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THE EFFICIENCY OF A CONTINUOUS PASTEURIZER AT DIFFERENT TEMPERATURES.

H. A. HARDING AND L. A. ROGERS.

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THE EFFICIENCY OF A CONTINUOUS PASTEURIZER AT DIFFERENT TEMPERATURES.

H. A. HARDING AND L. A. ROGERS.

SUMMARY.

These tests were made by passing mixed whole milk through a Danish continuous pasteurizer. At 70°C. (158°F.) the efficiency of the continuous pasteurizer varies greatly from day to day. Tests upon 14 different days gave an average of 15288 living germs per cubic centimeter left in the pasteurized milk with a maximum of 62790 and a minimum of 120 germs.

At 80°C. (176°F.) the reduction in germ content is both very uniform and very great. Tests upon 25 different days gave an average of only 117 living germs per cubic centimeter in the pasteurized milk with a maximum of 297 and a minimum of 20 germs.

At 85°C. (185°F.) the average reduction is not more marked than at 80°C. but the range of variation is less. This temperature has the added advantage, according to Dr. Bang, of removing the danger from germs of tuberculosis in the milk.

Even when the whole milk was heated to 85°C. the butter did not have a permanent cooked flavor.

INTRODUCTION.

An inquiry into the laws which underlie any of the complex commercial processes will progress slowly if each step is determined with a thoroughness that allows of safe generalization from the data obtained.

In order that the reader may see the relation of this piece of work to the problem that is being studied let the following facts be borne in mind.

THE DANISH SITUATION.

Dairying is one of the principal industries of Denmark and during the past two decades the government has fostered it both by the equipment of experts to study its problems and by protective legislation.

In 1890 Dr. Storch announced that by changing the kind of bacteria that grow in ripening cream he was able to change the flavor of the butter.

Dr. Bang, after studying the conditions under which tuberculosis was distributed among cattle, perfected a system of separating the diseased animals from the healthy ones and gradually replacing the former. In carrying out his plan the feeding of calves upon the skim milk brought from the creamery was found to be a source of danger, but this could be removed by heating the milk momentarily to 85°C. (185°F.).

As the result of these and other investigations there has spread over Denmark a peculiar method of making butter—a method so successful that to-day Danish butter is a standard of excellence wherever it is known.

Cleanliness in all details and an intelligent appreciation of the relation of bacteria to butter-making are wide spread, but the keynote of their system is preparation of the starter itself and of the cream to receive the starter.

By a starter they rarely mean the mixture of bacteria, desirable and undesirable, which commonly receives that title in New York. They mean a mixture of known kinds, each of which has been found desirable in itself. This united action of several species gives a better flavor to the butter than could be obtained from any single species.

This mixture of germs when received from a laboratory is introduced into milk that has been first heated to near the boiling point for 2 hours to kill other bacteria and then cooled below blood heat. This starter is propagated from day to day with so much care that at the end of four to six weeks when it is finally rejected for a new one the usual fault with it is merely a too sharp flavor of acid.

The preparation of the cream begins with cleanliness in the barn. Either the whole milk or the cream after separation is heated to free it of objectionable forms before receiving the starter. This heating is only momentary and various temperatures are advocated—those from 70°C. (158°F.) to 95°C. (203°F.) having been used. After heating, the cream is quickly and thoroughly cooled. Formerly, cream was heated after separation both for economy and because of less opportunity for after contamination.

A knowledge of the increase in feeding value produced by prolonging the period of sweetness and, later, a desire to prevent the spread of tuberculosis among their calves caused the skim milk to be heated above 85°C. (185°F.). Since it has been found that the capacity of the separator is increased by skimming at high temperatures and that whole milk can be heated to 90°C. (194°F.) without injury to the flavor of the butter, there is a tendency toward a single heating of the whole milk.

The points of excellence claimed for the Danish product are uniformly good quality and the property of holding its flavor for long periods.

THE AMERICAN SITUATION.

Butter is now selling at from 14 to 28 cents per pound with less than 15 per ct. of the product bringing the latter price. The quality of the best butter is above reproach but the lamentable thing is the lack of quantity of such butter. So great is this lack that during at least a portion of the year it is impossible to buy first class butter in many of the moderate sized cities in this, the greatest dairy State in the Union.

These facts show that there is abundant room for improvement and anything that will raise the average quality of the product will be gladly welcomed both by the diaryman and the consumer.

After the Danish success became an established fact Americans attempted to copy their methods but thus far the results have not been up to expectations. Tests carried on by the Agricultural Experiment Stations of Wisconsin and Pennsylvania as well as by the Department of Agriculture at Washington failed to show that there is any financial gain to be derived from the process when practiced as usually recommended.

Believing that the above failures are due to some of the modifications that the system has undergone in being brought from Denmark to America this Station has undertaken to follow the process step by step hoping to find the proper American conditions under which we can not only make a more uniform product but one that will be sufficiently improved to justify the additional expense in preparation.

The solution of this problem calls for the co-operation of a number of the departments of the Station and will require considerable time, hence it is proposed to issue the results in a series of bulletins of which this is the first. While the Bacteriological Department assumes the responsibility for the statements contained in this bulletin, much credit is due our Dairy Expert, Mr. Geo. A. Smith, whose wide experience in dairy matters has materially contributed to the success of the practical side of the work.

WHAT IS MEANT BY PASTEURIZATION.

As long ago as 1782, a Sweedish chemist, Scheele,[1] found that after immersing bottles of vinegar in boiling water for a time the vinegar would not become turbid or spoiled as long as it was kept carefully closed.

Early in the 19th Century Appert[2] applied this idea of heating inclosed fluids to prevent fermentative changes to the preser-

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[1] Hansen, Emil Chr. Practical Studies in Fermentation, p. 158.

[2] loc. cit., p. 159.

vation of fruits, vegetables, soups, milk, fruit juices, wine and beer.

A half century later Pasteur turned this knowledge of the effect of heat in delaying fermentation to practical account in combating some of the undesirable fermentations of wine and beer, with such success that the process has been called Pasteurization in his honor. Our present methods of canning fruit and vegetables are probably the result of the early discoveries. The application of heat in this way had become such a household matter by the time the process received this special title that the name was not carried over to the ordinary household heating and a can labeled "Pasteurized Peaches" would to-day be quite a puzzle although from its manner of preparation it can justly claim that title.

Pasteurization, then, is simply the application of heat to check the activity of fermentation. The temperature used depends upon the substance treated and the end to be attained. The effect upon germ life will vary both with the degree of heat and the length of exposure. The same results can be secured in the killing of *Bacillus tuberculosis* when the milk is heated at 60° C. (140° F.) for 30 minutes or at 85° C. (185° F.) for a very short time.

PASTEURIZATION CONFUSED WITH STERILIZATION.

Sterilization is a good word that has been debased by popular usage. In its true sense it means the total destruction of life. It is often used to mean anything from a simple warming to a thorough boiling. Such words are best used in their true sense or not used at all. It should be remembered that some of the organisms which are often found in milk will successfully withstand boiling for some hours and the sterilization, in the true sense, of any commercial quantity of milk at a single heating is a practical impossibility unless temperatures above that of boiling water are used.

THE TWOFOLD APPLICATION OF PASTEURIZATION TO MILK.

The subject of the pasteurization of milk has been presented to the American public with reference to two distinct problems —the sanitary milk supply of cities and the production of uniformly good butter.

While heat is applied in both cases the methods of application which have been found most successful in each are radically different and an attempt to accomplish either object by the other process has not yet been shown to be practical. The first method is too slow and expensive to be adapted to butter making and the second plan when carried on at a temperature sufficiently high to kill the tubercle bacillus gives an objectionable flavor to the milk. Fortunately this flavor does not remain in the butter.

THE DISCONTINUOUS OR HOUSEHOLD SYSTEM.

About ten years ago when the use of tuberculin was bringing home the alarming prevalence of tuberculosis among our dairy cows and the danger of transmission of the disease to invalids and children through milk seemed self-evident, pasteurization was brought forward as a safeguard from this danger. In this method the milk was heated at a definite temperature for a definite length of time.

At first 67.3°C. (155°F.) for 20 minutes was advocated but owing to the change brought about in the viscosity of the milk and cream by exposure to this temperature, heating to 60°C. (140°F.) for 30 minutes is now coming more into favor. According to the researches of Dr. Theobald Smith,[2a] 15-20 minutes at 60°C. (140°F.) is sufficient to kill the tubercle bacillus provided the milk is kept stirred so as to prevent the formation of a pellicle at the surface. Higher temperatures and a shorter time would give the same result but when the temperature of 70°C. (158°F.) is passed the milk takes on a disagreeable, cooked taste. This is largely due to an oxidation of some of the components of the hot milk and

[2a]Journal of Experimental Medicine, **4**:217–233. (1899).

it is possible that in the future a way may be found of avoiding this flavor.

The main feature in the discontinuous process is the removal of the danger from disease and this applies not only to tuberculosis but to all other germ troubles which are liable to gain access to the milk before it is heated. The keeping quality of the milk is much improved, especially if proper attention is given to keeping it cool after treatment and the effect of the carelessness and lack of cleanliness which are often prevalent at the barn is in a measure removed. A very commendable practice exists of passing the milk through a separator and remixing the milk and cream before pasteurization. This removes a large part of the hair, excrement, etc., which is so common in the ordinary milk supply of cities.

This method of handling milk for immediate consumption is in successful operation in a number of cities on a large scale. It has much to commend it and when done in a large way it does not increase the cost of production more than a small fraction of a cent a quart.

THE CONTINUOUS OR DANISH SYSTEM.

When the Danish system of butter making was introduced into America pasteurization came as a necessary part of it but in this case the principal object was the fitting of the cream to receive the starter of selected bacteria so that the desired flavor might be always obtained.

The problem that presents itself is not different from that which confronts every farmer who attempts to grow a field of oats. If he sows his seed upon land already filled with rapidly glowing clover, Canada thistles and ragweed his chances of a good oat crop are poor. If he first fits his land and kills off the other plants the oats will have a better chance. To make a success of this it is not necessary to kill off every weed in the field for if the oats are much in the majority and get the start of the others they will control the situation and suppress the weeds.

The bacteria are plants of more simple form than those in the above illustration but they obey the same laws of competition in growth. If conditions are so arranged that the starter when added to the cream finds the same filled with rapidly growing enemies, the effect of the starter will be largely or wholly lost; while if it is added to cream from which all or nearly all of its competitors have been removed, the starter will assume control of the situation and suppress its enemies.

In the Danish machine the milk is introduced at one end of a cylinder surrounded by steam and flows continuously from the other end having been momentarily heated to the temperature desired.

The temperatures used have had an upward tendency and since Dr. Bang announced that, when working with tuberculous cows furnishing the disease germs in their milk, the milk was rendered harmless when passed through one of these machines at 85° C. (185° F.), this has been taken as the Danish minimum legal temperature for heating all the by-products that are to be returned to the farm for feeding purposes.

In a country where the most determined effort is being made to stop the spread of tuberculosis among cattle the value of this protection to a dairyman who has succeeded in freeing his own herd from the contagion but yet is compelled to raise his calves upon mixed milk brought from the creamery, should not be overlooked.

In this as in their other acts regarding the suppression of tuberculosis the Danes have shown a laudable moderation and consideration of the rights of all concerned. The legal enactment as to the temperature to be used was not made until the pasteurizing process had been voluntarily adopted and the necessary machinery installed in practically every creamery in the country.

The American promoters of the Danish method, knowing from their previous experiences with the other form of pasteurization that a heating above 70° C. (158° F.) produces a disagreeable flavor in the milk, were either not willing to trust the practical experience of the Danes or hopelessly confused the two problems and recommended 67.3° C. (155° F.) to the American experimenters when the Danish practice is to employ a temperature at least 12.7° C. (25° F.) higher.

The points in which their reasoning went astray were two: First, the cooked taste in milk, at least for the most part, is not a matter of absolute temperature at which the milk is heated but rather the result of an exposure of hot milk to oxygen. Milk that has been highly heated in a Danish pasteurizer and immediately and thoroughly cooled, as is their practice, has surprisingly little of the cooked taste. Second, the cooked flavor does not attach itself tenaciously to the fat of which the butter is almost exclusively prepared and butter made from highly heated milk that may have a slightly cooked taste immediately after churning looses this objectionable flavor in a very short time.

Believing that a failure to properly heat the milk might be a factor in the lack of success of past American experiments our investigations began with this point.

THE PROBLEM STUDIED.

The objective point was to determine the effect upon the germ-life when milk was passed through a continuous pasteurizer at different temperatures. So far as data were at hand this had been done but twice in America. Both of these tests had been carried out at about 70° C. (158° F.) and the trials were too few in number and the results too contradictory to form a safe basis for generalization.

At the Wisconsin Station [3] it was found that, while there was considerable variation in the effect of a heating of 67.3°–74° C. (155°–165° F.), in some cases as many as 40 per ct. of the bacteria survived and in the tests published this number remaining amounted to over 2,000,000 germs per cubic centimeter.

A different kind of continuous machine was used at the Pennsylvania Station [4] and no numerical results were given but it was stated that "Heating to this temperature 67.3°–70° C. (155°–158° F), for this length of time, as was found by culture plates, destroyed few if any of the bacteria present in the milk."

Since 70° C. (158° F.) is the lowest temperature which is generally recommended for continuous pasteurizing this was taken as a starting point in our work and when the effect of this temperature had been observed higher degrees were used.

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[3] Pasteurization as Applied to Butter Making, Wis. Agr. Exp. Sta. Bul. 69.
[4] Heated Milk for Butter Making, Penn. Agr. Exp. Sta. Bul. 45.

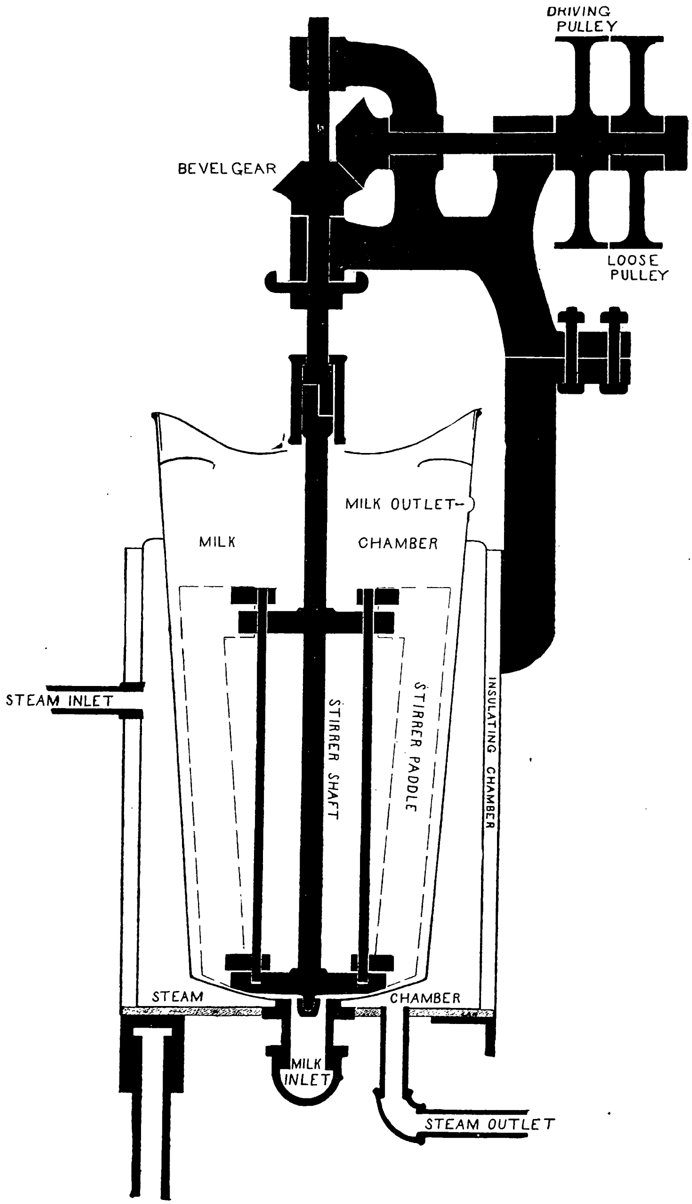

FIG. 1.—VERTICAL SECTION OF CONTINUOUS PASTEURIZER.

MACHINE USED.

We are indebted to D. H. Burrell & Co., Little Falls, N. Y., for the loan of a continuous pasteurizer made by Konstantin Hansen & Schröder, Kolding, Denmark. This has a rated capacity of 2,500 pounds of milk per hour heated to 70° C. (158° F.).

The accompanying drawing of a cross section (Fig. 1) explains the essential parts of the machine. The milk enters at the bottom into a central milk chamber. Here it is set in motion by the stirrer revolving 300 times per minute, which spreads the milk out in a thin layer against the wall and finally expels it at the tangential milk outlet above. This outlet has a lateral opening for receiving the thermometer. As the milk is spread out in this thin layer it quickly takes up the heat from the steam chamber surrounding it.

The temperature of the milk is controlled by changing either the valve admitting the steam or the valve regulating the milk flow. A slight change in either of these valves produces a quick response in the mercury column of the thermometer. Usually the milk valve was set to admit about all the milk that could be heated to the desired degree and the slight variations in temperature were controlled by changing the steam valve.

METHOD OF WORK.

In the manipulation of the machine at the different temperatures the effort was always made to give it a fair chance to show what could be expected of it when handled in the average creamery at that temperature. Our ability to give it a fair trial increased as we became familiar with the machine and its manipulation.

The first requisite was a method of regulating the flow of milk and steam so that the temperature might be held constant. When received, the machine was provided with a float intended to control the flow of milk automatically. After testing it in a variety of ways for some weeks it was condemned as too clumsy for our purpose and was removed.

As finally arranged a supply tank placed sufficiently high to

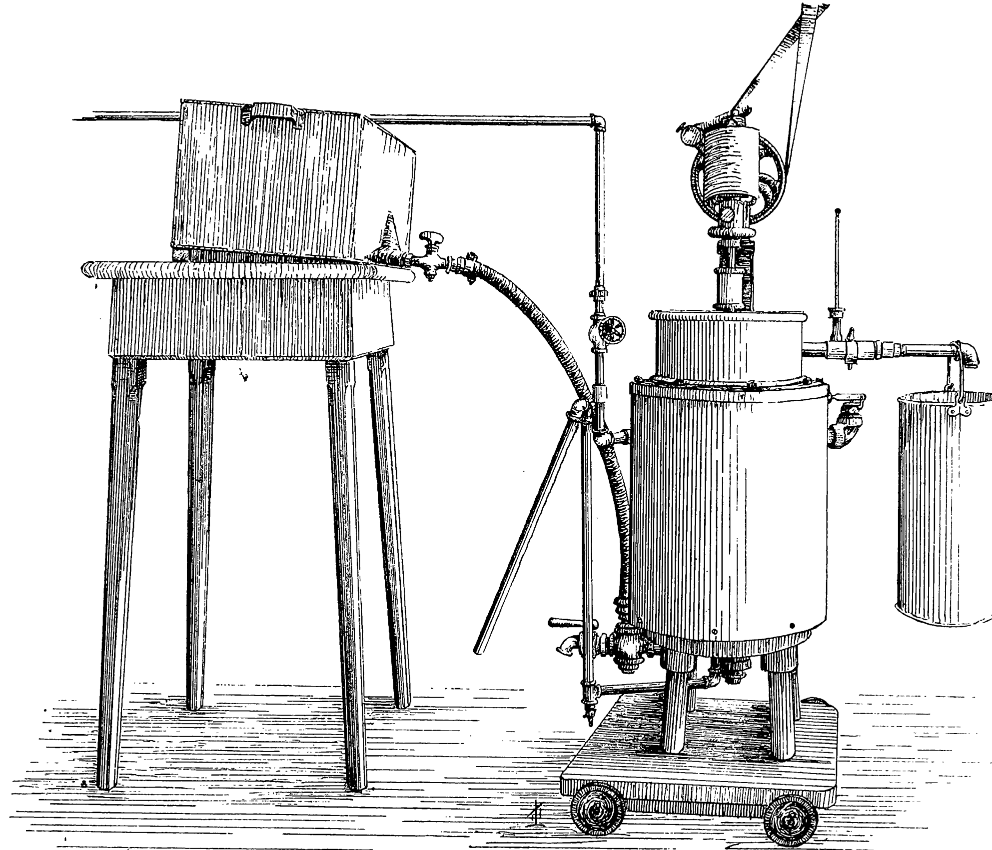

FIG. 2.—ARRANGEMENT OF MILK RECEIVER AND PASTEURIZER.

give a good fall was connected directly with the base of the pasteurizer and the flow regulated by a hand valve. This brought the milk and the steam valves near together where one man could reach both and still watch the thermometer. The maximum variation, which rarely exceeded 10°C., usually occurred at the beginning of the process before the valves were properly adjusted. This having been accomplished the desired temperature could be maintained with very little variation.

In order to make the control of the temperature as well as the collection of the desired data more accurate the milk was thoroughly mixed in a tempering vat before starting the machine. The arrangement of the apparatus will be better understood by referring to Fig. 2.

DATA COLLECTED.

In the Dairy the interest centered upon the temperature used and in the Laboratory upon the numerical content of germs in the milk before and after heating. A large amount of data was collected in both places bearing upon a number of points. Notes were taken upon the age, weight, initial temperature and acidity of the milk, the steam pressure in the boiler, the rate of the pasteurization and the maximum, minimum and pasteurizing temperature employed.

Age.—With age there is an increased growth of bacteria and a larger number of spores present. This is what makes the successful pasteurization of milk over 24 hours old so difficult. During a large part of the time the mixed milk was made up of portions 4, 12, 24 and 36 hours old.

Weight.—This varied considerably but averaged 350 lbs. As the machine while in operation contained only about five pounds of milk and all that was really necessary was to hold the temperature at the desired point at the time of taking the sample this was quite enough for our purpose.

Initial temperature.—The temperature of the mixed milk was noted in the tempering vat. For the most part our milk was brought to about 26°C. (78.8°F.) as being a high average temperature for summer conditions. As received ordinarily in creameries in this State milk varies from near the freezing point in winter to 35°C. (95°F.) in rare cases in summer.

The temperature of the milk as it enters the pasteurizer exerts an influence upon the amount that the machine can heat to a desired degree.

Acidity.—As the result of experience in the pasteurization of milk by the discontinuous method it has been found impractical to attempt to pasteurize milk intended for immediate consumption when the acidity is over 0.2 per ct. calculated as lactic acid. During a considerable portion of the time our mixed milk has had an acidity above this figure.

The custom of expressing acidity in milk by percentages of lactic acid has little to recommend it other than that it is common practice. It is a well known fact that a part of the reaction called acidity is due to the union of the alkali with the casein and that lactic acid is only one of a number of acids found in milk.

The fact always determined is the neutralization as indicated by phenolphthalin of a certain amount of normal solution of alkali. In our results this observed fact is expressed by the number of cubic centimeters of normal alkali neutralized by a litre of milk ($^{N}/_{L}$). For convenience of comparison the per ct. of lactic acid erroneously assumed from this data is given in parenthesis.

The acidity of our mixed milk ranged from 18.9 $^{N}/_{L}$ (0.17 per ct.) to 40 $^{N}/_{L}$ (0.36 per ct.) and during a considerable portion of the time it was above 22.2 $^{N}/_{L}$ (0.2 per ct.). Thus the conditions of acidity under which the pasteurizing was done were not what would be considered ideal but rather those which would be found in an average creamery. As the acidity of the mixed milk approached 40 $^{N}/_{L}$ (0.36 per ct.) a considerable layer burned fast to the sides of the milk chamber in the pasteurizer and the accumulation in the separator bowl was increased.

On Feb. 7 the milk with an acidity of 35.5 $^{N}/_{L}$ (0.32 per ct.) was pasteurized at 85°C. (185°F.) very successfully; but the next attempt with whole milk having an acidity of 40 $^{N}/_{L}$ (0.36 per ct.) quickly accumulated a layer on the walls of the pasteurizer and clogged the separator bowl after passing only about 80 pounds of milk.

Steam pressure.—The pasteurizer was connected by a ¾ inch pipe directly to the high pressure steam pipe. As will be noticed in the diagram (Fig. 1) the steam had a free outlet at a point nearly opposite to the inlet so that there was at no time any appreciable pressure on the pasteurizer itself. On the contrary the steam was nearly all condensed and there was rarely any waste even when the steam valve was opened to its full capacity.

The steam pressure given in the tables is that in the 30 horse power boiler and was noted as one of the possible factors in the great variation in rate of operation on different days.

Rate.—The amount of milk which a pasteurizer will heat to a given temperature in a given time is important from the practical standpoint.

In order to minimize the variation in temperature to which the milk was exposed and to determine the rate more accurately it was our custom to add water to the supply tank and when everything was running at full speed and the last of the water was leaving the tank to add the milk and note the time. After all of the milk had been added and just as the last was leaving the tank the time was again noted. The interval was taken as the time required to handle the milk. Since the amount of milk at any one time between the milk valve and the milk outlet was only about 5 pounds, the error was not great.

As one would expect, the rate varies with the pasteurizing temperature. The machine was expected to handle 2,500 pounds an hour at 70°C. (158°F.) and would do even more under favorable conditions. In our experience it did not much exceed 2,100 at 80°C. (176°F.) and handled less at 85°C. (185°F.). It will be noticed that the rate at 80°C. ranged from as low as 900 to a little over 2,100 pounds per hour. This extreme variation is due to a number of factors, among which are variations in steam pressure and initial temperature and the cooking of the milk on to the walls of the pasteurizer. This layer of cooked material not only acted as an insulator between the milk and the source of heat but also encroached upon the interval between the revolving stirrer paddles and the wall, forming a rough surface along which the milk must pass. The fact that the machine was not permanently placed and lacked in rigidity was also a contributing factor to the above variations.

Pasteurizing temperature.—As soon as the milk enters the bottom of the machine it takes up heat from the steam jacket and its temperature rises to the highest point just as it reaches the milk outlet. The temperature at this point is measured by a thermometer inserted in the outlet and constitutes the so-called "Pasteurizing Temperature" although the milk really attained this degree only momentarily. As soon as the milk passes from the machine the temperature falls with a rapidity depending upon the surroundings.

TAKING SAMPLES.

The samples of unpasteurized milk were taken from the tempering vat after the milk had been thoroughly mixed. The only exception to this was during the earlier part of the work when they were taken from the supply tank just before taking the samples of pasteurized milk from the machine.

The samples of pasteurized milk were taken from the milk outlet after sufficient had passed to remove the effect of the bacteria contained in the water used in starting the machine and in the machine itself. Care was taken to secure samples while the machine was running steadily at the desired temperature.

The samples of about 150 cubic centimeters each in sterile flasks were set into a room at 1.5° to 4.5°C. (35°–40°F.) until the pasteurization was ended when they were taken to the laboratory on the floor above and the quantitative analyses made.

BACTERIOLOGICAL TESTS.

Method of dilution.—One c. c. of the unheated milk was added to 9 c. c. of sterile water and the two thoroughly mixed. This process was repeated and a small fraction of a c. c. from the second dilution was added to the culture medium.

Cultures were made in Petri dishes having an internal diameter of 91–92 mm. For the sake of convenience in counting and to prevent the inhibiting effect of closely crowded colonies the aim was to so arrange the dilution that the growth would be about 500 colonies to the plate. In the case of the pasteurized milk no dilution was necessary but a measured fraction of a cubic centmeter was added directly to the nutrient media.

Media used.—The tabulated results given below were all obtained upon lactose agar made neutral to phenolphtalien with sodium hydroxide and containing 2 per ct. lactose and 1.7 per ct. agar. Agar was chosen in preference to gelatin because in some previous work of a similar nature at the Wisconsin Station it was found that agar at 28°C. (81.5°F.) gave higher numerical results than gelatin at room temperature. Among the substances now available there seems to be none that will call out all the individual germs when left at any one temperature.

It is not maintained by the authors that the numbers given below represent the exact number of organisms present either in the pasteurized or unpasteurized milk. All that is hoped for is that they are a close approximation and that having been taken under similar conditions may be found to be directly comparable.

Incubating temperature.—The plates were placed in an incubator at 30°C. (83°F.) and counted at the end of 48 hours. This temperature was believed to be near the optimum for the growth of most of the germs present and the time was thought to give maximum returns with a minimum amount of error. An exposure at higher temperature caused a rapid drying of the plates and one for a longer time did not usually give higher results while the rapid spreading of superficial colonies made the counting uncertain.

Growth at room temperature required so much longer time as to complicate the work and the rapid multiplication of certain proteus forms made an accurate count very difficult.

When plates that had been kept 48 hours at 30°C. were left 3–5 days at 21° C. (70 F.) there was a small average increase on the second count. This indicates that some of the organisms present in the milk did not thrive at the higher temperature.

TABLE I—WORKING CONDITION AND RESULTS OF CONTINUOUS PASTEURIZATION OF MILK AT 70°C.

Date.	Age of milk.	Wt. of milk.	Initial tem.	* Acidity.	Steam pressure on boiler.	Rate. (Lbs. per hour.)	Unpasteurized. Dilution.	Unpasteurized. Colonies on plate.	Unpasteurized. Total germs per c.c.	Pasteurized. Dilution.	Pasteurized. Colonies on plate	Pasteurized. Total germs per c. c.	Average. Unp.	Average. Past.
	Hours.	*Lbs.*	*Dg.C*		*Lbs.*									
Aug. 19						1776	1– 280	121	33,880	1– 8⅓	487	4,058	41,300	4,779
							1– 140	348	48,720	1– 5⅕	1058	5,500		
22						1560	1– 270	294	79,380	1–28	1068	29,904	83,362	23,898
							1– 135	647	87,345	1– 9⅓	1917	17,892		
23						1104	1– 270	96	25,920	1–13½	63	850	28,417	995
							1– 135	229	30,915	1– 6¾	169	1,141		
24						1356	1– 270	147	39,690	1–24	507	12,168	41,512	13,032
							1– 135	321	43,335	1–12	1158	13,896		
25						1434	1– 260	300	78,000	1–24	40	960	78,975	920
							1– 130	615	79,950	1– 8	110	880		
28						2118	1– 250	1,950	487,500	1–26	668	17,368	442,812	17,628
							1– 125	3,185	398,125	1–13	1376	17,888		
29						1872	1– 280	40,977	11,473,560	1–14	4485	62,790	11,473,560	62,790
Sept. 5						2286	1– 250	21,688	5,422,000	1–24	715	17,160	5,422,000	16,878
										1–12	1383	16,596		
12						2508	1–1250	22	27,500	1-62	258	15,996	23,237	15,936
							1– 575	33	18,975	1–42	378	15,876		
26						1266	1– 480	40	19,200	1–26	49	1,274	38,400	1,096
							1– 240	240	57,600	1–17⅓	53	918		
Dec. 30	36–24	367	21	21.5	65–45	2934	1– 300	66	19,800	1–14	21	294	27,900	287
	12–4			(0.193%)			1– 150	240	36,000	1–28	10	280		
Jan. 2	48–36	494	20	20	40–55	1740	1– 383	41	15,708	1–25	2	50	19,814	120
	24–12–4			(0.18 %)			1– 230	104	23,920	1– 5	38	190		
Feb. 2	36	364	25	25	60–60	2424	1–4200	124	520,800	1– 5	3250	16,250	637,350	17,062
	24–12			(0.20 %)			1–2100	359	753,900	1– 2½	7150	17,875		
5	36	388	27	26	65–60	2328	1–2000	2,697	5,394,000	1–26	2275	59,150	5,703,000	38,615
	24–12			(0.23 %)			1–1000	6,012	6,012,000	1– 5⅕	3477	18,080		

* The upper figures in each space indicate number of cubic centimeters of normal alkali required to neutralize 1 liter of milk, as explained on p. 520; figures in parenthesis indicate percentage of lactic acid, as ordinarily calculated.

The above results obtained from tests upon 14 days at 70° C. (158° F.) illustrate the uncertainty of the pasteurizing action at that temperature and in this particular quite agree with the results on 15 previous days when preliminary trials were being made. They also show what misleading conclusions might be drawn when generalizations are made after one or two observations.

It should be remembered that in any heating of the milk the most desirable class of acid formers will be among the first to be killed and the residue is composed of germs not likely to improve the flavor of the butter. Just how many of this class of bacteria may be left in the milk without imparing the quality of the product, like the problem of how many weeds can be left in the field without detriment to the crop, is not clearly understood and a conservative disposition would favor their reduction to the lowest practical limits.

A most important fact shown is that 70° C. (158° F.) lies near the lower limit of the killing effect of heat applied in this way. When operating a pasteurizer in a practical way temporary reductions of temperature are almost certain to occur and if this reduction goes much below 70° C. the killing effect upon bacteria will be very slight.

TABLE II.—WORKING CONDITIONS AND RESULTS OF CONTINUOUS PASTEURIZATION OF MILK AT 80° C.

Date.	Age.	Weight	Initial temp.	*Acidity.	Steam pressure on boiler.	Rate per hour.	Unpasteurized. Dilution.	Unpasteurized. Colonies on plate.	Unpasteurized. Germs per c. c.	Pasteurized. Dilution	Pasteurized. Colonies on plate.	Pasteurized. Germs per c. c.	Average Germs per c. c. Unp.	Average Germs per c. c. Past.
	Hours.	*Lbs.*	*Deg. C.*		*Lbs.*	*Lbs.*								
Sept. 27	12–4	206	13			1122	1– 500	134	67,000	1–28	9	252	69,500	217
							1– 250	288	72,000	1–14	13	182		
28	12–4	168	12			1680	1– 520	16	8,320	1–6½	11	71	10,010	61
							1– 260	45	11,700	1–4⅓	12	52		
Oct. 2	36–24	401	12			1266	1– 366	141	51,606	1–6	5	30	42,573	25
	12–4						1– 183⅓	183	33,540	1–4	5	20		
4	36–24	381	8		65-50	1632	1– 250	40	10,000	1–3$\frac{2}{9}$	18	58	9,583	46
	12–4						1– 416⅔	22	9,166	1–2	17	34		
6	36–24	382	10		35-33	1206	1– 157	126	19,782	1–2	10	20	18,191	21
	12–4						1– 100	166	16,600	1–1	22	22		
7	12–4	191	15		45-40	1636	1– 460	23	10,580	1–2	11	22	11,960	25
							1– 460	29	13,340	1–1	28	28		
9	36–24	364	12		40-30	1320	1– 300	121	36,300	1–2	20	40	38,100	36
	12–4						1– 150	266	39,900	1–1	33	33		
11	36–24	322	10		30-30	1248	1– 300	98	29,400	1–2	20	40	30,150	29
	12–4						1– 150	206	30,900	1–1	18	18		
13	36–24	326	13		60-65	1626	1– 300	41	12,300	1–2	13	26	15,750	20
	12–4						1– 200	96	19,200	1–1	15	15		
16	36–24	361	16		30-35	1272	1– 367	196	71,932	1–2	49	98	68,906	79
	12–4						1– 183	360	65,880	1–1	61	61		
18	36–24	323	17		45-55	1380	1– 400	82	32,800	1–2	31	62	47,300	51
	12–4						1– 200	309	61,800	1–1	41	41		
20	36–24	345	15		35-40	1146	1– 350	500	175,000	1–2	134	268	202,100	255
	12–4						1– 150	1528	229,200	1–1	243	243		
23	36–24	338	15		50-55	1194	1– 230	1200	276,000	1–2	49	98	313,222	98
	12–4						1– 383	915	350,445	1–1	97	97		
Dec. 13	36–24	361	15	23.5 (0.21 %)	60-50	1272	1–1150	57	65,550	1–2	119	238	61,650	222
	12–4						1– 350	165	57,750	1–1	207	207		

TABLE II.—*Continued.*

Date.	Age of milk.	Weight	Initial temp.	* Acidity.	Steam pressure on boiler.	Rate per hour.	Unpasteurized. Dilution.	Unpasteurized. Colonies on plate.	Unpasteurized. Germs per c.c.	Pasteurized. Dilution.	Pasteurized. Colonies on plate.	Pasteurized. Germs per c. c.	Average Germs per c. c. Unp.	Average Germs per c. c. Past.
	Hours.	*Lbs.*	*Deg. C.*		*Lbs.*	*Lbs.*								
Dec. 18	36–24	370	22	33	60.45	924	1– 400	41	16,400	1–3	62	186	19,000	210
	12–4			(0.298%)			1–1200	18	21,600	1–2	117	234		
20	36–24	331	26	20	50-65	1200	1– 150	100	15,000	1–3	69	207	15,000	190
	12–4			(0.18 %)						1–2	87	174		
26	48–36	468	25	20	55-52	948	1– 432	58	25,056	1–2.8	102	285	26,352	255
	24-12-4			(0.18 %)			1– 216	128	27,648	1–2	113	226		
28	36–24	376	21	18.5	60-20	900	1– 416	34	14,144	1–3	45	135	12,447	123
	12–4			(0.17%)			1– 250	43	10,750	1–2	56	112		
Jan. 4	36	362	25	21	60–62	1890	1– 230	2,649	609,270	1–3	25	75		
	24-12-4			(0.19%)			1– 383	1,462	559,946	1–6	7	42	584,608	58
6	36–24	320	25		65–65	1920	1– 575	2,166	1,245,450	1–2	29	58		
	12–4						1–1150	3,169	3,614,350	1–3¼	28	91	2,444,900	74
8	36–24	387	25	21	60–65	2108	1–2100	1,220	2,562,000	1–4	24	96		
	12–4			(0.19%)			1– 700	3,330	2,331,000	1–2	55	110	2,446,500	103
10	36–24	338	26		40–40	2136	1–2100	991	2,081,100	1–4	28	112		
	12–4						1– 700	2,652	1,856,400	1–2	40	80	1,968,750	96
13	36–24	387	25	26.5	40–40	1716	1–2100	350	751,800	1–3	91	282		
	12–4			(0.24%)			1 1050	733	769,650	1–2	156	312	760,725	297
15	36–24	304	25		60–65	1824	1–2200	709	1,559,800	1–3	69	207		
	12–4						1–1100	1,285	1,413,500	1–2	79	158	1,486,650	182
17	36–24	307	26	36	40–40	1602	1–2000	38,415	76,830,000	1–4	43	172		
	12–4			(0.32%)			1–2000	38,677	77,354,000	1–2	45	90	77,092,000	131

* See foot-note Table I.

The results of pasteurizing at 80°C (176°F.) show a surprising reduction in the germ life and this reduction was accomplished with very slight variation on each of the 25 days tested. These 25 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.

Comparing this average of 25 determinations made after continuous pasteurization with 6140, the average number of germs per cu. cm. found by Dr. H. L. Russell[5] in 50 samples of milk pasteurized by the discontinuous method for direct consumption, the surprising thoroughness of this continuous pasteurization at 80°C. will be understood.

Were it not for the fact that in the present state of our knowledge it is believed that a heating of milk to 85°C. (185°F.) in a continuous pasteurizer is necessary to remove all danger of tuberculosis, the use of 80°C. in pasteurization for butter making, at least in this special machine, would leave little to be desired.

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[5] Ann. Rept. Wis. Agr. Exp. Station, 1895, p. 159.

TABLE III.—WORKING CONDITION AND RESULTS OF CONTINUOUS PASTEURIZATION OF MILK AT 85°C.

Date.	Age of milk.	Wt.	Initial temp.	Acidity.*	Steam pressure on boiler.	Rate (Lbs. per hour).	Unpasteurized.			Pasteurized.			Average.	
							Dilution.	Colonies on plate.	Total germs per c. c.	Dilution.	Colonies on plate.	Total germs per c. c.	Unp.	Past.
	Hours.	*Lbs.*	*Deg. C*		*Lbs.*									
Jan. 19	36–24	392	28	31	60–62	978	1–2200	23,422	51,528,400	1–3	16	48		
	12			(0.28%)			1–1100			1–2	26	52	51,528,400	50
22	36–24	404	24	26	62–45	1860	1–2200	9,620	21,164,000	1–3	27	81		
	12			(0 23%)			1–1100	24,830	27,313,000	1–2	42	84	24,238,500	83
24	36–24	362	34	27.5	60–60	1974	1–2100	11,284	23,696.400	1–4	16	64		
	12			(0.24%)			1–2100	7,020	14,742,000	1–2	26	52	19,219,200	58
26	36–24	370	26		55–35	1584	1–4400	4,264	18,761,600	1–4	61	244		
	12						1–2200	7,410	16,302,000	1–2	112	224	17,531,800	234
29	36–24	361	25	27.5	60–60	1694	1–4200	2,671	11,218,200	1–3	32	96		
	12			(0.24%)			1–2100	10,135	21,283.500	1–2	35	70	16,250,850	83
31	36–24	353	30	27.5	65–60	1410	1–4200	118	495,600	1–4	50	200		
	12			(0.24%)			1–2100	262	550,200	1–2	106	212	522,900	206
Feb. 7	36–24	350	25	35.5	65–65	1314	1–4800	11,830	56,784,000	1–4¼	18	76		
	12			(0.319%)			1–2400	17,310	41,544,000	1–2	44	88	49,164,000	82

* See foot-note Table I.

Confining our attention to the number of germs found in the pasteurized milk the results of the above tests show that there is practically no increase in efficiency in passing from 80°C. to 85°C. If we can be allowed to generalize on so narrow a basis as seven determinations the gain comes in an increased regularity in the reduction of the number of germs present. There is also a practical advantage in working at a temperature well above that at which an active germ killing effect begins.

The strongest argument in favor of 85°C. (185°F.) lies in the fact that it is the lowest one that we can use and feel assured that we have removed the danger of returning germs of tuberculosis along with the mixed skim milk from the factory. Leaving out of account all relation of this disease to the human family, its effect upon our calves and pigs is one that we can not afford to ignore.

While it does not come within the province of this bulletin to discuss the effect of heating upon the butter, it will not be out of place to state that even with cream from milk which had been heated to 85° C., butter was made in which no cooked flavor could be detected when coming from the churn. While our efforts were not universally so successful, still in the cases where such a flavor was noticeable at churning this disappeared after a few hours standing. The experience of this Station, so far as it goes, is quite in accord with that of Dr. Storch, who states that whole milk can be heated to 90°C. without any permanent injury to the flavor of the butter.