intensive treatment of the churn barrel when the workers cannot be successfully treated. It is believed that a steam chest in which the entire workers could be subjected to prolonged steaming would furnish the only successful means of eliminating contamination from this important part of the Simplex churn, and then only if used daily from the time the churn was first placed into use. In the absence of such a sterilizing chamber the workers are a menace to the quality of butter; the impossibility of eliminating contamination from them through ordinary measures has been one of the factors responsible for the gradual withdrawal of the Simplex churn from creamery equipment.

## SUMMARY

1. An attempt was made to study, by yeast and mold counts, the contamination of butter from Simplex churns and workers in regular operation in a commercial creamery.

2. Bacterial, yeast and mold counts were made on the churn rinse water; yeast and mold counts were made on the cream in the churn after a 10-minute run and on the finished butter.

3. A steam treatment of 30 minutes, when used daily, left the churn barrel in a reasonably satisfactory condition. A number of low yeast and mold counts were obtained on the finished butter when a boiling water treatment of 150 gallons was used in a closed churn.

4. The use of chlorine compounds usually resulted in a reduction in the yeast and mold content of butter as compared with the inadequate hot water treatment which had been in routine use, but the counts invariably remained excessive.

5. It was demonstrated that heavy contamination was coming from the workers of the Simplex churn.

6. None of the treatments used—hot water or rinses containing chlorine compounds—was effective on the workers.

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