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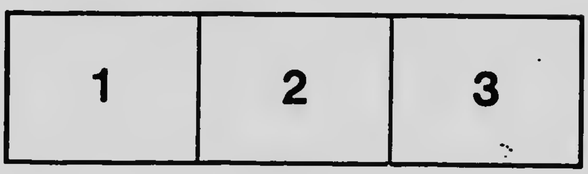
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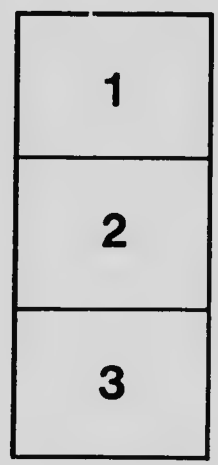
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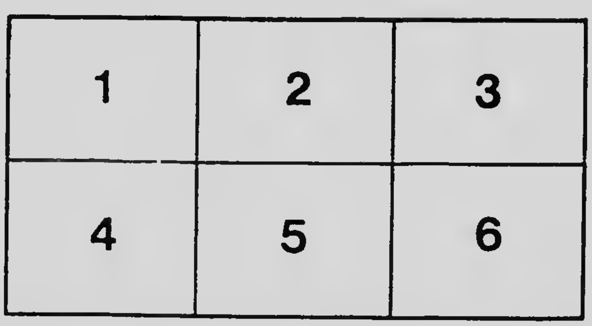
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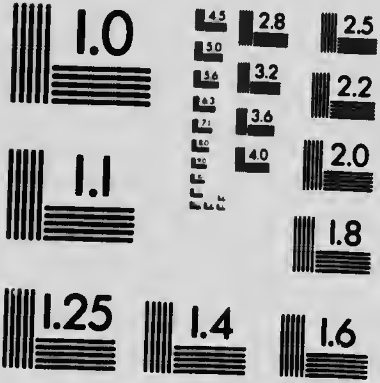


**BULLETIN 117** January 1902



Ontario Agricultural College and Experimental Farm.

# THE CONTINUOUS PASTEURIZATION OF MILK AT DIFFERENT TEMPERATURES FOR BUTTERMAKING.

BY PROF. H. H. DEAN, B.S.A., AND PROF. F. C. HARRISON, B.S.A.

The constant striving of agricultural countries to produce the best articles at the lowest possible cost for the English markets has resulted in very keen competition, and new competitors are constantly entering the field. We have lately heard that Siberia is sending considerable quantities of butter to England, and that special refrigerator trains and steamers have been built in order to handle this product. At present, this butter, although good in texture and make, lacks uniformity and flavor; but these defects will probably be speedily remedied, as the Russians have lately sent experts to Denmark, to study the methods followed in that country, and have even imported skilled dairymen for the purpose of instructing the Siberian peasants. Hence it behooves the Canadian maker to take advantage of every new method which is shown to be of value in producing a first-class article.

As it has been the strenuous endeavor to cheapen production in those countries which make a specialty of dairying, there must be good grounds for their adoption of pasteurization, an operation which increases the cost to a considerable extent in the outlay, both for apparatus and for the production of the heat required in the operation.

That buttermakers should incur this additional expense is very good evidence that pasteurization is an important operation, and that without it there is difficulty in obtaining the best results.

The comparison that has often been made between the farmer and the dairyman, explains the chief reason for pasteurization. The farmer cultivates his land and prepares his soil for the special crops he intends to grow; he eradicates as far as possible all weeds, and he selects with care a good variety of seed, from which he expects to reap as he has sown. The dairyman also prepares his soil, the raw milk, by heating it to such a temperature as will kill all or the greater number of bacteria which may be present, these being his weeds; then he seeds his milk with a selected variety of micro-organism found to produce a good flavor in butter; and he also expects to reap even as he has sown. These two points—first, the preparation of the milk by pasteurizing, and, secondly, the seeding with selected races of bacteria—have enabled all makers to secure the great desideratum, *uniformity of product*, which is of such importance to both producers and consumers

In addition to this uniformity, the butter-maker is incidentally able to drive off certain unpleasant odours that may be present in the milk supplied to him; and the keeping quality of his product is thereby increased, because he has killed the larger number of the harmful bacteria, which, if they had remained living, might have impaired the quality of his butter.

Further, if the right temperature is used, all *disease-producing organisms* are destroyed, including the bacillus tuberculosis, which is very frequently found in butter. This fact alone will add considerably to the comfort and security of the consumer.

The whole problem of pasteurization is a question as to the proper temperature; and unfortunately this is a matter of some complexity.

The effect of temperature on bacteria depends on the degree of heat and the length of exposure,—a low degree of heat and a long exposure being equivalent to a higher temperature and shorter exposure; but the former takes too much time and is not practicable, while the latter is apt to give a cooked taste to the milk. Hence we have two methods of pasteurizing for two different objects, which have been termed the Discontinuous and Continuous systems.

*The Discontinuous System*, or a system of pasteurizing from the milk-dealer's standpoint, requires that all disease-producing bacteria be destroyed, that the milk possess good keeping quality, and that the taste be not injured. In order to obtain these requisites, the milk must be heated in 140 degrees F., be stirred during the process, to prevent the formation of a pellicle, or scum, on the surface; and be held at this temperature for 15 to 20 minutes. This temperature, for this length of time, has been found sufficient to kill the bacillus tuberculosis, the most resistant disease-producing germ found in milk.

*The Continuous System*, or a system of pasteurization from the buttermaker's standpoint, was first introduced by the Danes. By this method, the milk flows in at the bottom of a vessel he[illegible] steam, is whirled against the side, and (having reached the [illegible] temperature) flows continuously from an outlet in the top. T[illegible] is to kill most of the bacteria present in the milk. By a re[illegible]actment in Denmark, this temperature has been fixed at 85 degrees C. (185 degrees, F.,) as Dr. Bang has shown that the tubercle bacillus or bacillus tuberculosis, is killed in milk heated to this temperature. By this means, the buttermaker gets rid of bacteria that might subsequently prove harmful, and prepares the milk for his selected bacteria, or culture, as it is usually called.

In Canada and the United States, the usual pasteurizing temperature is 158 degrees F., (70 degrees C.) to 160 Degrees F., a temperature selected because by the discontinuous system a cooked taste was imparted to the milk at higher temperatures; but, as pointed out by a recent New York Experiment Station bulletin, the American experimenters went astray in their reasoning, "for the cooked taste is the result of an exposure of hot milk to oxygen, and the cooked flavor does not attach itself tenaciously to the fat, and butter made from highly heated milk that may have a cooked taste, immediately after churning loses this objectionable flavour in a short time."

For six years the Dairy Department of the College has been conducting experiments to determine the effects of pasteurization on milk and cream for buttermaking.

To indicate the advancement in methods of pasteurization since 1896 and 1897, we quote from the annual report of the College for those two years :

"Owing to the lack of suitable appliances, most of our pasteurizing experiments were conducted by simply heating the cream contained in an ordinary shot-gun can (set in a hot water bath) to a temperature of 160 degrees. In about 20 minutes afterwards, the cream was cooled to ripening temperature and the "starter" was added."—(1896.)

"It has been suggested that pasteurizing the whole milk *before* separating was preferable to heating the cream and skim-milk *after* separating. A vat of milk was heated to a temperature ranging from 95 degrees to 98 degrees, and half of it was separated. The other half was then heated from 150 degrees to 160 degrees and separated. All the heating was done in a vat having a capacity of about 800 pounds. The chief difficulty was in preventing the milk from cooking on the sides of the vat. By carefully regulating the steam, and by keeping the milk in motion, this trouble was largely prevented."

The experiments instituted at the College Dairy in 1901 were to determine the quality and keeping property of butter made from milk pasteurized at different temperatures. In the Bacteriological Laboratory, our attention was directed to the number and kind of bacteria in the milk before and after pasteurization at the different temperatures employed.

Tests at the Wisconsin Station, with the Reid pasteurizer, at temperatures between 150-165 degrees F. showed considerable variation. The lowest number in the pasteurized sample was 87,400 bacteria per c.c., and the highest 17,500,000 per c.c.,—a very wide difference. The average number left (14 tests) after pasteurizing, was about 1,800,000, or nearly 92 per cent. of the bacteria were destroyed. But this hardly represents the variation in the effect of the heating; for in some cases 40 per cent of the bacteria survived.

The Pennsylvania Station, whilst giving no numerical data, states "that heating to this temperature (155-158 degrees) destroyed few, if any, of the bacteria present in the milk."

The New York Experiment Station have fuller data on this point. At 158 degress F., they found that the pasteurizing action was very uncertain, and that this temperature lies near the lower limit of the killing effect of heat applied in this way ; and, when operating a pasteurizer in ordinary practice, temporary reductions of temperature are almost sure to occur. Hence the killing effect below this temperature is very slight.

Observations by the same station were made at 176 degrees F., and the results of pasteurization at this temperature 'showed a surprising reduction in the germ life, and this reduction was accomplished with very slight variation on each of the 25 days on which the tests were made. These tests gave an average of only 117, with a maximum of 297 and a minimum of 20, living germs per c.c. in the pasteurized milk.'

Seven tests at the temperature used in Denmark, 185 degrees F., gave an average of 115 living germs per c.c.; and, as the writers remark, 'were it not for the fact that in the present state of our knowledge, it is believed that a heating of milk to 185 degrees F. in a continuous pasteurizer, is necessary to remove all danger of tuberculosis, the use of 80 degrees C. (176 degrees F.) in pasteurization for butter-making would leave little to be desired.'"

*The Pasteurizers.*—The pasteurizers used in the experiments here were the "Reid" in March and the first seven days in April, and the "Lister" for the remainder of the season.

The Reid machine is driven with a belt and, in addition to heating the milk, elevates it several feet. The milk is heated by passing over a steam heated surface, and it is kept in a circular motion by means of paddles which revolve in the milk. The weaknesses of the Reid pasteurizer are: The difficulty of maintaining a uniform temperature, and the fact that it requires a firm foundation for the large machine. Its strong point is that it not only pasteurizes the milk, but acts as a milk pump for lifting the milk from the receiving vat to the separator.

The Lister machine is driven with steam directly from the boiler, and is what is commonly called a turbine pasteurizer. It does not elevate the milk above the outlet near the top of the machine, and must be placed above the separator in order to have the milk flow into the separator. The milk for this machine was pumped from the receiving vat directly into the feeding funnel of the pasteurizer; and the temperature of the milk, which was received at a temperature of about 60 degrees, was raised from 125 to 130 degrees while passing through the machine, when fed at the rate of about 2,600 pounds of milk per hour. Milk which was heated above 185 degrees, required a preliminary heating before entering the pasteurizer. The three weak points of the Lister machine are: That it does not elevate the milk, that the centre bearing of the paddles fills with milk if the machine is allowed to get too full, and that the turbine has not at all times sufficient force to keep the milk in constant motion. The strong points of the Lister are that it occupies a small space, no belt is required to run it, and no special foundation is needed.

The Danish Pasteurizer, invented by Fjord, has of late been considerably altered, because the Danes are now compelled to heat the milk to 85 degrees C., and the old form of apparatus is not capable of economically heating the milk to this temperature. The improvements are as follows:

A series of rings are soldered on the heating surface of the pasteurizer. These rings slope downwards, giving the appearance of eaves arranged concentrically around the heater. These rings gather and shed the water formed by condensation of the steam on the heating surface; for this water deposited as a thick layer upon the surface of the heater, is a bad conductor, opposes the resistance, and enfeebles the penetration of the heat to the milk, which is thrown by the agitator against the inner surface of the heater.

The agitator has also been improved by the addition of horizontal plates on the paddle, to prevent the milk from taking too vertical a movement in the pasteurizer; and this improvement helps to give the same temperature to all parts of the milk, and prevents frothing.

A third improvement is an air-cock fixed on the water-trap, which allows the air carried along into the steam jacket to escape.

No doubt the efficiency of the Lister and Reid pasteurizers could be increased considerably by attaching the improvements suggested by Prof. Storch, of the Experimental Laboratory of the Royal Agricultural and Veterinary College of Copenhagen.

Dairy Data.—In our Dairy, the experiments consisted of several series.

*Series I.* In the first, about 3,000 lbs. of milk was mixed in a receiving vat. One-half of several lots was separated at a temperature of about 90 degrees F., and the other half was pasteurized at temperatures of 140, 160, and 185 degrees F.

*Series II.* In this series, 3,000 lbs. of milk was well mixed. One-half of several lots was heated to 140 degrees F. before separating; and the other half was heated to 160, 185, and 195 degrees F.

*Series III.* In this series, one-half of several lots was heated to 160 degrees, and the remainder to 185 degrees.

*Series IV.* In this series, samples of butter made from milk heated to 185 and 195 degrees were compared.

*Series V.* In this lot. one vat of about 3,000 lbs of milk was divided into four parts During April and May, each of these parts was heated to 140, 160, 185, and 195 degrees respectively; but during March, July, and August, the temperatures used were 90, 140, 160, and 185 degrees.

*Series VI.* In the last series, experiments conducted during March an June, vats of milk were divided into two lots. One part was left unpasteurized, and the other was pasteurized at about 160 degrees.

*Boiler Pressure.*—The boiler used for generating steam at the Dairy is a 50 horse-power boiler situated about 50 feet from the pasteurizer. An average pressure of 75 to 80 pounds was maintained as far as possible. When the steam pressure was reduced below 70 pounds, it was difficult to maintain the milk at 185 to 195 degrees, without reducing the feed. It is evident that, if pasteurizing at 185 degrees is practised, a large boiler and steady steam pressure will be required.

During the year nearly 100,000 lbs. of milk were used in the experiments. For April and May milk was received four times a week. The average percentage of fat in the milk of the first four series ranged from 3.64 to 3.69. The temperature of the milk when received was 40 to 60 degrees in March and April. In May it was about 59 degrees, June 60 degrees, July and August 65 degrees. The average acidity in the first four series, when the milk was delivered, was .17 to .18 per cent. The average acidity of the cream at the time the culture for ripening was added, varied from .088 per cent for the lots heated to 160 degrees to .118 for the lots heated to 140 degrees. Those heated to 185 degrees had an average acidity of .114; and those lots of cream from milk heated to 195 degrees before separating had an average of .104 per cent. of acidity at the time the culture was added. At the time of churning, there was very little difference in the acidity of the different lots—being from .5 to .6 per cent.

The percentage of fat in the cream in the first four series varied from an average of 32.7 in the lots separated at 140 degrees to 28.6 in the lots separated at 195 degrees. There was practically no difference in the fat lost in the skim-milk and buttermilk, whether the milk was separated at 140, 160 185, or 195 degrees The skim milk averaged one-tenth of one per cent. fat, and the buttermilk averaged about .15 per cent. fat. The temperature of the cream at the time the culture was added varied from 66 to 68 degrees. The average temperature for ripening the cream was about 65 degrees for all the lots. The average churning temperature was 49 degrees for all lots. The average time required to churn the cream was 41 minutes for the lots separated at 140 degrees, 39 minutes for the lots separated at 160 degrees, 38 minutes for the lots separated at 185 degrees, and 36 minutes for the lots separated at 195 degrees.

The percentage of moisture and salt in the butter were: Unpasteurized, 13.690 per cent. moisture and 2.15 per cent. salt. Pasteurized at 140 degrees, the moisture and salt were, respectively, 13.128 and 2.57 ; at 160 degrees, 13.224 and 2.85 ; at 185 degrees, 13.994 and 2.55 ; at 195 degrees, 13.561 and 2.62. All the butter was salted at the rate of one ounce of salt per pound of butter.

After working, the butter in the first four series was put into pound prints and wrapped in parchment butter paper. One print of each lot was numbered by the buttermaker, when it was placed in cold storage at an average temperature of 40 degrees. The prints were scored by numbers, so that the scorer did not know what kind of butter he was scoring. Nearly all of the butter was scored twice —once when made about two weeks, and again when one month to six weeks old.

## *Scoring of Series I.*

Comparison of butter made from unpasteurized milk with butter made from milk heated to 140, 160, and 185 degrees.

| No. of Samples. | Kind of Butter | Average flavor. Max 45. | Average grain. Max. 25. | Average color. Max. 15. | Average Total. Max. 100. |
|---|---|---|---|---|---|
| 8 | Unpasteurized. | 39.8 | 25 | [illegible] | 94.3 |
| 8 | Pasteurized at 140 degrees. | 41.2 | 25 | [illegible] | 95.7 |
| 8 | Unpasteurized. | 34.9 | 24.5 | [illegible] | 88.8 |
| 8 | Pasteurized at 160 degrees | 37.1 | 25 | 14.1 | 91.2 |
| 6 | Unpasteurized. | 40.3 | 25 | 14.5 | 94.8 |
| 6 | Pasteurized at 185 degrees | 41.5 | 25 | 14.3 | 95.8 |

## *Scoring of Series II.*

Comparison of butter made from milk pasteurized at 140 degrees with butter made from milk heated to 160, 185, and 195 degrees F.

| | | | | | |
|---|---|---|---|---|---|
| 9 | Pasteurized at 140 degrees | 38.9 | 24.8 | 14 | 92.7 |
| 9 | Pasteurized at 160 degrees | 39.9 | 24.9 | 14 | 93.9 |
| 9 | Pasteurized at 140 degrees | 39.6 | 25 | 14 | 93.6 |
| 9 | Pasteurized at 185 degrees | 40.4 | 25 | 14.1 | 94.5 |
| 6 | Pasteurized at 140 degrees | [illegible] | 24.8 | 14.3 | 94.3 |
| 6 | Pasteurized at 195 degrees | [illegible] | 24.8 | 14.3 | 94 |

## *Scoring of Series III.*

Comparison of butter made from milk pasteurized at 170 degrees with butter made from milk pasteurized at 185 degrees F.

| | | | | | |
|---|---|---|---|---|---|
| 10 | Pasteurized at 160 degrees | 40.7 | 25 | 14.2 | 94.8 |
| 10 | Pasteurized at 185 degrees | 41.0 | 25 | 14.1 | 95.1 |

## *Scoring of Series IV.*

Comparison of butter made from milk pasteurized at 186 degrees with butter made from milk pasteurized at 195 degrees F.

| | | | | | |
|---|---|---|---|---|---|
| 7 | Pasteurized at 185 degrees | 41.0 | 25 | 14 | 95 |
| 7 | Pasteurized at 195 degrees | 40.8 | 25 | 14 | 94.8 |

In the fifth series, where vats of 3,000 lbs. milk were divided into four different lots during April, May, July, and August, the average percentage of fat in the milk ranged from 3.7 to 3.8. The per cent. of acidity in the milk delivered was .17, and that of cream at the time of adding culture was .09 ; and at the time of churning it was .55 for the lots heated from 140 degrees to 195 degrees, and .59 for the lots separated at ninety degrees. The percentage of fat in the lots of cream ranged from 27.6 to 32. The percentage of fat in the skim-milk was less than one-tenth of one per cent. for all. The fat in the buttermilk was about .15 per cent. for the pasteurized lots, and .25 for the unpasteurized samples. All the lots had the cultures added at an average temperature of 68 degrees, were ripened at 65 degrees, and were churned at 46 degrees to 47 degrees. The average time required to churn the unpasteurized lots was 47 minutes; the 140 degrees lots, 40 minutes; the 160 degrees lots, 39 minutes; the 185 degrees lots, 37 minutes; and the 195 degrees lots, 42 minutes.

*Scoring of Series V.*

Comparison of butter made from unpasteurized milk and butter made from milk pasteurized at 140 degrees, 160 degrees, 185 degrees, and 195 degrees.

| No. of Samples. | Kind of Butter. | Average flavour. Max. 45. | Average grain. Max. 25 | Average color. Max. 15. | Average Total. Max. 100. |
|---|---|---|---|---|---|
| 2 | Unpasteurized.................... | 39.2 | 25 | 14.2 | 93.4 |
| 4 | Pasteurized at 140 degrees.... | 39.2 | 25 | 14.1 | 93.3 |
| 4 | Pasteurized at 160 degrees....... | 39.6 | 25 | 14.1 | 93.7 |
| 4 | Pasteurized at 185 degrees........ | 41.1 | 25 | 14.4 | 95.5 |
| 1 | Pasteurized at 195 degrees....... | 40.8 | 24.5 | 13.5 | 93.8 |

In the sixth series, during March and June, 26,600 lbs. milk, testing an average of 3.84 per cent. fat, was equally divided: and one-half was separated at about 90 degrees and the other half was pasteurized at 160 degrees. The per cent. of acidity in the milk when received was .155. The acidity of the unpasteurized cream at the time of adding the culture was .154, and that of the pasteurized cream was .131. Both lots had about the same acidity at the time of churning, viz., .5 per cent. The percentages of fat in the cream were 30 per cent. in both cases. The fat in the skim-milk in both cases was less than one-tenth of a per cent., and the buttermilk averaged .15 per cent. fat. Both lots were ripened at the same temperature (64 degrees) and were churned at the same temperature (47 degrees). The average time of churning was 41 minutes for the unpasteurized cream and 37 minutes for the pasteurized cream.

*Scoring of Series VI.*

Comparison of butter made from unpasteurized milk, with butter made from milk pasteurized at 160°.

| No. of Samples. | Kind of Butter. | Average flavor. Max. 45. | Average grain. Max. 25. | Average color. Max. 15. | Average Total. Max. 100. |
|---|---|---|---|---|---|
| 10 | Unpasteurized........................ | 38 0 | 24.8 | 14 4 | 92.90 |
| 10 | Pasteurized at 160 degrees........ | 39.4 | 25 | 14.2 | 93.65 |
| 3 | Unpasteurized, March ....... | 33.3 | 24.3 | 14.3 | 87 |
| 3 | Pasteurized at 160 degrees March. | 35.8 | 25 | 14.2 | 90 |
| 7 | Unpasteurized, June................ | 40 | 25 | 14.4 | 94.4 |
| 7 | Pasteurized at 160 degrees, June.. | 41 | 25 | 14.2 | 96.2 |

The keeping quality of boxed butter from milk pasteurized at different temperatures.

| Date of Making. | Temperature. | Scores for flavor at end of 14 days. | 60 days. | 125 days. | 164 days. |
|---|---|---|---|---|---|
| July 5...... | Unpasteurized.................. | 42 | 36 | 36 | ........ |
| Aug. 5 ..... | " ................... | 43 | 39 | .......... | .......... |
| Apr 24..... | Pasteurized, 140 degrees........ | 42 | 32 | .......... | .......... |
| May 27..... | " 140 " ........ | 43 | 42 | 42 | 40 |
| July 5..... | " 140 " ........ | 41 | 34 | 36 | .......... |
| Aug. 5 ..... | " 140 " ........ | 43 | 38 | .......... | .......... |
| Apr 24..... | " 160 " ..... | 42 | 37 | .......... | .......... |
| May 27..... | " 160 " ........ | 43 | 41 | 40 | 39 |
| July 5...... | " 160 " ....... | 41 | 37 | 35 | .......... |
| Aug. 5 ..... | " 160 " ........ | 42 | 39 | .......... | .......... |
| Apr. 24..... | " 185 " ...... | 43 | 38 | 41 | 41 |
| May 27. .. | " 185 " ........ | 42 | 41 | 40 | .......... |
| July 5 .. | " 185 " ........ | 42 | 41 | .......... | ........ |
| Aug. 5 ..... | " 185 " ..... | 43 | 40 | .......... | .......... |
| May 27..... | " 195 " ........ | 42 | 41 | 39 | 41 |

*Keeping Quality of the Butter.*—Butter for cold storage and for export must possess *keeping quality,* a point which is usually overlooked in judging butter. If we are to compete in the British markets, Canadian butter must overcome the prejudice which exists in England, that it will not "keep."

Our experiments during the past six years all indicate that pasteurization improves the flavor and keeping quality of butter made from winter milk. In summer, when conditions are more favorable for the making of fine-flavored butter, there is not so much difference in the flavor of the butter when first made, whether pasteurized or not. However, when samples are kept for some time—60 to 160 days—there is quite a marked difference in favor of the butter made from pasteurized milk. Our experiments for the past two years also show that the higher temperature of 185° is more favorable in the production of "keeping quality" than the lower temperatures of 140° to 160°.

*Bacteriological Data.*—The culture media used were ordinary lactose agar and whey gelatine. Usually 4 plates from each sample were poured, two of lactose agar and two with whey gelatine. The whey gelatine gave very satisfactory results. It was made from whey, boiled and filtered, to which was added ½ per cent. of peptone, ⅛ per cent. of Heyden's Nutriment (Nährstoff Heyden), and 10 to 12 per cent. of gelatine.

The agar plates were kept at 20 to 30° C. (83 to 86° F.), and the gelatine plates at 20 to 21° C. (68 to 70° F.). Of the two kinds of media, whey gelatine was preferable, as the colonies of the lactic acid bacteria were larger; and the spreading surface colonies on the agar plates made counting rather difficult. But little numerical difference between the plates made from the different media, was noticed.

The samples of unpasteurized milk were taken directly from the receiving vats, after the milk from all the different patrons was thoroughly mixed.

The temperature of the pasteurized milk was taken by a thermometer inserted close to the outlet of the milk from the pasteurizer; and these samples were taken from the outflowing milk in large sterilized test-tubes, and brought to the laboratory, where the analyses were made at once.

*Dilution.*—The sample was thoroughly shaken, and ½ c. c. was added to 10 c. c. of sterilized water, and ½ c. c. of this mixture again added to 10 c. c. water, and a small fraction of this was added to the culture medium, and plates poured. By means of this dilution, the colonies were not too crowded on the plates; so they could be easily counted. With the pasteurized sample no dilution with sterilized water was made, about 1-20 to 1-30 of a c. c. of the pasteurized milk being directly added to the culture medium.

## *Results of Continuous Pasteurization of Milk at 140-146° F. (60-63C.)*

Thirteen tests, percentage of bacteria killed, 96.42.

| Date. | Pasteurizing temperature. | Temperature of milk before pasteurizing. | Acidity. | Unpasteurized. Average No. of germs per c. c. | Pasteurized. Average No. of germs per c.c. |
|---|---|---|---|---|---|
| April 10 | 146 | 54 | .15 | 8,090,000 | 243,600 |
| " 12 | 140 | 52 | .16 | 3,736,000 | 235,000 |
| " 15 | 142 | 54 | .18 | 3,705 000 | 243,500 |
| May 1 | 144 | 58 | .15 | 8,736,000 | 557,000 |
| " 4 | 140 | 58 | .17 | 13,400 000 | 367,000 |
| " 18 | 140 | 61 | .19 | 14,510,000 | 837,000 |
| " 21 | 140 | 61 | .17 | 38,380,000 | 800,000 |
| " 27 | 140 | 58 | .17 | 16,250,000 | 667,000 |
| " 29 | 140 | 60 | .17 | 17,000,000 | 650,000 |
| June 3 | 140 | 60 | .17 | 15 670,000 | 720,000 |
| " 6 | 140 | 58 | .16 | 15,723,000 | 672,000 |
| " 8 | 140 | 60 | .17 | 22,340,000 | 812,000 |
| Aug. 5 | 140 | ........ | ........ | 51,900,000 | 1,400,000 |

## *Results of Continuous Pasteurization of Milk at 160-165° F. (71-74°C.)*

Twenty tests, percentage of bacteria killed, 99.95.

| Date. | Pasteurizing temperature. | Temperature of milk before pasteurizing. | Acidity. | Unpasteurized. Average germs per c.c. | Pasteurized. Average germs per c.c. |
|---|---|---|---|---|---|
| Mar. 29 | 160 | 53 | .15 | 507,600 | 510 |
| April 1 | 160 | 46 | .16 | 1,402,100 | 8,950 |
| " 3 | 164 | 52 | .15 | 288,000 | 510 |
| " 6 | 160 | 54 | .16 | 2,784,000 | 410 |
| " 8 | 160 | 53 | .15 | 7,040,000 | 9,025 |
| " 10 | 160 | 54 | .15 | 8,090,000 | 650 |
| " 17 | 160 | 56 | .19 | 9,090,000 | 2,300 |
| " 19 | 160 | 46 | .17 | 1,820,000 | 93,800 |
| " 29 | 165 | 60 | .21 | 25,100,000 | 11,420 |
| May 1 | 160 | 58 | .15 | 8,736,000 | 23,2[illegible]0 |
| " 15 | 165 | 60 | .19 | 4,050,000 | 15,700 |
| " 16 | 160 | 60 | .18 | 1,511,000 | 16,800 |
| " 18 | 160 | 61 | .19 | 14,510,000 | 13,000 |
| " 23 | 160 | 61 | .17 | 13,275,000 | 7,400 |
| " 27 | 160 | 58 | .17 | 16,250,000 | 12,000 |
| " 28 | 160 | 62 | .15 | 23,400 000 | 6,300 |
| June 3 | 160 | 58 | .16 | 15,670,000 | 4,700 |
| " 5 | 160 | 60 | ........ | 16,274,000 | 11,700 |
| " 7 | 162 | 58 | .16 | 31,113,000 | 8,370 |
| Aug. 5 | 165 | ........ | ........ | 51,900,000 | 10,200 |

*Results of Continuous Pasteurization of Milk at 185° F. (85° C.)*

Fourteen tests, percentage of bacteria killed, 99.99953.

| Date. | Pasteurizing temperature. | Temperature of milk before Pasteurizing. | Acidity. | Unpasteurized. Average No. of germs per c. c. | Pasteurized. Average No. of germs per c. c. |
|---|---|---|---|---|---|
| April 12 ............ | 185° F. | 52 | .16 | 3,736,000 | 80 |
| " 17 ............ | 185 | 56 | .19 | 9,090,000 | 144 |
| " 22 ............ | 185 | 56 | .12 | 2,964,000 | 44 |
| " 29 ............ | 185 | 60 | .21 | 25,100,000 | 30 |
| May 4 ............ | 185 | 58 | .17 | 13,400,000 | 33 |
| " 15 ............ | 185 | 60 | .19 | 4,050,000 | 30 |
| " 22 ............ | 185 | 62 | .17 | 18,500,000 | 112 |
| " 23 ............ | 185 | 61 | .17 | 13,275,000 | 60 |
| " 27 ............ | 185 | 58 | .17 | 16,250,000 | 56 |
| " 28 ............ | 185 | 62 | .15 | 23,400,000 | 200 |
| " 29 ............ | 185 | 60 | .17 | 17,000,000 | 24 |
| " 30 ............ | 185 | 61 | .16 | 14,500,000 | 90 |
| June 4 ............ | 185 | 60 | .16 | 22,110,000 | 117 |
| Aug. 5 ............ | 185 | .......... | ......... | 51,900,000 | 112 |

*Results of Continuous Pasteurization of Milk at 195 to 200° F. (94 to 93° C.)*

Eight tests, percentage of bacteria killed, 99.99968.

| Date. | Pasteurizing temperature. | Temperature of milk before Pasteurizing. | Acidity. | Unpasteurized. Average No. of germs per c. c. | Pasteurized. Average No. of germs per c. c. |
|---|---|---|---|---|---|
| April 15 ............ | 200 | 54 | .18 | 3,705,000 | 16 |
| " 19 ............ | 195 | 46 | .17 | 1,820,000 | 77 |
| " 22 ............ | 195-200 | 56 | .12 | 2,964,000 | 16 |
| May 16 ............ | 195 | 60 | .18 | 1,571,000 | 87 |
| " 21 ............ | 190 | 61 | .17 | 38,380,000 | 96 |
| " 22 ............ | 195 | 62 | .17 | 18,500,000 | 30 |
| " 27 ............ | 195 | 58 | .17 | 16,250,000 | 0 |
| " 30 ............ | 195 | 61 | .16 | 14,500,000 | 0 |

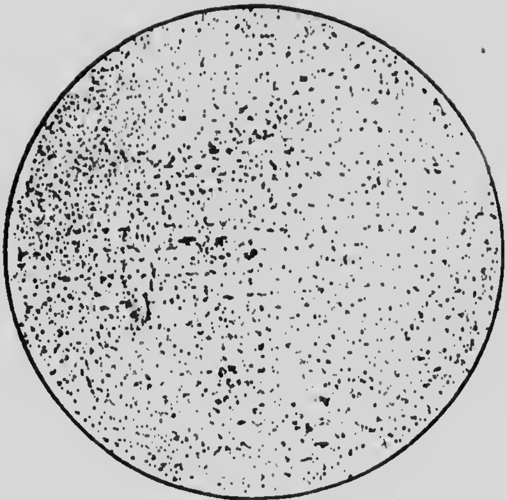
*The Bacteriological Results.*—The milk used in the various pasteurizing experiments may be said to have been of good quality. In only one or two instances did the acidity exceed 0.2 per cent. of lactic acid, an arbitrary standard proposed by Russell, as it was shown by that experimenter that milk having a low percentage of acidity, was, as a rule, freest from spore-producing bacteria; and the standard mentioned (0.2 per cent.) was found to give good results in practice.

A comparison of the acidity with the number of bacteria per c. c. in any of the tables will show, however, that no definite relation exists between the two; as, for instance, the bacterial content in one sample was over 38 millions, and in another two millions, and yet the acidity in both these cases was the same, viz., 0.17 per cent. The explanation of this fact is that large numbers of bacteria were present, which either produced no acid or else but a slight amount. Bacteria belonging to the colon group were often present in large numbers; and these, whilst producing acid, do so to a far less extent than the true lactic acid bacteria.

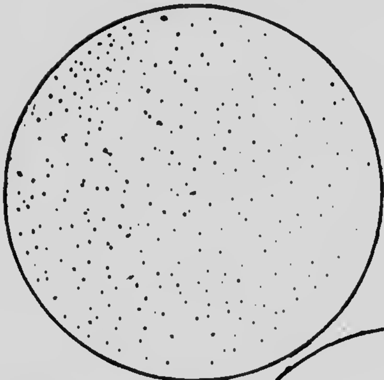
The effect of continuous pasteurization at 140 degrees is undoubtedly efficient, as 96.42 per cent. of the bacteria are killed; but we must remember that the effect of this temperature is just on the border between efficiency and non-efficiency. In practice there is apt to be a lowering of the temperature from time to time, perhaps due to lessened steam pressure, too great an inflow of milk, or other causes; and when this happens, there is a great loss of efficiency, and the number of bacteria which escape destruction is greatly increased

Unfortunately, too, the desirable lactic acid bacteria necessary for buttermaking are the first to succumb; and the undesirable bacteria, hardier and more resistant to adverse influences, are either not affected or only to a slight degree by this temperature; and if left, even in moderate numbers, they rapidly increase when the cream is placed in the ripening vat, and may give rise to "off flavors." A glance at the accompanying diagram (I.) will show the large number of bacteria which remain living after continuous pasteurization at 140 degrees—too many which are as a rule undesirable for the best results.

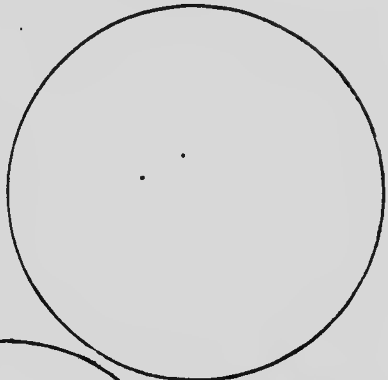
At 185 degrees, however, the results are much better (diagram III.), probably all bacteria except those forming spores being killed. We must also remember that this temperature has been shown by Prof. Bang of Copenhagen to be sufficient to kill the t[illegible]cle bacillus (*bacillus tuberculosis*) thus removing a source of dang[illegible] man and animals.



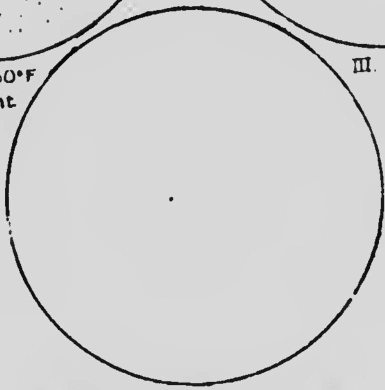
I. Pasteurised at 140° F.
15,776 Bacteria per cubic centimetre (16 drops)



II. Pasteurised at 160°F
321 Bacteria per cu.cent.



III. Pasteurised at 185° F.
2. Bacteria per cu. cent



IV Pasteurised at 195° F.
1 Bacterium per. cu. cent.

## Summary.

1. Milk, as ordinarily delivered at a creamery, may be successfully pasteurized. The milk used in these experiments was largely furnished by patrons who had but ordinary facilities for taking care of it. In the winter, we receive our milk but three times a week ; in summer it is delivered daily.

2. On but two occasions was the acidity of the milk over .2 per cent. The acidity averaged about .17 per cent. There is danger of the milk coagulating when heated, if it contains more than .2 per cent. of acidity.

3. It was noticed that the lots heated from 185 degrees to 195 degrees produced more foam than those heated to the lower temperatures of 140 degrees to 160 degrees. This was most noticeable in the samples heated to 195 degrees. At 185 degrees, the foam was not sufficient to cause much trouble in handling.

4. By cooling the skim-milk with water to a temperature of about 65 degrees immediately after it comes from the separator, we were able to return it to the patrons in excellent condition for feeding, even in hot weather.

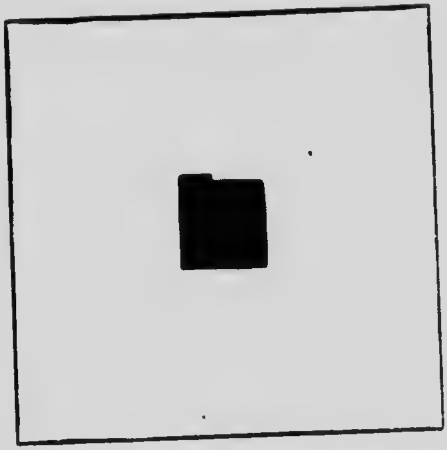
5. The use of 10 to 15 per cent, of culture in the pasteurized cream enabled us to ripen the cream without any difficulty. The culture used was a lactic acid bacillus.

6. Pasteurization of milk at 185 degrees and the use of a pure culture is the best method of securing uniformity, keeping quality, and the mild flavor requisite for export butter.

7. The cooked flavor, which was present in the butter made from milk heated from 185 degrees to 195 degrees, usually disappeared at the end of about two weeks. In one or two lots, heated to 195 degrees, the cooked flavor remained for some time. There is apparently no danger of cooked flavors on butter made from milk pasteurized at 185 degrees, at the end of two weeks, or by the time it would reach the British Markets.

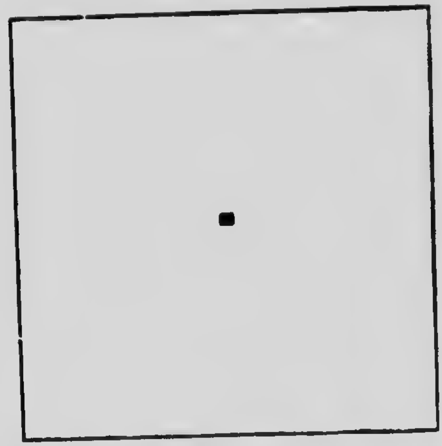
8. The species of bacteria present in the milk when the animals were kept in the stable, were very undesirable. Many putrefactive and fecal bacteria were present, hence the necessity of keeping the stable walls and rafters well cleaned. A good coat of whitewash increases the amount of light, and gives a general clean effect to the stables

9. The average number of bacteria per c.c. (16 drops) found in milk pasteurized at 140 degrees F. was 631,046, at 160 degrees F. was 12,848, at 185 degrees F. was 81, and at 195 degrees F. was 40. (See diagrams).



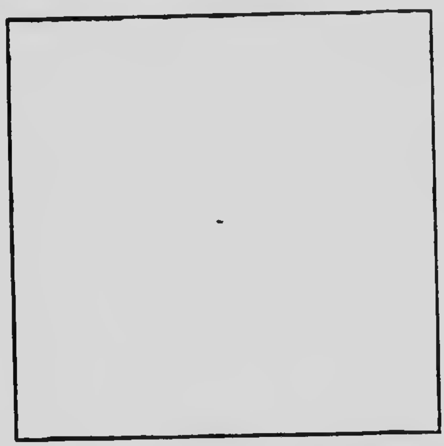
*The effect of the continuous pasteurization of milk at 140° to 146° F.*

The white square represents the bacterial content of raw milk—average of thirteen days in April, May, June and August. The black space represents the bacterial content of the same samples after continuous pasteurization at 140° to 146° F.



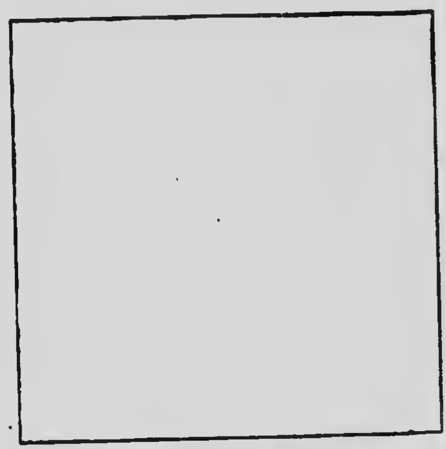
*The effect of the continuous pasteurization of milk at 160° to 165° F. (71°-74° C.).*

The white square represents the bacterial content of raw milk—average of twenty days in March, April, May, June and August. The black space represents the bacterial content of the same samples after continuous pasteurization at 160°-165° F.



*The effect of the continuous pasteurization of milk at 185° F. (85° C.).*

The white square represents the bacterial content of raw milk—average of fourteen days in April, May, June and August. The black slit represents the bacterial content of the same sample after pasteurization at 185° F.



*The effect of the continuous pasteurization of milk at 195° to 200° (F. 91°-93° C.)*

The white square represents the bacterial content of raw milk—average of eight days in April and May. The black spot represents the bacterial content of the same samples after continuous pasteurization at 190° to 200° F.