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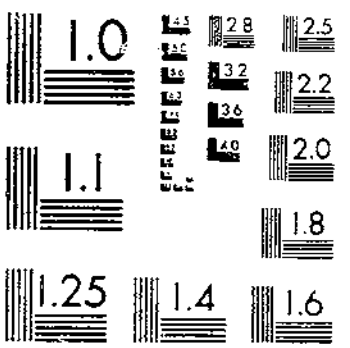

MICROCOPY RESOLUTION TEST CHART
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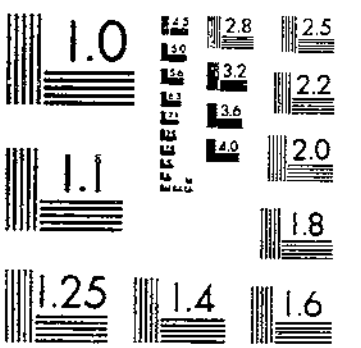

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NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 16 SEPTEMBER, 1927

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

A COMPARISON OF THE TEMPERATURE AND BACTERIAL COUNT OF MILK AND FOAM DURING CERTAIN STAGES OF THE PASTEURIZATION PROCESS

By H. A. WHITTAKER and R. W. ARCHIBALD, *of the Division of Sanitation, Minnesota Department of Health;* C. S. LEETE, *of the Bureau of Dairy Industry, United States Department of Agriculture;* and L. F. MILLER, *of the Department of Physics, University of Minnesota*

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INTRODUCTION

The presence of foam on milk during the Pasteurization process is a condition frequently observed at milk plants. In many plants a considerable quantity of foam develops in the Pasteurizer, particularly at certain seasons of the year, whereas in others the amount at any season is almost negligible. Observations made in routine laboratory control of the Pasteurization process have indicated that in certain cases the presence of foam during the Pasteurization of milk was responsible for high bacterial counts, ropiness, and other difficulties which plants experienced from time to time with Pasteurized milk. The investigation reported in this bulletin was undertaken for the purpose of studying the relation between the temperature and bacterial count of the foam in the Pasteurizer as compared with that of the corresponding Pasteurized milk.

These studies were begun during March, 1926, and were conducted cooperatively by the division of sanitation of the Minnesota Department of Health, the Bureau of Dairy Industry of the United States Department of Agriculture, and the department of physics of the University of Minnesota.

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METHOD OF CONDUCTING STUDIES

The studies were made at commercial milk plants in Minnesota where the batch method of Pasteurization was used. They were carried on during regular hours of work, so that they would be representative of actual commercial conditions. Observations showed that the operation of the various units conformed with that in general practice. In order to compare the effect of certain practices upon the temperature and bacterial count of foam, several changes were made at various times in the routine methods ordinarily followed. The milk used was that regularly delivered to the plants.

Studies made when milk was heated in an apparatus separate from that in which it was held will hereafter in this bulletin be known as studies of preheated milk. The term "vat heated" will be used to refer to milk heated and held in the same vat. In the studies of preheated milk raw milk was brought to the Pasteurizing temperature by means of a tubular heater and then held in insulated or water-jacketed vats of standard makes. In the studies of vat-heated milk cold milk was run in and then heated to the desired temperature by means of either steam or hot water circulated through the coils or in the water jacket.

Temperatures of milk, foam, and air above the foam were observed, and samples of milk and foam were collected for bacteriological examination. Records were kept also of the various methods of operating the vats at the time each sample was collected.

The following procedure was used in the collection of foam samples: Foam was skimmed from the top of the milk with evaporating dishes having handles, and the samples were immediately stirred or agitated with a sterile pipette. This was done to reduce the foam to milk, which in most instances required several minutes. When this had been done samples were taken for bacterial count and butterfat determinations. The bacterial count of the foam, as referred to in this bulletin, is the bacterial count of 1 cubic centimeter of milk that has been reduced from foam.

In order that both foam and milk samples might be as comparable as possible, milk samples were collected in the same manner as foam samples. Bacterial counts were made at the laboratory of the division of sanitation of the Minnesota department of health in accordance with the standard methods of the American Public Health Association.[1] Proper precautions were taken in all instances to reduce the samples promptly to the necessary low temperature and to store them at this temperature until plated. Butterfat determinations were made by the Babcock method.

THERMOCOUPLE USED FOR TEMPERATURE MEASUREMENTS

In order to observe temperatures of the milk, foam, and air above the foam, some method was required that would insure accurate measurements and in no way interfere with the regular procedure followed at the plant in the Pasteurization process. For example, it was observed that opening the covers of the vats during the holding

[1] AMERICAN PUBLIC HEALTH ASSOCIATION AND ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. STANDARD METHODS OF MILK ANALYSIS. BACTERIOLOGICAL AND CHEMICAL. Ed. 4, 40 p., illus. New York City. 1923.

process would immediately change the normal temperature conditions within the vats. Concrete evidence of this was noted by the manner in which foam fell away upon contact with cold air. The mercury thermometer could not well be used in this study because, in addition to its lack of sensitiveness, immersing it at different desired levels involves stem effects. The necessity of wiping off the scale in order to observe the readings involves the time element, which would produce a change in the reading. The heat capacity of the mercury thermometer can not be made small enough to avoid at least enough lag to make the readings uncertain. In addition to these factors, temperatures practically inaccessible to the mercury thermometer were desired at certain points.

After the various available methods of temperature determinations had been considered, the thermocouple with the potentiometer was decided upon as the most desirable instrument for use in this work. A thermocouple specially designed for this study was assembled in the physics laboratory of the University of Minnesota and used throughout all these experiments. This specially assembled instrument showed great flexibility in application and use. The construction and arrangement of the thermocouple and potentiometer were of such a character that repeated calibrations both before the work was undertaken and after its completion showed that the temperature readings were accurate to within 0.2° F.

In a review of the literature, no reference was found on the use of the thermocouple for determining temperatures in studies of the Pasteurization of milk. A thermocouple similar to the one used in these experiments, however, was used in 1921 by the United States Department of Agriculture for temperature studies in ice-cream machines.[2] The one used in the studies covered by this bulletin differed from that used in the ice-cream studies in that it employed a multiple circuit switch to throw in the successive junctions. This switch was necessary because 12 or more junctions were used instead of a single thermocouple. It was necessary also to design a thermocouple end of a somewhat different type in order to keep the heat capacity as low as possible and to make the element take on and follow more closely the various temperature measurements. The low heat capacity of the thermocouple used in this investigation was demonstrated by the fact that temperature gradients in the foam were readily detected.

The following is a brief description of the thermocouple junction or end:

The two wire elements, after being twisted together at the ends and soldered, were inserted in a thin-walled brass tube approximately 6 inches in length. After the junction was adjusted so as to extend about one-sixteenth inch beyond the end of the tube, the tube was pressed down tightly on the junction and soldered. This arrangement rendered the temperature element water-tight and at the same time directly exposed the junction to the medium to be measured. Enameled copper and a special alloyed wire that was particularly qualified for its homogeneity, both of No. 25 B. S. gauge, were used. The homogeneity of the alloy wire contributed largely to the possibility of the method employed, as the various thermocouples duplicated one another in calibration within 0.2° F. The 30-gauge, one-eighth-inch brass tubing was nickel-plated to

[2] ZOLLER, H. F. ROTATING THERMOCOUPLE AND COLD JUNCTION. Ice cream Trade Jour. 17 (8): 40–42, illus. 1921.

protect it against chemical action. From the brass tube the two wires extended into one-eighth-inch heavy rubber tubing that protected them until they were out of the liquid. The rubber tubing was fitted tightly over the end of the brass tube in order to make a water-tight connection. Where the wires passed from the brass to the rubber tubing they were wound with adhesive tape to prevent the enamel from wearing off through usage. As an insulation precaution, the brass tubing was protected by a rubber sleeve where it was clamped to the vertical support in the vat.

Figure 1 [3] shows a general perspective of the equipment arranged to measure the temperature at a number of positions in a Pasteurizing vat, and the figure also shows a detailed drawing of the thermocouple end.

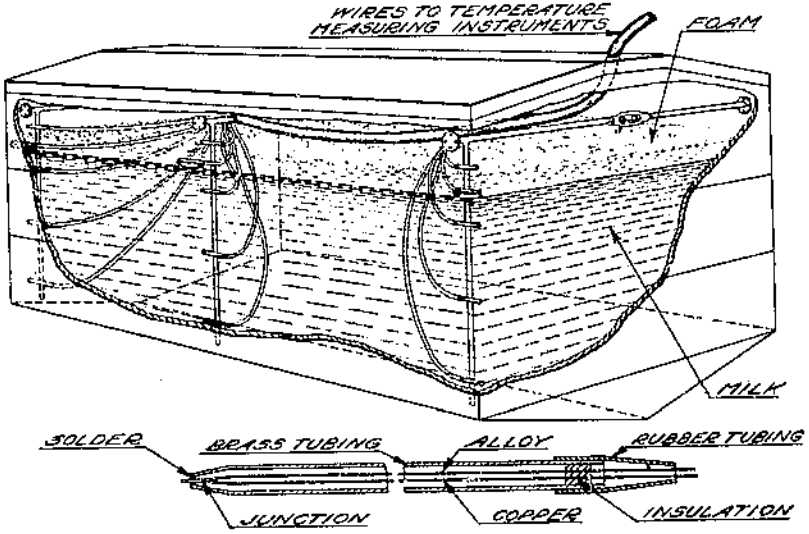

FIG. 1.—Location of the thermocouples in a Pasteurizing vat and a detail of thermocouple end

The following method of observing temperatures was used: Temperatures of the foam, the air above the foam, and the bottom, middle, and top layers of the milk were obtained at the front, middle, and rear of the vat by means of thermocouple junctions placed at these points. The specially designed floats held the thermocouple ends in the foam so that its temperatures could be obtained. Leads from these junctions to the recording instruments were passed through the thermometer opening in the top of the vat. This opening was sealed in order to preclude the entrance of cold air which might affect the Pasteurizing temperature inside the vat. A series of temperature readings of the milk, foam, and air above the foam were taken at various intervals during the run. This was done without opening the covers of the vats and under such conditions that the temperatures were in no way affected. A series of readings was recorded in so short a time as to minimize temperature fluctuations due to the time element.

[3] Drawing by J. A. Childs, Minnesota department of health.

CHARACTER AND AMOUNT OF FOAM

The appearance of foam in the Pasteurizers varied from a white froth which was light and airy, resembling the beaten white of an egg, to a thick, soggy, compact, deep yellow mass. In numerous instances both types of foam, with intervening graduations, were present. The light, airy foam when reduced to milk was approximately in the ratio of 50 parts foam to 1 part milk, whereas the heavy foam reduced from 10 parts foam to 1 part milk. The amount of foam present during Pasteurization varied from a thin layer not over one-half inch in depth to several inches. During some runs the entire area of the vat was covered, and in others only small islands of foam were observed. Gradations within these extremes were common.

OBSERVATIONS OF THE TEMPERATURE OF MILK, FOAM, AND AIR ABOVE THE FOAM DURING HOLDING PERIOD

Observations of 19 separate runs at Pasteurization plants were made with the thermocouple previously described. Altogether 578 temperature readings of the milk, foam, and air above the foam were recorded. Temperature measurements were undertaken whenever possible at the beginning, the middle, and the end of the holding period.

Table 1 shows a summary of the temperatures obtained. The temperatures of the milk, foam, and air above the foam recorded in this table are the averages of the temperatures computed from all the thermocouple readings. In the case of milk the average is usually the average of the temperatures at six to nine junctions located throughout the vat, whereas in the case of the foam and air it is usually the average of the temperatures at three junctions.

TABLE 1.—*Difference in temperatures between milk, foam, and air above the foam during the holding period*

Run No.	Temperature lower than milk during holding (° F.)						Method of heating	Position of cover	Foam		Agitation during holding
	Beginning		Middle		End				Depth	Character	
	Foam	Air	Foam	Air	Foam	Air					
									Inches		
1	1.7	24.7	1.9	23.1	1.7	20.2	Preheated	One end raised 3 inches	3	Light; airy	None.
2	2.9	22.1					do	do	3	do	Do.
3	12.0	21.6					do	Raised 1 minute	3	Medium heavy to soggy	Do.
4	18.1	23.9	14.2	21.4	14.4	20.9	do	Closed	3	Light; airy	Do.
5	12.3		9.0	16.6	9.1	19.5	do	Opened 5 times	4	Light; variable	Do.
6	12.4	19.3					do	Opened momentarily twice	4	Medium to heavy	Do.
7	11.9	23.8	11.2	22.6	14.4	25.0	do	Closed	2½ to 3	Light to heavy	Do.
8	15.2	27.2	15.1	27.8	15.2	26.8	do	One end raised 3 inches	3	Heavy; soggy	Do.
9	7.3	25.3	9.0	24.7			do	Closed	1½ to 4	Light to heavy	Do.
10	11.7	25.6	11.2	24.3			do	do	1 to 4	do	Do.
11	7.2	21.9					Vat heated	do	4 on side	Light to medium	Do.
12	6.2	14.4	6.6	13.9	6.8	13.4	do	do	do	Medium to heavy	Do.
13	9.6	21.3	13.6	19.4	11.6	23.5	do	do	4 in front; 1 in rear	Light	Do.
14	6.7	14.4	4.8	15.4	5.0	12.0	do	do	do	Light to medium	Coils revolved.
15	11.7	22.0	11.0	20.6	11.7	20.2	Preheated	do	3 to 4	Light; airy	Do.
16	5.0	12.2	5.3	10.7	11.9	18.4	do	do	4 front; 1 rear	do	Do.
17	8.7	23.4	2.8	18.3	1.9	15.6	Vat heated	Closed tight	1½ in center	do	Propellor run slowly.
18	15.2	10.3	11.4	6.6	11.7	7.0	do	do	2 to 3 in front and at center	do	None.
19	4.6	10.7	4.2	9.3	5.8	8.2	do	do	2 on half of vat	do	Do.

In Table 1 it will be noted that during the holding period in the 19 runs during which observations were made the depth of foam ranged from 1 to 4 inches, and the character varied from a light, airy froth to a heavy, soggy mass.

It will be observed also that in every instance the temperature of the foam and air above the foam was lower than that of the corresponding milk. At the beginning of the holding period, the minimum variation between the milk and the foam was 1.7° F. and the maximum 18.1°. At the middle of the holding period the minimum variation was 1.9° and the maximum 15.1°. At the end of the holding period the minimum variation was 1.7°, and the maximum was 15.2°. In 84.2 per cent of the measurements made at the beginning of the holding period, the temperature of the foam was 5° or more lower than that of the milk. The same was true of 73.3 per cent of the tests at the middle of the holding period and of 84.6 per cent at the end of the holding period. The temperature of the foam in the majority of instances was so much lower than the corresponding milk that effective Pasteurization of such foam obviously was not accomplished.

The minimum variation between the temperature of the air above the foam at any time during the holding process and the temperature of the milk was 6.6° F. and the maximum 27.8°.

Of 4 complete runs when the milk was agitated during the entire holding period, 2 showed that the temperature of the foam increased during the holding period, 1 that it remained constant, and 1 that it decreased. Of similar studies of 9 complete runs when the milk was not agitated during the holding period, 4 showed that the temperature of the foam decreased, 2 that it remained the same, and 3 that it increased.

Runs were made with the cover of the vat tightly closed by means of clamps, with the cover closed but not fastened, and with the cover at one end of the vat raised approximately 3 inches. The last-mentioned procedure was used regularly at one of the plants supposedly to permit the escape of odors arising with the steam. In the tests made with the cover raised, the average temperature of the foam remained practically constant during the 30-minute holding period. In the runs made with the cover closed but not fastened, the temperature of the foam increased approximately 1° F.; and in those made with the cover fastened tightly, the average temperature of the foam increased approximately 3° during the holding period.

Table 1 also shows that at the beginning of the holding period when the milk was heated in the vat, the average temperature of the foam in the 7 runs was 8.3° F. lower than that of the corresponding milk; whereas in the 12 runs in which the milk was preheated and pumped to the vat, the average temperature of the foam was 10.2° lower than that of the corresponding milk.

COMPARISON OF BACTERIAL COUNT OF MILK AND FOAM

In order to compare the effect of the actual holding time upon the bacterial count of milk and foam, a series of samples was taken at the beginning of the holding period. In the preheated milk and foam the average bacterial count was 37,000 per cubic centimeter for

the milk and 75,000 per cubic centimeter for the foam. In the vat-heated milk and foam the counts were 110,000 and 420,000 respectively. Thus, at the beginning of the holding period in the studies of preheated milk and foam the bacterial count of the foam samples was 102.7 per cent higher than that of the corresponding milk samples, whereas in the studies of vat-heated milk and foam the bacterial count of the foam was 281.3 per cent higher.

Samples taken at the end of the holding period showed that in the studies of preheated milk and foam the average bacterial count of the milk was 16,000 per cubic centimeter and that of the corresponding foam was 130,000 per cubic centimeter. In the studies of vat-heated milk and foam the counts were 13,000 and 76,000, respectively. Thus, at the end of the holding period in the studies of preheated milk and foam the average bacterial count of the foam samples was 712.5 per cent higher than that of the corresponding milk samples, and in the studies of vat-heated milk and foam, 484.6 per cent higher.

The average bacterial count of all samples of foam collected after Pasteurization was considerably higher than that of the corresponding milk samples.

All samples of milk showed a lower bacterial count at the end of the holding period than at the beginning. These reductions in the vat-heated milk were 88.2 per cent and in the preheated milk 56.8 per cent. Very different results were obtained in the foam samples.

In 63 tests of foam, 42, or 66.7 per cent, gave a higher bacterial count at the end of the holding period than at the beginning. The average increase in the bacterial count of these samples during the holding period was 176.3 per cent. The remaining 21 samples of foam showed an average decrease of 65.3 per cent.

It was found that the bacterial count of foam from samples taken at different places in the same vat varied considerably. At the beginning of the holding period the samples of foam collected at various points in the vat varied 356.5 per cent in the preheated milk, and 217.6 per cent in the vat-heated milk. After the holding period the variations in the bacterial count of the foam samples were 166.1 per cent and 49.1 per cent in the preheated and vat-heated milk respectively.

BUTTERFAT CONTENT IN RELATION TO BACTERIAL COUNT

Table 2 shows the butterfat percentage of milk and foam in runs in which the milk was preheated. The foam results show the butterfat prcentage at the beginning and the end of the holding period. The percentage of increase in bacterial count of foam over milk after Pasteurization is also shown in this table. The table is arranged in order of increasing butterfat percentages of the foam after Pasteurization.

TABLE 2.—*Relationship between butterfat content and bacterial count in preheated milk and foam*

Butterfat			Increase in bacterial count of foam as compared with that of milk after Pasteurization	Butterfat			Increase in bacterial count of foam as compared with that of milk after Pasteurization
Milk	Foam before holding	Foam after holding		Milk	Foam before holding	Foam after holding	
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
3.4	3.6	4.1	614.3	3.5	14.6	16.0	23.1
4.0	3.6	4.2	2,871.4	3.6	10.0	18.2	766.0
3.6	4.0	0.2	4,300.0	3.6	19.0	19.2	400.0
3.4	6.2	8.4	157.1	3.6	13.2	20.4	900.1
3.6	8.0	8.6	3,150.0	3.6	18.2	20.4	29.4
3.6	8.2	0.2	2,000.0	3.5	20.0	21.6	170.9
3.5	12.6	14.2	78.6	3.6	21.2	22.4	587.5
3.8	4.0	14.6	1,190.0	3.4	21.4	22.6	1,108.3

It will be noted that the butterfat content of the samples of foam collected at the beginning and at the end of the holding period varied considerably as compared with that of the milk samples. In nearly all the tests the butterfat in the foam was much higher than that in the milk. This table shows also a wide variation in the butterfat content of the samples of foam collected at the beginning of the holding period as compared with those collected at the end. Apparently no correlation existed between the butterfat content and the bacterial count.

Table 3 contains the results of similar studies when the milk and foam were vat heated. A variation in butterfat content similar to that shown in Table 2 will be noted in this method of Pasteurization. Table 3 also shows that the butterfat content and the bacterial count were not correlated.

TABLE 3.—*Relationship between butterfat content and bacterial count in vat-heated milk and foam*

Butterfat			Increase in bacterial count of foam over milk after Pasteurization	Butterfat			Increase in bacterial count of foam over milk after Pasteurization
Milk	Foam before holding	Foam after holding		Milk	Foam before holding	Foam after holding	
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
3.8	1.7	6.0	14.3	4.0	6.0	0.2	1,900.0
3.8	4.0	6.2	2,275.0	3.8	12.0	10.6	216.0
3.6	8.0	8.4	63.6	3.8	8.2	16.6	200.0

AGITATION DURING HOLDING PERIOD IN RELATION TO BACTERIAL COUNT

A comparison of the effect of agitation during the holding time was made with both the preheated and the vat-heated milk and foam. The results are given in Table 4.

TABLE 4.—*Agitation during the holding period in relation to bacterial count*

	Pre-heated milk and foam	Vat-heated milk and foam
	Per cent	*Per cent*
Agitation:		
Reduction in total bacterial count of foam during holding	42.5	95.1
Reduction in total bacterial count of milk during holding	97.2	86.8
No agitation:		
Increase in total bacterial count of foam during holding	61.3	10.5
Reduction in total bacterial count of milk during holding	95.8	99.8

It will be observed that in both methods of Pasteurization the bacterial count of the foam increased when there was no agitation during the holding period. Similar studies when the milk was agitated during this period showed a decrease in the bacterial count of the foam.

POSITION OF COVERS IN RELATION TO BACTERIAL COUNT

Studies were made of the bacterial count of milk and foam Pasteurized in a vat with the cover tightly closed as compared with that Pasteurized in a vat with the cover slightly raised or loosely fitting. Table 5 gives the results of the series of runs.

TABLE 5.—*Position of covers in relation to bacterial count*

	Per cent
Covers down but not tight:	
Increase in bacterial count of foam during holding	100.4
Decrease in bacterial count of milk during holding	72.6
Covers down tight:	
Decrease in bacterial count of foam during holding	94.9
Decrease in bacterial count of milk during holding	91.2

These studies show that in the vats where the covers were not tightly closed or where they were opened slightly, the bacterial count of the foam increased to a marked degree during the holding period. Similar studies with the covers tightly closed showed a perceptible decrease in the bacterial count of the foam. The percentage of decrease in the bacterial count of the milk was considerably higher in runs made when the vat covers were kept tightly closed than in those made when the covers were loose fitting or were kept open slightly.

RELATIONSHIP BETWEEN AMOUNT OF FOAM AND BACTERIAL COUNT

The depth of the foam layer on Pasteurized milk has apparently no great effect upon the total count or the percentage of reduction of the bacterial count of foam. Observations made when the foam layer was 2 inches deep or less showed an increase of 10 per cent in the bacterial count of the foam during the holding process, and in those runs in which the foam layer was 4 or more inches deep the increase was 14.9 per cent.

SUMMARY AND CONCLUSIONS

The studies in this report were made at milk plants that use the batch method of Pasteurization and were undertaken during the regular periods of operation.

The amount of foam observed during the holding period varied in depth from approximately one-half inch to several inches, and in area from small islands to the entire surface of the vat. In the 19 runs where temperature studies were made, the depth of the foam varied from 1 to 4 inches.

Measurements made with the thermocouples showed that the temperature of the foam during the holding period was lower in every case than that of the corresponding milk. At the beginning of the holding period, in 84.2 per cent of the tests the average temperature of the foam was 5° F. or more lower than that of the corresponding milk. The same was true in 73.3 per cent of the tests at the middle of the holding period and in 84.6 per cent of the tests at the end of the holding period.

The temperature of the air above the milk was lower in all cases that that of the corresponding milk. The minimum variation was 6.6° F. and the maximum 27.8°.

The bacterial count of the foam was considerably higher in every instance than that of the corresponding milk at the beginning and at the end of the holding period. Although the bacterial count of the milk decreased during the holding period, 66.7 per cent of the foam samples gave a higher count after holding than before. The average increase in the bacterial count of these samples of foam during the holding period was 176.3 per cent.

At both the beginning and the end of the holding period there was a wide variation in the bacterial count of samples of foam taken at different locations in the same vat.

The depth of the foam layer apparently had no great effect upon the bacterial count of the foam or upon the reduction of bacterial count during the holding period.

The butterfat content of the foam samples varied considerably when compared with that of the corresponding milk samples. In nearly all the tests the foam was higher in butterfat than was the milk. A wide variation was also shown in the butterfat content of samples of foam collected at the beginning and at the end of the holding period. The butterfat percentage was generally higher in the samples taken at the end of the holding period.

Apparently no relation existed between the butterfat content and the bacterial count of the foam.

A reduction was shown in the bacterial count of foam in vats where the cover was tightly closed, whereas in those vats where the covers were open or loose fitting an increase was shown in the bacterial count of the foam.

The average temperature of the foam increased approximately 3° F. during the holding period in vats with the covers tightly closed. No increase in temperature was noted in the vats with the covers raised.

Pasteurization as performed at the plants under observation and during the time the studies were made was not effective in raising the foam to a satisfactory Pasteurizing temperature or in always accomplishing as great a destruction of bacteria in foam as in the milk.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

August 25, 1927

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