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The Manufacture of Cheddar Cheese from Pasteurized Milk

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The Manufacture of Cheddar Cheese from Pasteurized Milk

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I. PASTEURIZATION AND ACIDULATION OF MILK FOR CHEESEMAKING

THE NEED FOR A NEW METHOD OF CHEESEMAKING

Economy of time and labor, and improved quality and uniformity of the cheese produced make the large cooperative factory more profitable to farmers than the small factory provided they retain the control, if not the complete ownership of it.

The objections sometimes raised against the replacement of four or five small cheese factories in a neighborhood, by one larger, better equipped, better manned, and more economical cheese factory, are (1) that by the present factory methods cheesemakers could not make as good cheese from milk gathered over a large territory, because it would be longer on the road to the factory and would not be so fresh as otherwise;

[1] The work here described was conducted at Madison, Wis., by the Wis. Agr. Expt. Sta., and the Dairy Div., U. S. Dept. Agr., in cooperation. The Dairy Division was represented at Madison by expert cheesemakers, J. W. Moore, F. W. Laabs, and A. T. Bruhn, in succession; by bacteriologists, L. D. Bushnell, Alfred Larson, and Miss A. C. Evans, in succession; and by chemists, S. K. Suzuki, and E. F. Flint. The Wisconsin Station is represented by J. L. Sammis, Asso. Prof. of Dairy Husbandry, who has had charge of the work on this project from the beginning.

making, and of skim milk when used for feeding stock. It seems likely that any process such as pasteurization which will kill the acid, taint, gas, and disease producing organisms in milk, would also improve the quality of the cheese produced therefrom.

Pasteurization of Milk for Cheesemaking Suggested. In view of the possible presence of tubercle bacilli in market cheese, Mohler[3], in 1908, recommended the "pasteurization of the milk in order to make the cheese perfectly safe."

Mohler, Washburne, and Doane prepared and studied cheese from milk to which cultures of *Bacillus tuberculosis* had been added. They inoculated guinea pigs with such cheese at various periods of time after its manufacture, and found that "advancing cases of generalized tuberculosis were developed (in guinea pigs) by means of inoculations of cheese 220 days old, and that slight tubercular lesions were caused by the injection of an emulsion of cheese when 261 days old." They add: "If it is possible to use pasteurized milk in the manufacture of cheese without injuring the product, a simple solution of the problem is offered to the cheese manufacturer in the process known as pasteurization."[4]

These authors also give a brief resumé of previous work on this subject in Europe and America.

It is evident that the bacillus of tuberculosis not only retains its life but also its virulence in cheese for a considerable period of time, and that cheese made from raw, unpasteurized milk should therefore be considered as a possible carrier of tubercle bacilli.

There is a strong tendency at the present time to cure American cheese more rapidly than in the past, so that it commonly reaches the consumer at less age than four months. It has also been shown[5] that practically all (95% to 98%) of the bacteria present in milk are retained in the cheese. These facts serve to emphasize the desirability of pasteurizing milk for cheesemaking.

Ordinances passed by the Common Council of the City of Chicago on July 13, 1908, contemplate the pasteurization of

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[3] Mohler, U. S. Treas. Dept., Hyg. Lab., Bul. 41, 1908, p. 495.

[4] U. S. Dept. Agr., Bur. Anim. Indus., Rpt. 1909, p. 139.

[5] Wis. Expt. Sta. Res. Bul. 7, p. 30.

milk used for cheesemaking, although at that date, no practical methods for making American cheese from pasteurized milk had been published.

Department of Health, City of Chicago.
Ordinances, Passed by City Council,
July 13, 1908.

Cheese. Be it ordained by the City Council of the City of Chicago:

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Section 2. It shall be unlawful to sell any such cheese in the City of Chicago unless there be stamped on the package in plainly legible letters of not less than one-eighth inch type: "Made of milk (or cream) from cows free from tuberculosis as shown by tuberculin test," or "Made from milk (or cream) pasteurized according to the rules and regulations of the Department of Health of the City of Chicago."

* * * * * * * * *

Section 4. This ordinance shall be in full force and effect from and after January 1, 1909.

The question as to what temperature of pasteurization will kill disease-producing bacteria in milk is of interest to the consumer and all connected with the business.

The thermal death point of various pathogenic organisms is already well known. Rosenau states as a result of his work and that of others, that, "milk heated to 60° C. and maintained at that temperature for two minutes will kill the typhoid bacillus. The great majority of these organisms are killed by the time the temperature reaches 59 degrees and few survive to 60° C. (140° F.). The diphtheria bacillus succumbs at comparatively low temperatures. Oftentimes it fails to grow after heating to 55°C. Some occasionally survive until the milk reaches 60° C. The thermal death point of the cholera vibrio is similar to that of the diphtheria bacillus. It is usually destroyed when the milk reaches 55° C.; only once did it survive to 60°C. under the conditions of the experiments. The dysentery bacillus is somewhat more resistant to heat than the typhoid bacillus. It sometimes withstands heating survive to 60° C. under the conditions of the experiments. minutes. However the great majority of these microorganisms are killed by the time the milk reaches 60° C.[6]

In 1904, Russell and Hastings found that the tubercle bacillus is killed by heating at 71° C. (160° F.) for one minute.[7]

[6] U. S. Treas. Dept., Hyg. Lab., Bul. 56, 1909, p. 686.
[7] Wis. Expt. Sta., Rpt. 1904, p. 185.

It is clear that pasteurization at 71° C. for one minute, and in most cases for a shorter period, is effective in destroying pathogenic bacteria in milk, and preventing their entrance into cheese.

Babcock and Russell,[8] from their experiments upon the thermal destruction of galactase, state that "heating the enzyme solutions for ten minutes at 76° C. (169° F.) suffices to destroy the digestive ferment galactase, and even at 71° C. (160° F.) for the same exposure, its action was materially reduced."[9] It seems likely, however, that an exposure to 160° F. for one minute or less in the continuous pasteurizer would not greatly weaken the action of this enzyme in milk for cheese making purposes.

Much less attention has been paid by bacteriologists to the thermal death points of those bacteria in milk which produce gas and tainted flavors in cheese. Moore and Ward have described a gas-producing bacillus isolated from milk and from gassy cheese, which "is destroyed in freshly inoculated small tubes of bouillon, when exposed to a temperature of 60° C. (140° F.) for ten minutes in a closed water bath."[10] It is to be hoped that in the future, investigators will determine also the minimum temperature required to kill various species of milk bacteria with an exposure of one minute or less as in the continuous pasteurizer.

Previous Attempts to Make Cheese From Pasteurized Milk. The possibility of making American cheese from pasteurized milk has been studied at several experiment stations and elsewhere.

The difficulties met are (1) the fact, long known, that heated milk coagulates slowly with rennet, giving a loose, spongy curd, which is not suitable for cheesemaking, because it is too fragile to be handled; and (2) pasteurization also causes curd to expel whey more slowly than otherwise. In order to restore the coagulability with rennet to pasteurized milk, Klein and Kirsten,[11] in 1898, added calcium chloride, and a bacterial starter, and were able to obtain fairly good Limburger and other soft cheese. They used, for 100 kilo-

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[8] Wis. Expt. Sta., Rpt. 1898, p. 82.
[9] U. S. Treas. Dept., Hyg. Lab., Bul. 56.
[10] N. Y. (Cornell) Expt. Sta., Rpt. 1899, p. 236.
[11] Milchztg., 1898, pp. 785, 803. See also Fleischmann, Lehrbuch der Milchwirtschaft., 4th Ed., p. 304.

grams of skim milk, 100 to 125 c. c. of a solution containing, in 100 c. c., 40 grams of calcium chloride, corresponding to 20 grams calcium oxide.

In Denmark a kind of cheese [12] is made from pasteurized skim milk to which about 10% of buttermilk is added, so as to bring the acidity up to about .21%, just before adding rennet.

In 1907 Dean[13] stated as a result of experiments in the use of calcium chloride with pasteurized milk for cheesemaking, "the coagulum was of a soft, weak nature and the cheese tended to be soft and porous." He also added 1½% to 3% of bacterial starters to milk pasteurized at 180° F., and ripened some time before adding rennet. The rennet coagulated the milk, but the curd was weak in body. He noted an increased yield of cheese, but the cheese tended to be open and weak in body and texture. He adds, "on the whole, the results are not very satisfactory, and we shall require more light on the subject of making pasteurized milk cheese before we could recommend the method to Canadian cheesemakers."

In 1910, C. A. Publow [14] mentioned briefly some experiments in making cheese from pasteurized milk, adding to each 100 pounds of milk, 2 c. c. of a 25% solution of calcium chloride and 2 or 3 pounds of bacterial starter. The details of the method and the opinions of cheese judges, other than the author, respecting the product are not published.

At this station, in previous years, efforts [15] have been made to obtain good American cheese from pasteurized milk, with the aid of calcium chloride, but without success.

Difficulties Met in Making Cheese from Pasteurizd Milk. Pasteurization of milk prevents or greatly delays subsequent coagulation with rennet. The curd from such milk, when finally cut into cubes, expels moisture with much greater difficulty than a raw milk curd, probably because of some chemical change produced in casein by the heat of pasteurization. Rapid acid formation by bacterial action, which occurs in raw milk and raw milk curds, does not occur in the pasteurized material. The presence of a moderate amount of lactic acid in raw milk curds greatly hastens the separation of whey

[12] Decker, Cheesemaking, 1909 Ed., p. 194.
[13] Ont. Agr. Col., 33d Rpt., p. 120.
[14] C. A. Publow, Fancy Cheese in America, 1910, p. 20.
[15] Results unpublished.

from curd, and the lack of acid development in pasteurized milk curds is another condition favoring the retention of excessive moisture in the curd and cheese.

The addition of calcium chloride to milk which has been pasteurized is known to restore in a measure the coagulability of the milk with rennet, but we have observed as Publow points out, that although coagulation begins in about five minutes, "the curd does not become firm enough for cutting in the usual time and should not be cut before it is firm." Although the addition of calcium chloride restores the coagulability with rennet it does not correct the acidity and other difficulties mentioned above as being caused by pasteurization. The lack of acidity in such curd might be supplied by adding starter to the pasteurized milk and ripening for several hours before starting the cheese making, but the resulting loss of time would prohibit this practice in factories. Where both starter and calcium chloride are added to milk after pasteurization as suggested by Publow and the cheesemaking process is begun at once, without waiting for ripening, the daily variations in natural acidity of milk used produce corresponding variations in the moisture content of the cheese which affect the quality of the cheese. (See Table I.)

What is needed in place of calcium chloride for addition to pasteurized milk is something which will not only restore the coagulability with rennet, but which will also bring up the acidity without delay to a sufficiently high percentage to induce reasonably rapid and complete separation of whey from curd, and give acidity so as to avoid daily variations in moisture content of cheese.

Difficulties Overcome by Acidulation of Pasteurized Milk. The substance which has been found to meet all of these requirements and which appears to be unobjectionable from all standpoints is hydrochloric acid. While it might appear impracticable at first glance to acidulate milk in large quantities daily at a factory, yet upon trial, this is found to be entirely practicable; and it has now been done almost daily for nearly three years, without any trouble arising from coagulation of the milk with acid, at any time.

In Table I is shown the moisture content of green cheese obtained on twelve days from pasteurized milk by the use of calcium chloride, in the proportions suggested by Publow

TABLE I. MOISTURE CONTENT AND QUALITY OF CHEESE MADE WITH CALCIUM CHLORIDE AND WITH HYDROCHLORIC ACID

Date made	Acidity of milk when pasteurized	Moisture content of dressed cheese made with		Scores and criticisms				
		Calcium chloride	Hydrochloric acid	Scores of cheese made with calcium chloride		Criticisms	Scores of cheese made with hydrochloric acid	
				Flav.	Text.		Flav.	Text.
1911	Per cent	Per cent	Per cent					
Aug. 18	.165	42.25	....	38	26	Flat, pungent; Curdy, loose, weak	....	....
18	.165	....	37.70	....	....	Clean; Trifle loose	41½	27½
22	.165	42.35	....	40	26	Flat, lacking; Weak, sticky	....	....
22	.165	....	38.80	....	....	Clean and O. K.; Trifle weak	41	27½
July 28	.17	41.50	....	38	24	Lacks acid; Wet and sticky	....	....
28	.17	....	37.70	....	....	Trifle acid; Trifle sticky	41½	28
Aug. 23	.175	44.27	....	39½	25½	Low, lacking; Trifle weak	....	....
23	.175	....	39.20	....	....	Trifle sharp; Trifle weak	40½	27
24	.175	44.27	....	37	25	Sour milk flavor; Very loose, weak	....	....
24	.175	....	39.62	....	....	Trifle sharp; Trifle weak	41	26½
25	.175	44.45	....	41½	26½	Clean and O. K.; Sticky, loose, short	....	....
25	.175	....	39.02	....	....	O. K.	41½	28
11	.185	42.90	....	40	25	Bitter, lacks acid; Coarse, loose	....	....
11	.185	....	39.90	....	....	O. K.	41½	28
Sept. 4	.190	41.50	....	39	26	Sweet, bitter; Weak, mechan. holes	....	....
4	.190	....	39.95	....	....	Acid aftertaste; Mechanical holes	41½	27½
Aug. 17	.21	39.20	....	41	26	Taste salty; Weak and sticky	....	....
17	.21	....	39.62	....	....	Taste salty; Loose, sticky	41	26½
16	.21	38.70	....	39	26½	Vinegar flavor; Sweet holes	....	....
16	.21	....	38.60	....	....	Clean and O. K.; Trifle loose	41½	27
28	.22	40.60	....	41	26½	Trifle bitter; Short, sticky	....	....
28	.22	....	39.95	....	....	Trifle bitter; Trifle short	41	27½
7	.31	....	39.05	....	....	....	....	....
10	.187	....	37.58	....	....	....	....	....
21	.215	....	38.67	....	....	....	....	....
	Av'r'ge	42.00	38.95	39.45	25.73	....	41.23	27.36

(See page 143), and by use of acid, using always sufficient acid to raise the acidity of the milk to .25%, calculated as lactic acid.

The milk used in the two vats was taken from the same receiving vat of milk, after thorough mixing. It was all pasteurized alike and one-half was then treated with calcium chloride and the other with hydrochloric acid. These were then made up into cheese separately and were sampled for moisture at the time the cheese were dressed, after pressing one hour. From the table it can be seen that whenever the acidity of the milk used was low (.16% to .18%) the moisture content of the cheese made with calcium chloride was high (40% to 44.45%) and when the acidity was high (.21% to .23%) the moisture content was low (38% to 40%). But in all cases where hydrochloric acid was added to the same milk instead of calcium chloride the moisture content of the curd was 37.5% to 40% whether the natural acidity of the milk was high or low.

From this it is evident that when milk is acidulated with hydrochloric acid after pasteurization, as in the new method, the moisture content of the green cheese is not affected by the ripeness of the milk before pasteurization and is quite constant between 37.5% and 40.0%, which advantage does not attend the use of calcium chloride.

The daily variations of moisture content between 37.5% and 40%, shown in column 4, are doubtless due to causes other than acidity, and did not noticeably affect the quality of the cheese. The scores and criticisms given in Table I show that the cheese made with calcium chloride were neither as uniform, nor so good in quality, as those made with hydrochloric acid. The addition of hydrochloric or lactic acid to cream to raise its acidity without delay, preparatory to churning, was attempted by Müller in 1884.[16] The addition of a commercial acid to raw milk[17] to raise its acidity with-

[16] Müller, Milch-Zeitung, 1894, pp. 301, 425, 701.

[17] During the years 1905–1906, the effort was made, following the suggestion of Dr. Babcock, to avoid the necessity for ripening milk for cheesemaking, at the factory, and to substitute for such ripening, the addition of a commercial acid to the milk, as soon as it was received. Immediately after acidulating the milk, it was heated to 86°, rennet was added, and the process completed in the usual manner. These experiments showed conclusively that a commercial acid, as hydrochloric acid, can be added to milk, without in any way damaging

out waiting for bacterial action was suggested to the writer in 1905 by Dr. S. M. Babcock, Chief Chemist of the Wisconsin Experiment Station. The addition of acids to pasteurized milk for cheesemaking was begun by the writer in 1907.

Pasteurization and acidulation of milk appear to be complementary processes, each supplying what the other lacks, and together forming the basis of an improved method of cheesemaking.

TABLE II. COMPARISON OF CALCIUM CHLORIDE WITH HYDROCHLORIC ACID AS TO THEIR EFFECTS ON PASTEURIZED MILK CHEESEMAKING

Date	Acidity of milk used	Time required for visible coagulation after adding rennet		Per cent of fat in whey at time of drawing whey and matting curd	
1911		Calcium chloride	Hydrochloric acid	Calcium chloride	Hydrochloric acid
	% Acid	Minutes	Minutes	% Fat	% Fat
July 28	.17	14	7	.23	.13
Aug. 11	.185	15	7	.35	.14
16	.21	6	7	.16	.12
17	.21	4	7	.21	.14
18	.165	14	7	.32	.19
22	.165	14½	7	.32	.18
23	.175	18	7	.39	.20
24	.175	18	7	.42	.20
25	.175	16	7	.38	.16
28	.22	6½	7	.17	.13
Average...	....	....	....	.295	.159

Since the use of calcium chloride in pasteurized milk cheese making will not be referred to again in this paper, two other points will be mentioned here, in which the use of hydrochloric acid is more advantageous. These are: 1st, that the hydrochloric acid curds always begin to thicken 6½ to 7 minutes after rennet was added, while with calcium chloride, the first visible coagulation occurs earlier if the milk used was very ripe, and later if the milk was sweet, thus varying from day to day as shown in Table II; 2nd, the per cent of fat lost in the whey is on the average about .14% greater in the method using calcium chloride than when hydrochloric acid is used, as shown in Table II. This is probably because cal-

the quality of the cheese obtained. However, the quality of cheese obtained from overripe or tainted milk was not improved by the use of acid, and it was concluded that acidulation, alone, does not offer sufficient advantages to warrant its recommendation to cheesemakers.

cium chloride curds are always more mushy and easier to break up in stirring than curds made with hydrochloric acid. The latter are really superior in this respect to curds obtained by the regular factory methods.

THE PASTEURIZATION PROCESS

Experiments with Discontinuous Pasteurizer. In May, 1907, one day's milk supply was divided in two portions, one of which was made up by the regular method. The other was pasteurized 18 minutes at 160°, and acidulated with hydrochloric acid. The pasteurized vat gave the best flavored cheese, after curing, though it was inferior in texture to the others.

On March 12 and 27, 1908, milk pasteurized at 140° for twenty minutes, and then acidulated gave such good cheese that a systematic study of the combined process of pasteurization and acidulation was begun in July 1908. Cheese were made from milk pasteurized at 140° for 20 minutes, either in a Potts pasteurizer or in the cheese vat by running steam or cold water into the jacket. At the same time part of the milk supply after mixing and dividing was used for making cheese by the regular methods. The scores given by J. W. Moore and F. W. Laabs to the two lots of cheese thus obtained are shown in Table III.

TABLE III. COMPARISON OF FLAVOR AND TEXTURE OF CHEESE OF REGULAR MAKE AND THOSE MADE FROM MILK PASTEURIZED AT 140° FOR TWENTY MINUTES

Date made	Pasteurized cheese		Regular make	
	Flavor	Texture	Flavor	Texture
1908 July	Score	Score	Score	Score
16	38.3	26.2	36.2	27.8
17	40.0	27.0	38.5	26.25
18	41.7	27.5	39.25	27.0
20	40.8	26.3	37.3	26.75
21	41.2	26.0	41.2	26.2
22	41.3	26.8	38.0	26.75
23	40.8	26.7	39.5	26.5
24	41.0	27.25	38.3	26.25
31	40.25	26.25	36.5	26.5
Average	40.59	27.00	38.30	26.66

In every case but one the pasteurized cheese have better flavor, and there is little difference in texture between the two lots.

Continuous and "Held" Pasteurization Compared. On account of the large volume of milk which must be handled daily in a cheese factory, and the greater expense involved in providing arrangements of sufficient capacity for heating and cooling 5000 to 7000 pounds of milk at one time, as compared with the small cost of a continuous pasteurizer, which latter could be used for handling any required volume of milk by running it for a longer time, most of the later work was done with continuous pasteurizers. These are believed preferable for cheese factory use over any form of intermittent pasteurized yet devised. Since good results had been obtained in pasteurization at 140° for 20 minutes, while continuous pasteurization seemed the only practical factory method, it was determined to use both methods in comparison on the same milk for several days.

On eight days between July 16 and 24, 1908, half of the milk was pasteurized at 140° for twenty minutes and the other half was pasteurized at either 150°, 160°, or 170° in the continuous machine. The effectiveness of the two methods of pasteurization was judged from the increase in acidity observed in the whey within the time from cutting curd to drawing whey, specified in each case, in Table IV.

TABLE IV. INCREASE OF ACIDITY AFTER PASTEURIZATION

Date	Past. at 140° 20 min.		Past. at 150° Instantaneous		Past. at 160° Instantaneous		Past. at 170° Instantaneous	
	Increase	Time	Increase	Time	Increase	Time	Increase	Time
1908 July	Per cent	Hrs. min.	Per cent	Hrs. min.	Per cent	Hrs. min.	Per cent	Hrs. min.
16	.11	2 57	....	....	.055	3 0	....	....
17	.068	2 17	....	....	.03	2 59	....	....
18	.055	2 17	....	....	.03	2 46	....	....
20	.01	2 31	....	....	....	....	.01	3 30
21	.02	2 19	....	....	....	....	.01	3 30
22	.03	2 21	....	....	....	....	.035	3 20
23	.078	2 10	....	....	....	....	.053	3 8
24	.018	2 30	.01	2 40	....	....	....	....

From this, it can be seen that where milk was highly inoculated when raw, as on July 16, 17, 18, and 23, the acidity of the whey rose .05%, .06%, .07%, and .11% in about two hours and a quarter after pasteurizing at 140° for 20 minutes; while it rose only about half as high in three hours after pasteurizing at 160° or 170° in the continuous machine.

A further substantial difference between curds from milk pasteurized at 140° for 20 minutes, and that pasteurized 160°

in the continuous machine, is that the former curds often become mellow, and greased on the surface, and leak white whey after milling, in this respect resembling some raw milk curds. It was supposed at first from analogy to ordinary factory methods, that the curd which became mellow and somewhat greased on the surface, and which leaked more or less white whey was more likely to turn out well than the other, which was supposed to be lacking in acid or acid forming bacteria. The observation was made that a curd from milk pasteurized at 170°, and afterwards treated with 5% starter, did not become mellow in the least, while the same day's milk, pasteurized at 140° for 20 minutes and then treated with .75% starter, became very mellow and abundantly greased, before milling. It was judged unnecessary, thereafter, to wait for mellowness or any other evidence of bacterial action or acid development in a pasteurized milk curd. If a sufficient proportion of starter has been added, after pasteurization, it is perfectly certain that the bacteria are present in the curd, and will take part in the curing on the shelf. From this point of view, the mellowness which the 140° curds occasionally exhibit is to be regarded as objectionable and as evidence of lack of uniformity between different days' make, and since this never occurs with milk pasteurized at 160° in the continuous machine, the latter appears preferable.

TABLE V. BACTERIA PER CUBIC CENTIMETER IN RAW AND PASTURE-IZED MILK

Date	Raw milk	Pasteurized milk		
1908		Past. at 140° 20 minutes	In continuous machine	
July	Bact. per c. c.	Bact. per c.c.	Bact. per c.c.	Temperature
17	102,000,000	2,206 000	652,000	160°
18	72,000,000	2,620,000	1,960,000	160°
20	119,000,000	262,000	200,000	170°
21	30,000,000	33,000	9,200	170°
22	173,000,000	320,000	38,000	170°
23	360,000,060	15,320,000	1,300,000	170°
24	65,000,000	62,000	1,100.000	150°

The cause for the greater increase of acidity in whey, after cutting curd, from milk pasteurized at 140° for twenty minutes is no doubt the fact that the milk thus pasteurized contained more living, active bacteria than that pasteurized in the continuous machine. In every case, samples were taken for bacteriological count immediately after pasteurizing, and then .75% of starter was added to each vat, followed immediately by rennet, as soon as the vat could be heated up. Bacterial counts were made on these samples by Mr. L. D. Bushnell, bacteriologist. (See Table V.)

Best Temperature for Pasteurization in the Continuous Machine. The temperature selected should be high enough to make sure that the ripening of milk each day shall be uniformly checked, regardless of the bacterial content of the milk used, and it should not be so high as to injure the quality of the cheese.

TABLE VI. SCORES OF CHEESE FROM RAW MILK, AND FROM MILK PASTEURIZED AT DIFFERENT TEMPERATURES IN THE CONTINUOUS MACHINE (FARRINGTON DUPLEX)

Date made	Regular make		Past at 140° F.		150° F.		160° F.		Judge
1909 July	Flavor	Texture	Flavor	Texture	Flavor	Texture	Flavor	Texture	
14	…	…	40.0	28.5	41.5	28.5	43.0	28.5	Laabs
15	40.0	28.5	40.5	28.5	41.0	29.0	41.0	29.0	Laabs
16	36.0	27.0	38.0	28.0	40.0	29.0	41.0	29.0	Laabs
17	36.0	28.0	38.0	28.5	41.0	29.0	42.0	29.0	Laabs
20	38.0	28.5	40.0	28.5	41.0	28.5	42.0	29.0	Laabs
21	39.0	29.0	41.0	28.5	41.0	28.5	41.5	29.0	Laabs
22	35.0	28.0	37.0	28.0	38.0	28.0	39.0	27.5	McAdam
15	38.0	27.0	…	…	…	…	41.0	27.5	Noyes
…	40.0	26.0	…	…	…	…	44.0	28.0	Baer
…	40.0	26.0	…	…	…	…	42.0	28.0	McAdam
16	38.0	26.0	…	…	…	…	40.0	27.0	Noyes
…	38.0	24.0	…	…	…	…	44.0	28.0	Baer
…	36.0	27.0	…	…	…	…	41.5	28.5	McAdam
17	37.0	26.0	…	…	…	…	38.0	23.0	Noyes
…	40.0	26.0	…	…	…	…	44.5	29.5	Baer
…	35.0	26.5	…	…	…	…	43.0	29.0	Marty
20	37.0	26.0	…	…	…	…	40.5	28.0	McAdam
…	42.0	27.0	…	…	…	…	44.0	29.0	Noyes
…	33.0	28.0	…	…	…	…	41.0	28.0	Baer
21	36.0	28.0	…	…	…	…	40.0	28.0	Noyes
…	37.0	25.0	…	…	…	…	40.0	27.0	Baer
…	39.0	26.0	…	…	…	…	44.0	29.0	Noyes
…	36.0	28.0	…	…	…	…	37.0	29.5	Baer
22	42.0	28.0	…	…	…	…	40.0	25.0	Noyes
…	37.0	27.0	…	…	…	…	35.0	25.5	Baer
23	44.0	26.0	…	…	…	…	43.0	27.0	Noyes
…	36.0	27.0	…	…	…	…	40.0	28.0	Baer
24	43.0	28.0	…	…	…	…	43.5	28.5	Noyes
…	32.0	28.0	…	…	…	…	36.0	26.0	Baer

On several days, the milk supply after mixing, was divided into four lots, and one part made up by regular methods. The others were pasteurized at 140°, 150°, and 160° and made up in separate vats. The cheese after curing, were examined by several expert cheese judges, including Messrs. U. S. Baer, Robert McAdam, H. J. Noyes, F. W. Laabs, and Gottlieb Marty, whose scores are given in Table VI.

In nearly every case, cheese from milk pasteurized at 160° were cleaner in flavor and scored higher than the check; and in every case higher than the cheese pasteurized at 140° or

TABLE VII. BACTERIAL CONTENT OF MILK PASTEURIZED AT DIFFERENT TEMPERATURES IN THE FARRINGTON DUPLEX MACHINE

Date	Raw milk	Bacteria per cubic centimeter		
		Past. at 140° F.	Past. at 150° F.	Past. at 160° F.
1909 uly				
22	....	6,080,000	600,000	50,000
23	423,000,000	5,800,000	600,000	60,000
24	11,600,000	1,540,000	139,000	23,000

TABLE VIII. BACTERIAL CONTENT OF MILK BEFORE AND AFTER PASTEURIZATION IN THE FARRINGTON DUPLEX MACHINE AT 160° F.

Date	Raw milk	Pasteurized milk	Decrease
Aug. 1909	Bacteria per c. c.	Bacteria per c. c.	Per cent
17	161,600,000	223,350	99.8
18	43,300,000	1,275,000	97.0
19	57,600,000	211,000	99.6
20	16,560,000	252,160	98.5
21	20,938,000	40,960	99.8
22	15,548,000	420,250	97.0
24	89,750,000	544,250	99.0
26	44,075,000	86,120	99.8
27	76,000,000	30,450	99.9
28	78,825,000	166,400	99.8
31	148,200,000	77,560	99.9
September			
1	25,836,000	9,670	99.9
2	51,650,000	52,125	99.9
14	27,150,000	29,250	99.9
16	77,650,000	341,600	99.6
17	38,900,000	136,350	99.6
18	124,700,000	159,880	99.8
19	60,280,000	287,500	99.5
21	185,000,000	477,600	99.6
22	63,500,000	263,200	99.7
23	45,525,000	142,300	99.7
28	18,376,000	202,600	98.8
29	13,660,000	31,000	99.7
30	980,000	14,580	98.5
July 1910			
11	6,500,000	27,000	99.6
12	1,600,000	25,000	98.5
13	5,250,000	17,200	99.7
14	4,700,000	36,000	99.3
15	10,000,000	28,700	99.7
20	5,350,000	21,000	99.6
September			
19	2,525,000	30,000	98.8

150°. The different judges scored the cheese at different ages, which will account for the wide variation of some scores.

Bacterial counts made by W. H. Wright,[18] shown in Table

VII, indicate that pasteurization at 160° is more effective than at lower temperatures.

That 160° for pasteurization is a high enough temperature to kill most of the bacteria in milk, so as to meet requirements, such as those of the Chicago Ordinance referred to above, is shown in Table VIII by the bacterial counts made by Mr. Alfred Larson.

Similar determinations made by Miss A. C. Evans upon milk pasteurized in the Reid Machine, in 1910, are shown in Table IX.

TABLE IX. BACTERIAL CONTENT OF MILK BEFORE AND AFTER PASTEURIZATION IN THE REID CONTINUOUS MACHINE AT 160° F.

Date	Number of bacteria in milk		Killed by pasteurization
	Raw	Pasteurized	
1910	Bacteria per c.c.	Bacteria per c.c.	Per cent
August			
3	7,950,000	4,700	99.95
4	4,250,000	15,300	99.65
5	9,750,000	142,000	98.45
9	1,500,000	4,850	99.68
11	6,450,000	11,250	99.83
15	2,850,000	43,600	98.47
16	1,017,500	12,725	98.75
17	38,000,000	700	99.99
18	4,500,000	6,000	99.87
19	3,750,000	5,500	99.86
24	18,150,000	13,800	99.93
25	14,000,000	6,500	99.96
30	47,300,000	16,200	99.97
September			
1	2,150,000	12,000	99.44
7	5,650,000	27,000	99.53
8	8,800,000	63,000	99.29
9	2,800,000	5,500	90.80
12	10,200,000	21,200	99.73
13	2,120,000	18,500	99.13
16	18,000,000	5,700	99.97
19	2,525,000	4,300	99.83
21	1,700,000	11,000	99.35
23	9,000,000	30,000	99.67
26	11,200,000	28,000	99.75

Objections to Higher Temperatures than 160°. Cheese made by the new process from milk pasteurized at 160° always has a clean mild flavor which suits practically all markets, and will please any consumer who likes a mild flavored cheese. It may not suit those who are accustomed to and prefer very old high flavored cheese but estimates by leading cheese dealers indicate that the proportion of consumers preferring such is very small. The fact that most of the cheese sold today is

[18] Instructor in Agricultural Bacteriology, Univ. of Wis.

only a few weeks old, and that dealers generally avoid long storage of cheese, preferring quick sales and immediate profits, makes it practically impossible for most consumers to develop taste for any but the new, mild cheese sold in most markets. The steady sales of pasteurized milk cheese during the past two years indicate that the flavor of the 160° pasteurized product is satisfactory for regular orders. Indeed, it is an open question whether most of the "high, snappy" flavor often observed in old cheese is not due to the long continued slow development of those same taints and off flavors from unclean milk which we recognize as objectionable, when they develop rapidly.

The use of higher temperatures than 160° for pasteurization was tried on several days with the result that the flavor production in cheese was practically prevented and the texture of the cheese was inferior. The scores given to these cheese by F. W. Laabs are shown in Table X.

TABLE X. SCORES FOR CHEESE FROM MILK PASTEURIZED AT DIFFERENT TEMPERATURES IN THE CONTINUOUS MACHINE (FARRINGTON DUPLEX)

Date made	Past. at 160° F.		Past. at 170° F.		Past. at 180° F.	
1909	Flavor	Texture	Flavor	Texture	Flavor	Texture
Oct.						
12	40.0	29.0	38.0	27.0	35.0	15.0
13	40.0	29.0	39.0	28.0	35.0	15.0
14	40.0	28.5	38.0	27.0	35.0	15.0

The 180° cheese have no cheddar cheese flavor, but taste like first class cottage cheese. They are so crumbly and short that it is impossible to draw a solid plug. They keep well and it is possible that a good trade might be built by the sale of this product, under the name of "pressed cottage cheese," etc. In all cases the use of 160° for pasteurizing milk gave better cheese than higher temperatures.

Three reasons have been suggested why the milk pasteurized at 180° gives flavorless cheese: (1) if bacteria are the essential cause of flavor production, it would appear likely that the necessary kinds of milk bacteria are destroyed by the higher temperatures of pasteurization; (2) if milk enzymes, such as galactase, are the essential cause of flavor production these enzymes are perhaps destroyed by the use of 180°; (3) it may be that the casein or other native milk constituent which in normal cheese undergoes cleavage forming the flavor-giving substances present in ripened cheese, is changed chemically either in composition or as to constitution by heating to 180°, so that upon cleavage by bacteria, enzymes, acids, or other agencies, it yields different cleavage products, lacking the flavor, etc., which characterize normal cheese. In attempting to test the first of these possible explanations a variety of substances have been added as starters to milk after pasteurizing at 180° or other high temperature, in order, if possible, to supply the bacteria or enzymes needed for normal curing and flavor production. Among the special starters so used were pure cultures of various bacteria, raw milk up to 20% of the vat contents, cultures of bacteria isolated from milk and cheese capable of developing 1.6% or more lactic milk[19], cheese of various ages rubbed to creamy consistency with milk and added in different proportions through a hair sieve, to the pasteurized milk in the vat, cultures made by adding cheese in this manner to milk and incubating over night before adding to the cheese vat. All of these materials were added to milk which had been pasteurized at high temperatures, as 180°, and cheese was made therefrom; but in no case was it possible to get a normal flavor development in the resulting cheese.

The lack of flavor production under these circumstances where many kinds of bacteria and starters were added to the pasteurized milk, seems to indicate that the casein, etc., in milk thus treated is incapable of cleavage into the flavor giving substances, in other words that the casein, etc., is changed chemically by the heat of pasteurization. There is additional evidence that such a change occurs.

Effect of Pasteurization on the Properties of Cheese Curds. A series of cheese curds made from milk pasteurized at 160°, 170°, 180° or higher temperatures, show a regular gradation of certain characteristics. The first peculiarity is that the higher the temperature of pasteurization, the more tenaciously the curd retains moisture, and the more difficult it is to expel the whey by ordinary means. This is shown in the following experiment. The milk in the receiving vat each morning was thoroughly mixed, and then divided into three por-

[19] Hastings, Wis. Expt. Sta. Res. Bul. 6.

tions which were run through the pasteurizer at different temperatures and made up into cheese in different vats. Three-fourths per cent of starter was added to each vat and the milk and curds were handled in all respects as nearly alike as possible, the only difference being in the temperature of pasteurization. The cheese were pressed in separate hoops in the same press, and moisture tests were made on each, the next morning. This entire work was repeated on several days. (See Table XI.)

TABLE XI. MOISTURE CONTENT OF GREEN CHEESE MADE FROM MILK PASTEURIZED AT DIFFERENT TEMPERATURES IN THE FARRINGTON DUPLEX PASTEURIZER

Date	Moisture in green cheese from milk pasteurized at		
1909	160° F.	170° F.	180° F.
October	Per cent	Per cent	Per cent
12	38.4	42.2	46.6
13	37.0	39.9	43.5
14	39.0	40.7	45.5

Each per cent given is the average of two closely agreeing duplicates. In every case the higher temperatures of pasteurization cause higher moisture content in the green cheese. These curds were all cut with a $\frac{3}{8}$ inch knife and heated to 104° in the whey. Even after cutting a 180° curd with $\frac{1}{4}$ inch curd knives, the moisture content of the green cheese remained higher than in the 160° curd cut with $\frac{3}{8}$ inch knife as shown in Table XII.

TABLE XII. MOISTURE CONTENT OF CURDS MADE FROM MILK PASTEURIZED AT DIFFERENT TEMPERATURES IN THE FARRINGTON DUPLEX PASTEURIZER, CUT WITH DIFFERENT SIZED KNIVES

Time after cutting curd			Past. at 160° F.	Past. at 180° F.	
			⅜ inch cubes	⅜ inch cubes	¼ inch cubes
Hrs.	Min.	Operation	Per cent moisture	Per cent moisture	Per cent moisture
1	0		67.6	70.0	66.5
2	0	Drew whey	60.1	63.9	61.0
2	30		47.2	52.4	50.6
3	30	Milled curd	43.3	47.2	46.0
4	30	Salted curd	42.2	45.9	44.6
4	50	Hooped curd	41.4	45.1	43.9

Each per cent given is the average of two closely agreeing moisture determinations.

It is unquestionably true that pasteurized milk curds retain moisture more tenaciously than raw milk curds, and this effect is more marked the higher the temperature used in pasteurization.

On this account, the weight of cheese obtained from pasteurized milk is greater the higher the temperature used in the pasteurizer. The yield per hundred pounds of milk, weighed before pasteurization, in each vat on three days is given in Table XIII.

TABLE XIII. YIELD OF CHEESE PER HUNDRED POUNDS OF MILK PASTEURIZED AT DIFFERENT TEMPERATURES

Date made	Temperature of pasteurization		
	160°	170°	180°
1909 Oct.	Lbs.	Lbs.	Lbs.
12	12.28	13.42	15.42
13	12.10	12.97	14.53
14	11.93	12.70	14.44

It will be shown later that the yield of cheese obtained by pasteurizing at 160° is slightly greater than that obtained from raw milk, so that in this respect the effect of pasteurization is distinctly noticeable even when the lower temperature is used in the pasteurizer.

Second among the peculiarities of pasteurized milk curds, is their decreased power to coalesce or mat, when on the rack or in the press. This effect is not noticeable with milk pasteurized at 160°—165°, but is perceptible at 170° and very marked in milk pasteurized at 180° or higher. The 180° curd cubes when piled on the rack, pack together, like raisins or figs in a box, but do not coalesce or unite, and at any time, by rubbing the finger over the mass, the pieces can be pulled apart. The same effect is noticed when the curd is pressed in the hoop. The pieces pack tightly, but do not unite; and at any time during the curing, a plug drawn with a trier will come out either in fragments, or will break into pieces instantly when handled. Instead of milling such a curd, it is merely stirred or shaken apart with the hands.

These two peculiarities of pasteurized milk curds which cannot be remedied or avoided by any other means than reducing the temperature of the pasteurization, considered together with the impossibility of developing cheddar cheese flavor after pasteurization at high temperature appear to indicate that pasteurization produces some deep seated change in the chemical constitution of casein.

The peculiarity of pasteurized milk, of coagulating with rennet only with great difficulty, need only be mentioned in this connection, because in the process of cheesemaking here described, the addition of hydrochloric acid to the pasteurized milk entirely restores the coagulability with rennet, producing a curd in many respects superior to and easier to handle than the curd commonly obtained in the regular way, from raw milk.

From what has been said it will be seen that the use of 160°—165° for pasteurization offers many practical advantages. It is sufficiently high to check effectually the further ripening of the milk during the next few hours, while 150° is not high enough for this purpose. One hundred and sixty degrees gives cheese of cleaner flavor than 140° or 150°, (no doubt by more effectual destruction of taint producing bacteria) or than raw milk, as shown in Table VI. Over 99% of the total bacterial content of the milk is destroyed by use of 160°, as shown in Tables VIII and IX. One hundred sixty degrees is preferred to 170° or 180°, because the cheese obtained by use of 160° is more nearly like the best American cheese in moisture content (see Table XI), in texture and in flavor (see Table X).

So far as it is possible to say at the present time, the use of 160° is sufficient to kill most (probably 99%) of the gas and taint forming bacteria in milk. It cannot be claimed that they are all killed, because it is true that when very unclean milk is handled by this process, the cheese sometimes shows slight traces of unclean flavor, though not enough to affect the market value. While gas and pinholes have often been seen during the seasons of 1909, 1910, and 1911 in cheese made by regular methods at this factory, no gas whatever was seen in any curd or cheese made by the pasteurization process during 1909 or 1911; while the gassy cheese obtained on nine days in succession in 1910 were due to the use by mistake, of a gassy starter, which was added to the milk after pasteurization. The fault arose at that time from the inefficient means then at hand for preparing and heating milk for propagation of the starter. An improved steam sterilizer was at once set up for this purpose, preventing all further difficulty of this sort during the past two years.

The temperature finally selected as most completely securing the advantages and avoiding the disadvantages of pasteurization for cheesemaking is 160°—165° F. In practice the pasteurizer is set running at 163° and held there as closely as possible.

Different Types of Continuous Pasteurizers Used. Two different pasteurizers were used in this work with entire success, being apparently equally effective in producing the desired results at 160—165 degrees. These were a Farrington Duplex, capacity 2000 lbs. per hour, and a Reid Improved, of 1200 lbs. capacity per hour. The Reid is a machine of the same general type known as the Jensen. The choice between these two types of pasteurizing machines for use in this process appears to depend upon their relative cost, and ease of operation and cleaning, rather than upon any difference in effectiveness. They were used alternately on successive days for several weeks and on three days, Sept. 1, 12 and 19, 1910, the milk was divided and one-half run through the Reid, and one-half through the Duplex. The cheese showed no differences that could be traced to the use of different machines, and were all first class. Larger sizes of pasteurizers, up to 7000 lbs. per hour capacity can now be obtained from the manufacturers.

THE ACIDULATION PROCESS

The Standard Acidity of Milk for Cheesemaking. Milk as it flows from the pasteurizer varies daily in acidity and is lacking in bacteria of the lactic acid type, needed to aid in cheese curing. By the addition of sufficient hydrochloric acid to raise the acidity of the milk to .25% (as lactic acid) after pasteurizing, and of .75% of a first class starter, the pasteurized milk is brought daily into standard condition both as to acidity and bacterial content for cheesemaking purposes. The acidity of pasteurized milk is raised to .25% rather than .20% or .30% for the following reasons:

(1) In regular cheesemaking, the acidity of whey when drawn is, on the average, about .17%, corresponding to an acidity of milk of about .25%. Anyone can test the correct-

ness of this statement by transferring a pint of milk from a cheese vat, just before adding rennet, to a small tin pail, keeping the milk sample at the same temperature as the vat, and titrating the milk in the pail as well as whey from the vat at intervals. When the whey reaches .17% the milk reaches nearly .25%.

The control of acidity at the instant the whey is drawn is commonly regarded as most important in regular cheesemaking. With milk pasteurized at 160°, there is little or no increase of acidity (usually about .01%) in whey before the whey is drawn. The acidity of milk is adjusted to .25% in this process after pasteurizing in order to parallel ordinary working conditions at the time of drawing whey.

(2) Mixed milk in the factory cheese vat, is commonly at .16 to .18% acidity when received, often at .19% to .21%, and should never be over .23% acidity. It is found that an addition of hydrochloric acid equal to at least .02% of lactic acid is required to restore the coagulability with rennet to such milk after pasteurization but the daily addition of only .02% acid would leave the milk of varying acidity which is objectionable. If .20% were adopted as the standard acidity, after adding .02% in the form of hydrochloric acid, this rule would exclude from use all milk having a higher acidity than .18% when received, which it is not desirable to do. Only rarely is a vat full of milk at .23% acidity received at any factory, but even such milk can be handled in the routine manner at the standard acidity of .25% by adding the required .02% after pasteurization.

It might be stated as a matter of record, not as a precedent for factory practice, that vats of milk of .24% to .28% acidity when received, have been successfully made up into good cheese without varying the process in any particular, excepting that only enough acid is added, after pasteurization, to raise the acidity .01% which is sufficient to restore the rennet coagulation to such ripe milk. The only apparent limit of acidity for milk to be handled by this process is that the milk should not, of course, be sour enough to curdle in the pasteurizer, and this limit is reached at or about .30%.

However, it should be recognized by everyone that milk that has reached .30% or even .25% acidity, before it gets to the cheese factory, must have received very poor care and attention on the farm, and must be entirely unfit for cheesemaking from a sanitary point of view.

Comparison of Different Kinds of Acids for Use in Cheesemaking. Of the more common acids, sulfuric, hydrochloric, and phosphoric, the first, sulfuric, is the least convenient to handle, especially in a cheese factory, because of the great amount of heat liberated when it is diluted, and the impossibility of diluting it in the carboy in which it is received. Hydrochloric acid is much better in this respect, as it can be readily diluted with an equal volume of water, pouring the water into the acid, with no danger and very little heat evolution. Thus diluted, it fumes very little if at all, and can be readily and accurately standardized by titration with N/1 caustic soda, and phenolphthalein indicator. Phosphoric acid can be purchased in carboys of about 50% strength, requires no dilution in the carboy, and liberates little or no heat when diluted.

The choice between hydrochloric acid and phosphoric acids made from phosphorus is greatly in favor of the former because of high cost of the latter. Recently, however, phosphoric acid made from bone ash or bone black has been put on the market, in this country, containing about 45% free phosphoric acid, and containing less than one per cent each of hydrochloric acid, sulfuric acid, and phosphates of iron and alumina, this product being offered at 6 cents a pound in paraffined barrels. The price of this acid is very nearly the same as that of C. P. hydrochloric acid for equal neutralizing power.

C. P. hydrochloric acid is and has been for years a standard article of manufacture, whose purity is tested daily by use in hundreds of laboratories. On the other hand the manufacture of phosphoric acid from bone ash in a form free from objectionable impurities has been accomplished only very recently.

A number of cheese were made with phosphoric acid, but these showed no advantage over cheese made with hydrochloric acid and they seemed to have a slight peculiarity of flavor, as a rule, after curing. Most of the cheese made from pasteurized milk so far have been made with hydrochloric acid, and the use of this acid is described and recommended in the present bulletin.

The selection of hydrochloric acid was made on the grounds that it is cheap and more easily obtained than any other C. P. acid, and being a natural constituent of gastric juice in the human stomach, no objection could be raised on sanitary or other grounds against its use in this process.

The Proportion of Acid Required Daily. It is necessary to determine what the acidity of each receiving vat full of the mixed milk is, in order to add the requisite quantity of hydrochloric acid after pasteurizing, to bring the acidity up to .25%.

Where only one vat of milk is to be pasteurized, and only one workman is employed, it is probably better to weigh in all the milk, then stir the vat well and take out a half cupful of milk for the acid test.

Where two men are employed, and it is desired to start the pasteurizer running as early as possible (before the receiving vat is full), the intake man should take from each weigh can full of milk a sampling tube full, mixing these samples in a pint jar. The acidity of this mixed sample will then be the same as the average acidity of all the milk run into the vat. As soon as one cheese vat full of milk (say 5,000 pounds) has been run from the weigh can into the receiving vat, the pint jar containing the sample for the acid test is handed from the intake to the man running the pasteurizer, together with the total weight of milk run into that vat. The pasteurizer was started when perhaps only half of this milk had been received, but the receiving vat is still about half full, and after making the acid test on the sample, the operator can tell exactly how much more hydrochloric acid must be added, while pasteurizing the remaining milk, in order to bring the acidity of the whole vat up to the right point of acidity, .25%.

Testing Milk for Acidity. In determining the acidity of milk, measure a 17.6 c. c. pipette full of the milk sample into a white china cup, which should be shallow and wide rather than narrow and deep. Add two drops of phenolphthalein indicator and, while shaking or stirring the milk in the cup, run in tenth-normal alkali (Manns' solution) from a burette, rapidly at first, and later by single drops, until the pink color produced by the last drop does not disappear on thorough mixing. The volume of tenth-normal alkali used is read from the burette, and this volume divided by 20, which can be done mentally, gives the exact acidity of the milk in per cent of lactic acid by weight. For example, if the volume of alkali solution used was 3.2 c. c., the acidity is 3.2 divided by 20, which equals .16%. Subtracting the acidity of the raw milk from .25% shows how much the acidity of the milk is to be raised with hydrochloric acid after pasteurizing. For example, subtracting .16% from .25% leaves .09%, which shows that the acidity is to be increased .09% with hydrochloric acid.

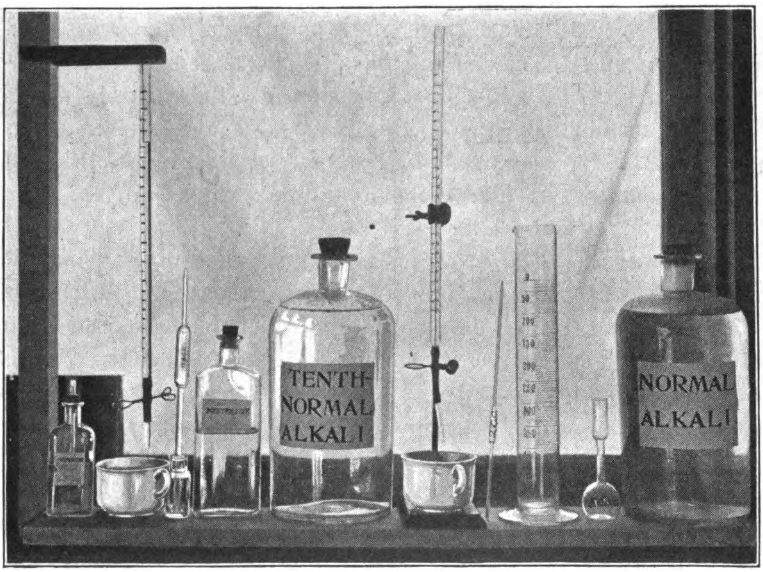

FIGURE 1. OUTFIT FOR TESTING ACIDITY OF MILK

This is the Manns outfit together with additional glassware specially needed in making pasteurized cheese.

The outfit needed for testing milk is shown in Figure 1. It consists of:

1. A burette, with rubber tip and pinch-cock, capacity 25 c. c., with 1/10 c. c. graduations.
2. A 17.6 c. c., pipette, as used for the Babcock test.
3. A white china teacup, which is best if shallow and wide, and with wide flat bottom.
4. A support for the burette, which may be an iron stand and clamp, or a wooden strip with a hole in it, fastened to a window casing, as shown at the left in the figure.

5, A rubber stoppered bottle of Manns' solution (tenth-normal alkali) which may be purchased at $1.00 per gallon, of dealers in dairy supplies, or may be made by diluting the normal alkali solution, which is required in this process of cheesemaking as described on page 169, and which must be purchased.

6. A two ounce or four ounce bottle of phenolphthalein indicator solution.

The additional outfit required for use in this process of cheesemaking is also shown in the figure. It consists of one gallon of normal alkali (ten times as strong as Manns' neutralizer), a 50 c. c. measuring flask, a 500 c. c. measuring cylinder, and a 2 c. c. pipette, which should be accurately made. A gallon of normal caustic alkali contains about five ounces of caustic soda, worth about fifteen cents, and should cost the cheesemaker no more than a gallon of tenth-normal solution, that is about $1.00.

Preserving the Tenth-Normal Solution. Instead of using the large bottle of tenth-normal solution to fill the burette with, it is much better to get a smaller bottle, holding six or eight ounces, also provided with a rubber stopper, and to fill this smaller bottle occasionally from the larger bottle which is then put away, tightly stoppered, in a safe place. The small bottle is kept near the burette, and used daily in filling it; and the large bottle is thus protected from unnecessary exposure, loss of strength, and from danger of spilling. The use of two bottles in this manner has proved most satisfactory in this laboratory and Dairy School, during the past four years. It is recommended [20] as a means of avoiding loss of strength through exposure to air, which has heretofore been the greatest difficulty to overcome in the use of Mann's test, in the cheese factory.

Diluting Normal Alkali to Tenth-Normal. One may prepare tenth-normal alkali by diluting the normal alkali as follows: Pour into a 500 c. c. graduated cylinder, exactly 50 c. c. of the normal solution measured in the 50 c. c. flask. Add at once 450 c. c. of pure water, either rain water or condensed steam. Pour the mixture into a clean glass bottle, mix by shaking, and keep closed with a rubber stopper to avoid loss

[20] Hoards Dairyman, 1909, p. 1200.

of strength by exposure to air. If the mixture is muddy or turbid the water used in diluting was not pure. A slight turbidity may be neglected.

Adding Acid to Milk After Pasteurization. For this purpose, the acid of normal strength is placed in an acid-proof container, on a shelf, near the outlet of the cooler. A glass bottle or a paraffined wooden cask can be used as shown in Figures 2 and 3. The container has a small opening on one side near the bottom, through which the acid is drawn by a rub-

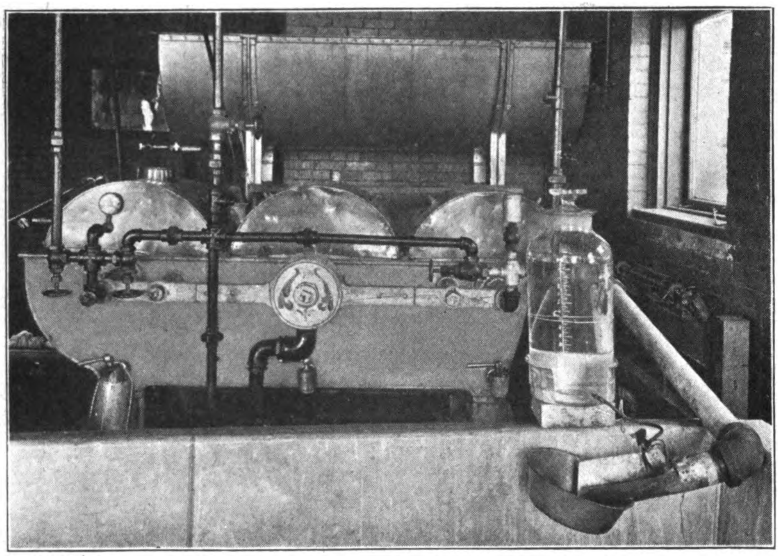

FIGURE 2. ACIDULATING SMALL AMOUNTS OF MILK

Near the bottom of a 2-½ gallon glass bottle is inserted a rubber tube which leads the acid to the milk delivery pipe where it is thrown against the inflowing milk for thorough mixing. Note the scale showing the weight of the contents and the string around the bottle which shows when to stop the acid.

ber tube ⅛ or ¼ inch internal diameter, closed by a screw pinch-cock. On the outside wall of the container beginning at the top, a scale is engraved or otherwise permanently attached, with graduations showing pounds, halves, and quarters of acid delivered. If the container is opaque, a glass level tube, placed outside near the scale, shows the acid level within at any instant. The capacity of the acid container should be about ten gallons for use with a 7,000 pound vat of milk. In addition, a two quart tin pan is connected by means of a short piece of conductor to the cooler outlet. The milk from the cooler and the acid from the container are thoroughly mixed in the conductor and mixing pan, from which the acidulated milk overflows, and runs into the cheese vat.

In order to avoid coagulation of the milk, the acid is added from a jet so as to strike the milk while the latter is moving in a thin stream rapidly down the short, steeply inclined piece of open conductor pipe. It then enters the mixing pan, and

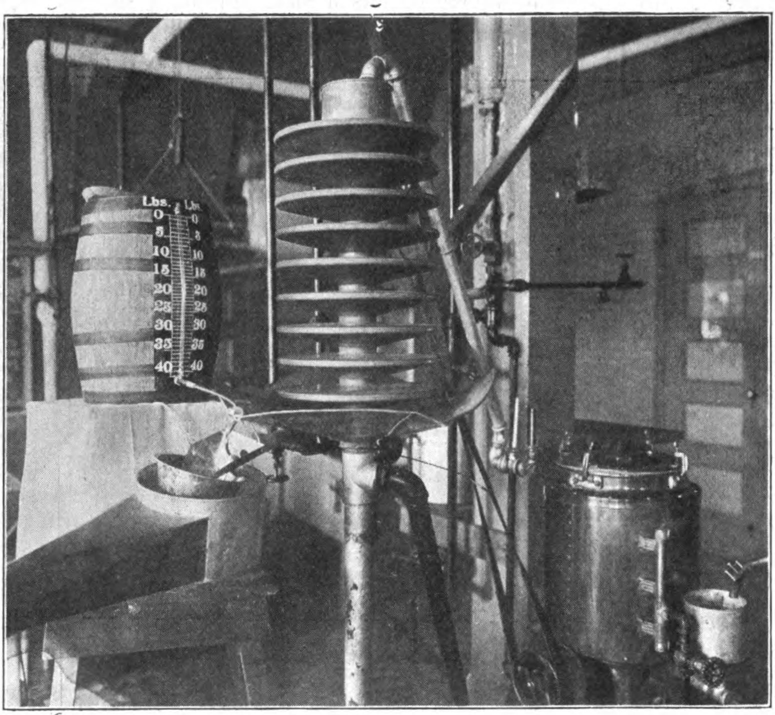

FIGURE 3. ACIDULATING LARGE AMOUNTS OF MILK

A wooden cask, paraffined, has a glass tube on the outside to indicate the acid level on a scale graduated to ¼ pound. Both acidulators may be removed when not in use.

its direction is abruptly changed twice, securing thorough mixing of milk and acid, before it flows over the edge of the pan into the cheese vat. Figures 2 and 3 show two complete outfits.

In using this acidulator, there is never any danger of coagulation, if the operator remembers always to shut off the acid before the milk flow stops. It has been repeatedly shown that two pounds of acid or twice as much as commonly required, can be safely added in this manner to 100 pounds of milk at 60° or 80° without causing coagulation. If any small particles of curd are formed they rise to the surface of the milk, when quiet in the vat, and can be plainly seen. They can be taken up with a hair sieve, and rubbed through the sieve into the milk without causing loss of yield. In practice, the acidity of the vat of milk, when all in and stirred, always comes between .24 and .26 when attempting to make it .25%, and this degree of accuracy is entirely satisfactory.

Calculating How Much Normal Hydrochloric Acid to Add to a Vat of Milk to Bring its Acidity up to .25%. To calculate how many pounds of normal hydrochloric acid are required by any vat of milk after pasteurizing, remember that one pound of the acid added to 100 pounds of milk will raise its acidity just .09%. From this it is easy to see that for 2,500 pounds of milk of .16% acidity, just 25 pounds of normal strength acid will be required; and for 3,050 pounds of milk, 30.5 pounds of acid will be needed to bring the acidity up to .25% (calculated as lactic acid).

TABLE XIV. WEIGHT OF NORMAL ACID REQUIRED PER HUNDRED POUNDS OF MILK

Acidity in milk when pasteurized	Weight of normal acid added to 100 pounds of milk	Acidity of milk after the addition of acid
Per cent	Lbs.	Per cent
.15	One and one-ninth	.25
.16	One	.25
.17	Eight-ninths	.25
.18	Seven-ninths	.25
.19	Six-ninths	.25
.20	Five-ninths	.25
.21	Four-ninths	.25
.22	Three-ninths	.25
.23	Two-ninths	.25
.24	One-ninth	.25
.25	One-ninth	.26
.26	One-ninth	.27
.27	One-ninth	.28

If the milk showed an acidity of .21% when raw, then subtract .21%, from .25%, which leaves .04%. Since the milk is riper to start with, less acid will need to be added. In this case only 4/9 of a pound of acid for each 100 pounds of milk will be needed to bring the acidity up from .21% to .25%. In any case, the weight in pounds of acid required is equal to

$$\frac{.25\%-a}{.09 \times 100} \times \text{weight of milk or } \frac{.25\% - a}{} \times \frac{\text{weight of milk}}{9}$$

where a is the acidity of the raw milk. Stated in words, the rule is, divide the weight of milk by 9 and multiply by .25% minus the acidity of the raw milk.

In acidulating pasteurized milk, one pound of normal acid is used to raise the acidity of 100 pounds of milk .09%, as from .16% to .25%. Eight-ninths of a pound of acid is required to raise 100 pounds of milk of .17% acidity to .25% and so on as shown in Table XIV.

Where milk appears to be of, say .175% when received, it is treated as if it were at .17% dropping the .005 out of the calculation. Table XV, conveniently posted, may aid in calculating the weight of acid required for any weight of milk, at any acidity.

TABLE XV. WEIGHT OF NORMAL HYDROCHLORIC ACID REQUIRED FOR PASTEURIZED MILK

Acidity of raw milk	.27% to .24%	.23%	.22%	.21%	.20%	.19%	.18%	.17%	.16%	.15%	.14%
Raw milk, Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs	Lbs.
10,000	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	100.0	111.1	122.00
9,000	10.0	20.0	30.0	40.0	50.0	60.0	70 0	80.0	90.0	100.0	110.00
8,000	8.9	17.8	26.7	35.6	44.4	53.3	62.2	71.1	80.0	88.9	97.80
7,000	7.8	15.5	23.3	31.1	38.9	46.7	54.4	62.2	70.0	77.8	85.60
6,000	6.7	13.3	20.0	26.7	33.3	40.0	46.7	53.3	60.0	66.7	73.30
5,000	5.6	11.1	16.7	22.2	27.8	33.3	38.9	44.4	50.0	55.5	61.10
4,000	4.4	8.9	13.3	17.8	22.2	26.7	31.1	35.5	40.0	44.4	48.90
3,000	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.6	30.0	33.3	36.70
2,000	2.2	4.4	6.7	8.9	11.0	13.3	15.6	17.8	20.0	22.2	24.40
1,000	1.1	2.2	3.3	4.4	5.5	6.7	7.8	8.9	10.0	11.1	12.20
900	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.00
800	0.9	1.8	2.7	3.6	4.4	5.3	6.2	7.1	8.0	8.9	9.80
700	0.8	1.6	2.3	3.1	3.9	4.7	5.4	6.2	7.0	7.8	8.60
600	0.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.30
500	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.6	6.10
400	0.5	0.9	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.4	4.90
300	0.4	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.70
200	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2	2.40
100	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.20
75	0.08	0.17	0.25	0.34	0.42	0.50	0.60	0.67	0.75	0.83	0.92
50	0.06	0.11	0.17	0.22	0.28	0.33	0.39	0.44	0.50	0.56	0.61
25	0.03	0.06	0.09	0.11	0.14	0.16	0.19	0.22	0.25	0.28	0.31

To find for example, how much normal hydrochloric acid will be needed to raise 6,754 pounds of milk of .17% acidity to .25% acidity, take from the table the figures given under .17% and opposite 6,000 .... 53.3

Add to this the figure opposite 700 .... 6.2

And the figure opposite 50 4

This gives the number of pounds of acid required 59.9

Preparation of Normal Hydrochloric Acid, in the Cheese Factory. Chemically pure hydrochloric acid solution as purchased in carboys, contains about 40% by weight of hydrochloric acid, and 60% of water, and costs about seven cents a pound. Its strength varies somewhat, and it must be diluted with water, before it can be be added to milk in this process. The preparation of normal strength acid used in cheesemaking is carried on at the cheese factory, in two steps, as follows:

First Step. Remove the wooden cap from the top of a fresh carboy of acid, and loosen the glass plug in the neck, by tapping it on different sides very gently, with a piece of wood, (not metal) until it can be drawn out readily with the hand. Set an empty carboy beside the newly opened carboy. Fill both limbs of a glass siphon with water, removing all air bubbles, and insert the two limbs into the carboys at once in the manner shown in Figure 4. When the siphon is in place, as shown in Figure 5, acid will flow from the full carboy into the empty one, until in about half an hour each is practically half full. Now fill up each carboy nearly to the neck with water, leaving space enough beneath the neck to permit mixing the contents readily by shaking. Tip each carboy up on edge, and rock vigorously for about five minutes, with the stopper out, to induce thorough mixing. On mixing, the liquid gets slightly warmer. It must be stoppered and left over night to cool, and is then called "dilute" acid. To determine how much further each carboy of dilute acid requires to be diluted with water, to make it exactly "normal" in strength, set up the burette used in Manns' test, but fill it with *normal alkali* solution, which is ten times as strong as that used in testing milk. Using a two c. c. pipette, transfer exactly two c. c. of the dilute acid from the carboy to the porcelain cup containing a little pure water, letting the pipette drain into the cup half a minute by the watch, and blowing out the last drop of acid from the tip into the cup. Now add one or two drops of indicator and after reading the level of alkali in the burette, draw out the alkali from the burette, precisely as in testing milk, rapidly at first, later by single drops, while shaking the cup in a circle, until the last drop added produces a distinct pink color which remains throughout the entire liquid after thorough mixing. Read and record the volume of alkali solution used. Rinse out the cup, fill up the burette, shake up the acid in the carboy for a minute, and test another two c. c. of the acid for the sake of accuracy.

If the contents of the carboy were thoroughly mixed at first, the titrations made before and after the second shaking

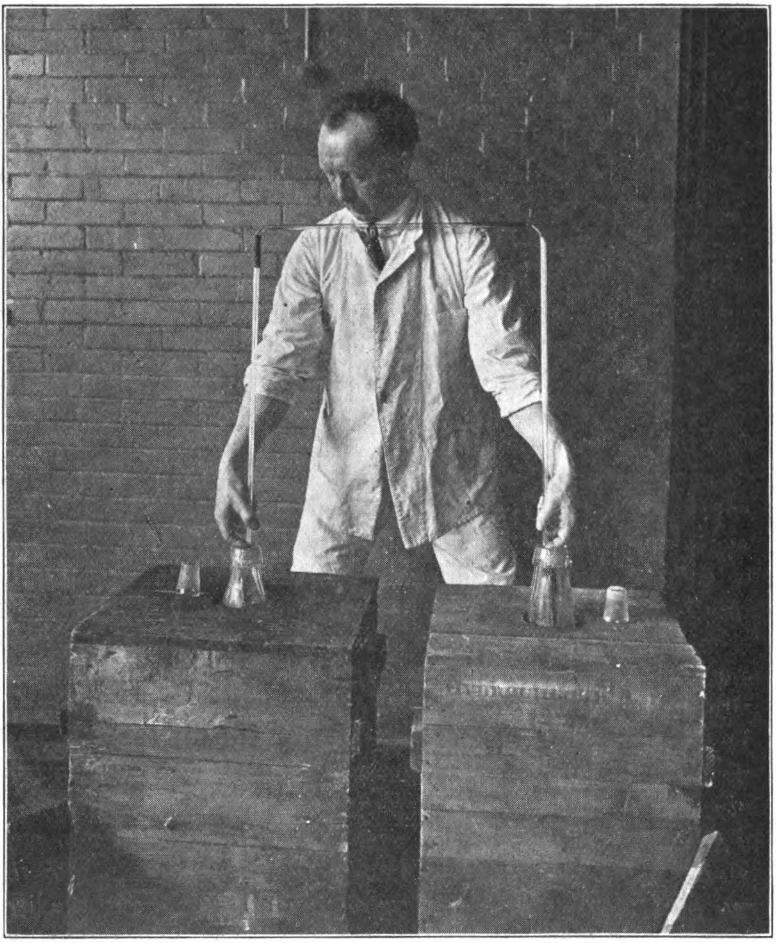

FIGURE 4. SIPHONING ACID FROM FULL TO EMPTY CARBOY

The siphon, either glass as shown in the figure, or rubber, is filled with water and the ends closed with the fingers which are removed just before dropping the siphon into place.

will agree closely, not differing by more than .2 c. c. If they do not agree, the carboy contents were probably not well mixed at first, and should be given another very thorough shaking for five minutes, after which the titrations are repeated. Once thoroughly mixed, the acid and water remain mixed, and never need to be shaken again.

Suppose that in the two tests, the two c. c. of acid required 11.0 and 11.2 c. c. of normal alkali to produce the pink color, the average being 11.1 c. c. Divide the volume of alkali by 2, the volume of acid used, which gives in this case $\frac{11.1}{2} = 5.55$

This means that the acid is 5.55 times as strong as it should be for normal acid, and that it must be diluted to 5.55 times its volume with water to make it exactly normal in strength.

The work described above is performed once on each car-

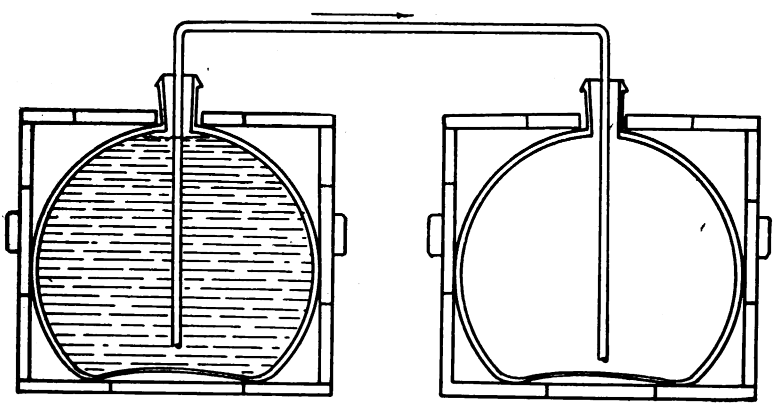

FIGURE 5. THE SIPHON IN ACTION

It is sure to stop working when the acid has been transferred.

boy of dilute acid before using it for cheesemaking, and the object is to get the figure (5.55 in this case) which shows how much too strong the acid is, and how much it must be diluted to make it normal in strength. The second step consists in diluting up, each day, as much of the acid as will be needed for the milk on that day. This second step is performed as follows:

Second Step. Having determined for example that the dilute acid is 5.55 times stronger than normal, the acid is further diluted for use each day, adding one volume of acid to 4.55 volumes of water, making the total volume 5.55 times as great as the acid used.

To do this measure out any convenient volume (say 500 c. c. for about 2500 pounds of milk) of the acid in a glass measuring cylinder and add it to 4.55 times its volume of water (in this case, 500 x 4.55 equals 2,275 c. c. water). The acid should always be measured, but the water can be weighed in pounds, if more convenient, remembering that 453 c. c. of water weigh one pound. In this case $\frac{2275}{453} = 5.02$ pounds of water needed.

The acid and water can be mixed in the acidulator or in a wooden pail, or in a bright tin pail, if the water is put in first, and the acid added later. After the proper amounts of acid and water have been poured into the acidulator, they should be thoroughly mixed at once by stirring with a wooden paddle, and once thoroughly mixed, the normal acid is always ready for use. Of course, the acid should not be handled in galvanized iron, or aluminum vessels, as it will corrode them. The undiluted acid will also discolor tinware, and should be measured in the glass cylinder, as directed.

There is nothing difficult about the preparation of normal strength hydrochloric acid for use in cheesemaking, and anyone who knows how to titrate milk for acidity, can learn to do this also. To test the correctness of the work when completed, transfer 2 c. c. of the acid with a pipette from the acidulator to the porcelain cup, and titrate it with the *normal* alkali in the burette. The volume of alkali required should be beween 1.9 c. c. and 2. 1 c. c.; or better, exactly equal to the volume of acid used.

The degree of accuracy required in this whole process is very easily attained, as quite satisfactory results will be obtained in acidulating milk if the normal acid used is anywhere between .95 and 1.05 normal.

General Directions for Pasteurizing and Acidulating Milk. This method is well adapted for use in a large factory. At a factory handling two or three large vats of milk daily, two men should be employed. The inspection and weighing of milk at the intake is performed by one man, while the other makes the determinations of acidity and runs the pasteurizer. After the milk is all in and pasteurized, the two men work together, heating up the vats, adding the starter, color, and rennet to the vats at least 10 or 15 minutes apart. They cut the curds in the same order, each 25 minutes after the rennet was added, and start the agitators in each curd as soon as cut.

The vats are heated up and the whey is drawn from the vats, in the same order, both men working together in putting the curds on the rack, finishing each vat of curd in time to handle the next.

If more than three vats are handled in one factory, additional help will be needed, especially for bandaging hoops, turning cheese, and other labor.

Where only one vat of milk is handled daily, the milk is run first into the receiving vat, from which it flows into the pasteurizer, through the cooler, and into the cheese vat. If two vats of milk are handled daily, the first milk received may be run into one cheese vat from which it is pasteurized into the other cheese vat, while the milk received later is run into the steel receiving vat from which it is later pasteurized into the second cheese vat.

If three or more vats of milk are handled daily, the receiving vat and the first cheese vat are filled alternately with milk from the intake, and alternately emptied through the pasteurizer into the other cheese vats. It is only necessary to see to it that the last vat filled from the intake shall be the receiving vat in order that this last milk may be run into one of the cheesemaking vats after pasteurization. One receiving vat is needed in addition to the necessary cheese vats, wherever this process is used.

Making Ready to Pasteurize. Since pasteurization is essentially a cleaning process, care should be taken to keep the make-room, the vats, machinery, etc., and everything with which the pasteurized milk comes in contact, as clean as possible.

Although milk flows intermittently from the weigh can, it is desirable that the pasteurizer, once started, shall run continuously, with a steady milk supply, and for this purpose, a receiving vat is provided. The milk should be run into the receiving vat through a strainer which will remove all flies, straw, etc., and which cannot by accident fail to work properly. Such a strainer is shown in the Figure 6. It is set up by slipping a piece of seamless cheese bandage over the wooden frame of the vat strainer, and placing the metal part on top. The metal part collects all large pieces of dirt, and prevents the milk from splashing over the side. The two thicknesses of cheese cloth effectually remove finer particles of dirt. This arrangement has been used in this series of experiments for about two years, and is heartily recommended. Of course, the cloth should be scalded daily.

The weigh can, conductors, receiving vat, and pasteurizer should be washed daily, immediately after use, again rinsed with clean hot water before use, if necessary. The pasteurizer, and cooler, and the connecting pipes should be washed thoroughly daily. Just before starting the pasteurizer each

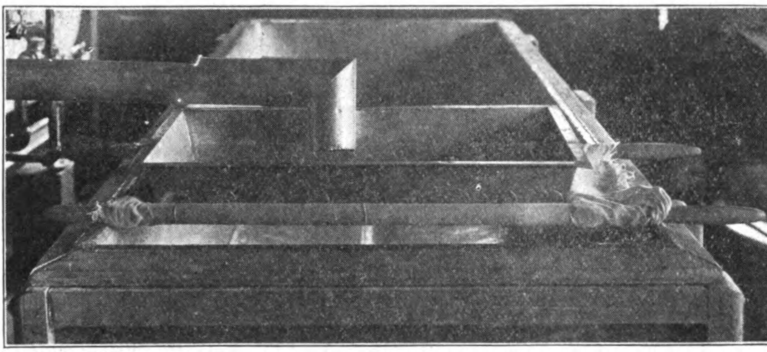

FIGURE 6. A DOUBLE MILK STRAINER

The metal part takes out flies and coarse dirt and never runs over; the double thickness of cheese cloth removes finer particles of dirt.

morning the operator should rinse out the cheese vat and steam it by running steam into the jacket. The pasteurizer and delivery pipes, especially those parts which are in contact with the cooled, pasteurized milk, should be also scalded or steamed. This can be done by running a couple of pails of hot water into the heating compartment, heating it up there to 180° or higher, and running it over the cooler, without having any cold water inside the cooler.

Where only one vat of milk is being pasteurized the acidulator may be set on the edge of the vat; but to avoid moving it, when several vats of milk are handled daily, the acidulator should be set near the pasteurizer, and the acidulated milk run into the different vats through a movable conductor.

Starting and Stopping the Pasteurizer. When milk enough has been received to ensure a continuous supply for the pasteurizer, the latter may be started.

First, see that everything is in place, and that the pump supplying water for cooling is running. Set the pasteurizer in motion, turn on a little steam, and run enough milk into the heating compartment nearly to fill it, so as to register its temperature on the naked glass bulb of the thermometer placed near the exit to the cooler. Do not allow any milk at all to run into the cooler. If any does by accident, draw it out, and scald the cooler with a pail of hot water.

Open the steam valve to the full running capacity. When the thermometer in the milk registers about 155°, start the milk supply again, and adjust so that the thermometer stands at 162° at the exit from the heater. Use care to see that no milk at all is allowed to run to the cooler at a temperature below 160°. If any irregularity occurs in starting, it is much better that the first milk should be heated higher than 160° even up to 180°, rather than that any portion should pass over into the cheese vat without reaching 160°. It will do no harm at all if for a few minutes at first, milk at 170° or 180° passes over into the cooler, because this milk will at least be thoroughly pasteurized, but if milk at 140° or any temperature below 160° passes over it may carry over harmful bacteria which would injure the entire vat of cheese.

A file mark on the steam valve handle is a great help in quickly adjusting the steam supply, to the right point.

Once adjusted and with steady milk and steam supply, the pasteurizing temperature remains nearly constant, and requires only momentary inspection, every few minutes. No doubt an automatic temperature controlling device could be used to advantage here.

Although the thermometer now supplied with some forms of pasteurizer is metal jacketed to prevent breakage, yet in all the experiments here reported, this metal cased thermometer was found to register more slowly than a naked glass bulbed thermometer set in a rubber stopper. The latter has been used two years without breaking and is therefore preferred.

In stopping the pasteurizer for any reason, the operator should remember to stop the acidulator first, then the milk supply, and last of all the steam. If the stoppage is for long, as at the end of the day's run, the hot milk in the heating compartment is drawn out in a pail, (its temperature should be 160° or above,) and added to the vat. The milk in the cooler is also drained and rinsed into the vat.

The water supply for cooling must be ample (see page 239) so that a thermometer placed in the milk flowing from the cooler is not above 85° at any time, and preferably at 80° or lower, since the milk in the vat can easily be heated to 85° or 86° for setting with rennet, but cannot be set or easily cooled if above 86°.

Starting and Stopping the Acidulator. As soon as the pasteurizer has been started and regulated, the pinch cock at the acidulator is opened, allowing one or more small streams of hydrochloric acid to run into the milk. The height of the liquid in the acidulator should be marked on the glass scale with a pencil or string, when starting, and another mark placed lower down on the scale to show how much acid is to be drawn out for that vat of milk. By this means the operator can see from any part of the room, when the acidulator is ready to be stopped. Always stop the acidulator before stopping the milk.

THE USE OF BACTERIAL STARTER IN THIS PROCESS

The Reason for Adding Starter in Making Pasteurized Milk Cheese. The addition of hydrochloric acid to milk raises its acidity at once to .25%, but does not cause any further increase of acidity at any time. Of the acid thus added only about 2.5% remains in the curd, the rest escaping in the whey. No artificial or chemical method has been found for increasing the acidity of a curd on the rack, so that if acid plays any important part in the cheese curing process, it will be necessary to add bacteria to the milk, in order to develop the necessary acid in the curd and cheese. A number of experiments were performed in which the milk supply was divided and made up in different vats, using different proportions of starter. The cheese were finally scored by J. W. Moore, as shown in Table XVI and summarized in Table XVII. In these tables and throughout this bulletin the letter C following a cheese number, as 1076 C, indicates that the cheese so designated was made from raw milk by ordinary factory methods.

These scores indicated that the cheese obtained with .75%, 1%, or 1.25% starter are about equally good, considering both

TABLE XVI. QUALITY OF CHEESE OBTAINED WITH DIFFERENT PROPORTIONS OF STARTER

Date made	Cheese	Proportion of starter	Temperature of pasteurization	Flavor	Texture
1908 Aug.	No.	Per cent	Degrees	Score	Score
17	1076C	....	....	40.50	27.00
	1079	0.25	157	40.50	27.25
	1081	0.50	157	41.25	27.25
	1083	0.75	157	42.50	28.00
18	1085C	....	....	41.00	27.25
	1087	0.25	157	41.75	27.75
	1089	0.50	157	41.00	27.25
	1091	0.75	157	40.25	27.00
19	1093C	....	....	40.50	27.00
	1095	0.25	157	41.25	27.00
	1097	0.50	157	42.50	27.75
	1099	0.75	157	42.75	28.00
20	1101C	....	....	41.25	27.00
	1103	0.25	157	42.50	28.25
	1105	0.75	157	42.25	27.75
21	1109C	....	....	40.75	27.00
	1111	0.75	157	42.25	27.25
	1113	1.00	157	42.50	27.25
	1115	1.25	157	42.50	27.75
22	1117C	....	....	39.50	27.25
	1119	0.75	157	42.25	27.00
	1121	1.00	157	41.75	27.25
	1123	1.25	157	42.25	27.00
31	1157C	....	....	41.00	27.00
	1159	None	162	41.00	27.00
	1161	0.30	162	42.50	28.00
	1163	0.60	162	42.50	28.00
Sept. 1	1165C	....	162	39.00	28.50
	1167	None	162	40.50	26.00
	1169	0.30	162	42.00	27.50
	1170	0.60	162	42.50	28.00
Sept. 2	1173C	....	....	40.00	27.00
	1175	None	162	41.00	26.00
	1177	0.30	162	41.00	27.00
	1179	0.60	162	41.50	27.00
	1024	0.00	170	Sour	Color-cut
	1026	3.00	170	Sour	Color-cut
		5.			

TABLE XVII. SUMMARY OF SCORES IN TABLE XVI

Proportion of starter	Number of cheese scored	Average score		
		Flavor	Texture	Combined
Per cent				
0.00	3	40.83	26.33	67.16
0.25 to .30	7	41.64	27.53	69.18
0.50 to .60	6	41.88	27.54	69.42
0 75	6	42.04	27.50	69.54
1.00	2	42.12	27.25	69.37
1.25	2	42.37	27.37	69.75

flavor and texture; and the use of .75% starter has been continued since August, 1908, with good results. The starter used should be first class in quality, just beginning to thicken, containing the maximum number of lactic acid bacteria in active condition, and free from all objectionable germs or flavors.

Only a starter above criticism, such as every good cheesemaker should know how to prepare, can be used with pasteurized milk. If the starter is at all tainted, it is sure to damage the flavor of the cheese to some extent. With raw badly tainted milk, especially in warm weather, a starter of only fair quality will often greatly improve the quality of the cheese, but pasteurized milk is freed from practically all taints by the pasteurization, and to such milk, only the best starter can safely be added.

Preparation of Starter. At the beginning of the season a small bottle of bacterial starter can be obtained from dealers, or from the College of Agriculture. This is added to a quart of milk, which has been sterilized by heat, to destroy its content of living bacteria, and then cooled. The bacteria thus added increase in number and produce lactic acid, souring and thickening the milk. The accumulation of lactic acid above .7% checks the further growth of the bacteria. It is generally believed that the starter added to the cheese vat should contain bacteria in their most active condition, as occurs when the starter, at 60° to 70°, is just thickening. In order always to have ready a supply of bacteria in full activity, a portion of the starter must be added when about 24 hours old to a fresh portion of sterilized milk, and left to grow; and every day, a fresh propagation of the starter must be made in this manner. It is well to begin propagating the starter several days before cheese making is to begin, and also to carry along two or more starters from different sources, separately, so that if one be lost or found unsuitable, another will be at hand. The quantity of milk used each day for each culture, thus carried, need not be over a pint or a quart and on account of its small size, this culture is often called a startoline, meaning, a little starter.

This daily process of propagating the startoline, was performed in the cheese factory during the year 1911, by A. T. Bruhn, with entire success, carrying along the same culture of bacteria throughout the year.

The essential equipment for propagating startoline, is some sort of a sterilizer, and an incubator, and a dozen pint cream bottles which are best provided with fairly tight tin covers about two inches deep. Various different sterilizers have been recommended, the simplest being an inverted tin pail covering bottles of milk on the steam table. To keep the bottles of growing startoline at proper temperatures, without danger of getting them contaminated with dirt and harmful bacteria, is of the utmost importance. For use as an incubator, a small covered shot gun can may be steamed out daily, and after placing the bottles therein, and adjusting the cover, it may be carried to the ice box, the cellar, a hay cooker, or any room of suitable temperature. Where startoline must be handled and carried about, there is always some danger of its spoiling and this can only be prevented by intelligent work on the part of the operator.

A Practical Sterilizer for the Cheese Factory. A combined sterilizer, cooler, and incubator, illustrated in Figure 7, made of galvanized iron was devised; and has been used in our work during the past year, with entire satisfaction. Its use saves time in handling and reduces danger of contamination to a minimum.

It consists of a galvanized iron container with cover, a movable false bottom, steam, water, and drain connections, etc. Where pint bottles are used, the perforated shelf is raised and set on lugs as shown. If quart bottles are used, the perforated bottom is lowered, so that the tops of the bottles always stand at the top of the sterilizer.

The bottles, having been cleaned and filled nearly full of the best whole milk obtainable, are each covered with a loose tin cap, and set in the sterilizer, together with one bottle of water carrying the thermometer. The lid is put on, and the steam turned on, very slowly at first to avoid breakage. After the thermometer projecting through the small hole in the lid shows that the contents of the bottles are heated to 200° or above, the steam is left running for ¾ to 1 hour, and then turned off. To cool the bottles of sterilized milk, open the valve and slowly run in cold water, which escapes at the overflow. If the water were turned on by mistake faster than the overflow could carry it off, the tin caps would keep it from entering the bottles of milk. When the thermometer shows that the bottle contents are cooled to about 70°, the water may be turned nearly or entirely off. The bottle of startoline from the previous day, which has not yet been opened, is now brought in and a portion, about a tablespoonful by guess, is poured into a bottle of the newly sterilized milk in the apparatus, lifting the tin caps for an instant for this purpose.

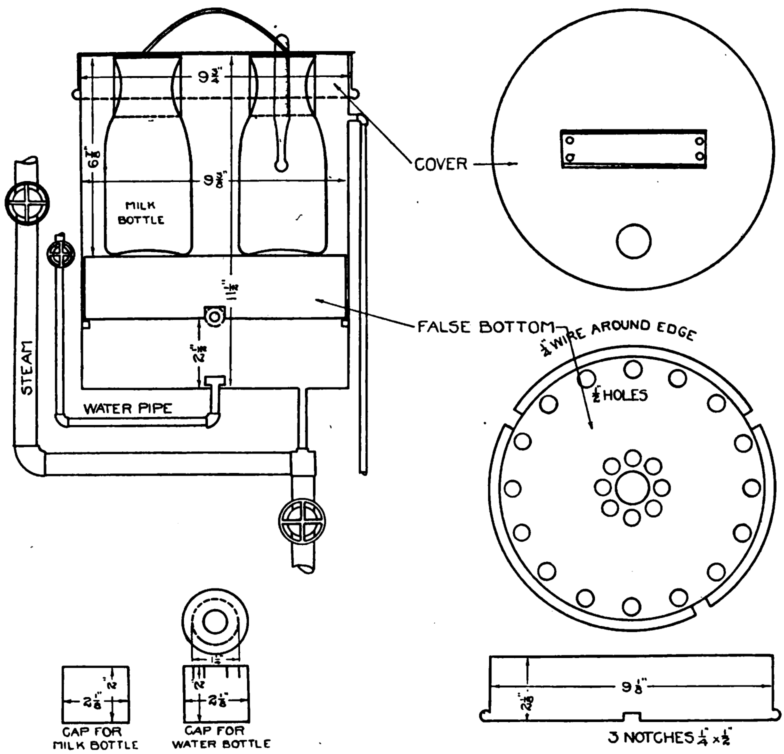

FIGURE 7. STEAM HEATED STERILIZER FOR STARTOLINE

A combined sterilizer, cooler, and incubator for propagating a first-class starter daily throughout the season.

The room should be free from drafts, floating dust, or other source of contamination, and the transfer should be made as quickly and carefully as possible. The cap is then replaced, and the cover put on. The temperature of the water can be kept between 60° and 70° for a few hours; and in the evening, in summer, if the weather is very warm, a piece of ice can be added to the water. By such means the startoline is propagated daily throughout the season. Each day, after inoculating the fresh bottle of milk, the remainder is examined by pouring out a little in a teaspoon or cup, to be tasted and smelled to see that it is in good condition[21], and the remainder in the jar is used in making up starter for the next day's cheese, in the following manner.

To prepare starter from this startoline, place about eight or nine pounds of milk (per thousand received daily) in a shotgun can, cover, and heat in a tub or deep pail of water, by passing steam until the water is boiling and a thermometer in the milk reads 180°, at least. Keep it at this temperature for ¾ hour, and then cool by filling the tub with cold water. A dash stirrer, whose handle is slipped through the smallest possible hole, cut in the cover, is a convenience, and saves opening the can for stirring. When thoroughly cool, and at about 70°, add to the contents of the can, the remaining contents of the startoline jar, as stated above. Stir this up well and leave five or six hours at this temperature, after which it may be put in a cooler place to stand over night. The general principle on which the temperature of starters, etc., is regulated, is, that the starter should ripen just fast enough to be barely thick, or just getting thick, when required for use next day. If the acidity increases too rapidly at first, the bacteria are kept too long before use, in a highly acid medium not favorable to their growth, and in general this is to be avoided. The thickening of the milk at about 60° or 70° may be taken as an indication that the acidity is approximately .6%, which is about right for this purpose.

To control the temperature of ripening is not so likely to be troublesome as to avoid getting dirt and foreign bacteria into the startoline or starter, after it has once been thoroughly sterilized. Strictly speaking, it is impossible to sterilize milk perfectly, so as to kill all spores, by one such heating; and on this account attention should be given to selecting the best possible milk for starter making.

The importance of a good starter was made apparent when, beginning June 9, 1910, nine days' make of pasteurized milk cheese proved to be gassy and off-flavor, and bacteriological examination of the starter as well as the cheese demonstrated the presence of the same gas-forming organism in both. It

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[21] To further test the quality of the starter, a bottle of the thickened milk, unshaken and unopened, may be set away in a warm place for a day or two, to see if gas bubbles, or unpleasant flavors develop.

was clear that the organisms in question did not pass through the pasteurizer, since their thermal death point was found to be lower than the pasteurization temperature, 160°, employed in the process. Therefore, there could be no doubt that the improper preparation of milk for propagating startoline was the cause of the trouble in this case. The combined sterilizer and incubator described above was designed to make this work easier and more certain; and since it has been in use, no trouble has occurred.

II. CHEESEMAKING ON A FIXED TIME SCHEDULE, AFTER ADDING RENNET

General Arrangement of Schedule. In making cheese by the new method, the cheesemaker is relieved of a great deal of the uncertainty which attends cheesemaking by the ordinary methods. Having inspected the milk at the intake and rejected any that is curdled or otherwise unfit for use, he determines by means of the Manns acid test, the acidity of the entire vatful of mixed milk. This may be anywhere from .14% to .25%, or even a little higher, but if much above .28% the milk is likely to curdle and clog the pasteurizer. He then runs the milk through the pasteurizer, and adds to the cold milk as it flows into the cheese vat, enough dilute hydrochloric acid to raise the acidity of the whole vat to just .25% (calculated as lactic acid). Three-quarters per cent of a first class starter is added, and after heating to 85°, the color and rennet are stirred in immediately.

The rest of the process is conducted according to a fixed time schedule, which is never varied. The time from adding rennet to hooping the curd is always exactly 5 hours and 15 minutes, and this is divided every day in the season without exceptions, as shown in Table XVIII.

For example, if the rennet was added to the milk at exactly 9 a. m. the curd would be ready to put in the hoops 5 hours and 15 minutes later, i. e., at 2:15 p. m. As soon as the rennet is added, it is best to write out a schedule showing the time when each operation should be performed. Having once learned how to perform each operation in this method of cheesemaking, it is only necessary to do everything in as uniform a manner as possible, every day throughout the season, in order to get satisfactory results. There is never any need to hurry the process if the milk was over-ripe at the beginning, because the lactic acid bacteria are practically all killed by the pasteurization. No time is lost in working gas out of the curd because the gas forming bacteria are practically all killed in the pasteurizer. There is no reason for waiting to ripen the milk at the beginning of the process before adding rennet.

TABLE XVIII. TIME SCHEDULE FOR MAKING CHEESE BY THE NEW METHOD

Operation	Time intervals between operations		Total time after adding rennet	
	Hrs.	min.	Hrs.	min.
Adding rennet	0	0	0	0
Cutting the curd	0	25	0	25
Beginning to heat	0	15	0	40
Turning off steam	0	20	0	60
Placing rack, after drawing whey	1	25	2	25
Milling the curd	1	30	3	55
Salting the curd	1	00	4	55
Hooping the curd	0	20	5	15

Uniform Proportion of Cheese Color Used in 1911. Throughout the season of 1911, 2/3 of an ounce of a standard make of cheese color per thousand pounds of milk was used, giving the cheese a medium shade of color. These cheese were shipped into a number of different cities, and appeared satisfactory to dealers in all parts of the country, except in Philadelphia and Boston, Mass., where some dealers asked for white and others for highly colored cheese, as shown by the following extracts from letters.

Aug. 8, 1911	"Color is exactly right"	New York City, R. B. & Co.
Aug. 7, 1911	No comment on color	Minneapolis, Minn., C. V. & Co.
July 15, 1911	No comment on color	Marshfield, Wis., B. M. C. Co.
June 20, 1911	No comment on color	St. Louis, Mo., C. E. & Co.
June 6, 1911	"A good commercial color, but might stand a trifle more"	Sheboygan, Wis., C. S. S.
July 6, 1911	No comment on color	Sheboygan, Wis., P. H. P.
July 12, 1911	"A little too light color"	Fond du Lac, Wis., Z. M. Co.
May 29, 1911	"A very light color, would not do for this market"	Boston, L. M. & Co.
March 18, 1911	"Our market uses white cheese exclusively"	Boston, L. M. & Co.
March 18, 1911	"Most of our customers want it colored"	Washington, D. C., J. F. O.
March 21, 1911	"Have to have white cheese for Philadelphia"	J. S. M. & Co.
March 18, 1911	"Use both white and colored"	Boston, C. B. & Y.
Aug. 19, 1911	No comment on color	Plymouth, Wis., H. J. B. Co.
Sept. 1, 1911	No comment on color	Geneva, N. Y., G. A. S.
Aug. 1, 1911	No comment on color	Waterloo, Wis., R. & S. Co.
Aug. 19, 1911	No comment on color	C. & M. Chicago.
Aug. 4, 1911	"Should have a trifle higher color"	New York, P. C. Co.

Uniform Proportion of Rennet Required. The same proportion of rennet is always used in this process, because the milk is always in the same condition as to acidity at the time of adding rennet, and always ripens equally fast afterward. Therefore, having once selected the most suitable proportion of rennet, there is no reason for changing it. The use of two ounces of Hansen's or Marschall's rennet per thousand pounds of milk is adopted as the best practice, since this quantity produces visible coagulation in seven minutes as shown in Table II and the curd is in prime condition for cutting, 25 minutes after adding rennet. If the rennet extract is weaker than it should be, such amounts should be used as will cause coagulation in the time stated.

If a larger proportion of rennet than two ounces per thousand pounds milk were used there would hardly be time for the milk to become quiet before visible thickening began, and the curd might be damaged and broken through thickening while still in motion. On the other hand, over two years' experience with the method has shown that there is no need for using a smaller proportion of rennet than two ounces. Good cheese can be made with one ounce of rennet per thousand pounds of milk, but the coagulation of the milk is unnecessarily slow.

As in regular cheesemaking great care must be taken not to measure or dilute rennet extract in any container in which there is present the least trace of cheese color, because the cheese color is strongly alkaline, and rennet loses its coagulating power almost instantly, when in contact with alkalies.

Adding Starter, Color, and Rennet to the Milk. The temperature of all the mixed milk after pasteurizing is never above 85°, and commonly only 70° or 80°. The acidity may be tested, if desired, and should be between .24% and .26%. Three-quarters of a pound of starter per hundred-weight of milk in the vat is added immediately through a hair sieve, stirring the milk. The rake is then put in and the vat stirred, while heating up to 85°. The desired amount of color is stirred in, and always without exception the rennet is stirred in last of all. The rennet extract measured out for 5000 pounds of milk should be diluted in a pailful of water.

In adding rennet, first stir the milk across the vat the short way, going rapidly from one end of the vat to the other.

With the largest sized vats, two men with rakes may begin at the middle and walk toward the ends while stirring. Then walk back along the vat, adding the diluted rennet from a pail while the milk is still in vigorous motion, noting on the clock the instant when the rennet first enters the milk. Set down the pail and again stir the milk across the vat the short way, with the rake or rakes, for exactly one minute, in which time the operator should be able to walk up and down the vat three or four times. In this way the largest vats of milk or the smallest should be set. Take out the rakes promptly one minute after the rennet entered. Cover the vat at once, and leave undisturbed. No top stirring is necessary or permissible, as the milk begins to thicken in almost exactly seven minutes after adding rennet, before there is any visible cream rising. Follow the directions exactly as to temperature, acidity, and proportion of rennet, every day in the season.

Cutting, Stirring, and Heating the Curd. The curd formed in this process is always ready to cut exactly twenty-five minutes after the rennet entered the milk. Therefore, as soon as the rennet has been added, it is best for the operator to write the entire time schedule as shown in Table XVIII for the rest of the day's work on a paper or, better, on a black-board, which can be seen across the room. Some operators may suppose that possibly the curd might be cut a little earlier or later, but experience has shown that the curd is always in a thoroughly satisfactory condition for cutting, just 25 minutes after adding rennet. There is therefore no need for repeated testing of the curd with the finger, but one need only keep an eye on the clock, and follow the time schedule.

In cutting, begin with the horizontal knife, and cut lengthways of the vat; then use the vertical knife across the vat, cutting alternately towards and away from the operator. Finally, cut lengthways with the vertical knife. Do not cut the vat more than once in each direction, and try to do the cutting in exactly the same manner, every day. The different cuts should not lap, nor should portions of the curd wider than 3/8 inch be left uncut between the knives, except in the following case. In cutting next to the sides of the vat, as in the first and last cuts in each direction, hold the knife as close to the metal side of the vats as possible. If the knife does not appear wide enough to cut the remaining curd at the last stroke, cut close to the tin and leave a narrow strip of uncut curd not at the edge of the vat, but between the last cut and next to the last. This strip will be cut more thoroughly by the knives moving in the other directions, than if it had been left next the tin. Knives with blades, 3/8 inch apart, are required for this method.

Immediately after cutting, put the agitator blades in place, and start them in motion. The curd obtained in this process is so firm and solid that this can always be done safely. With the hand, go around the vat sometime during the next fifteen minutes, loosening the curd from the sides, bottom, and corners of the vat at every point. A form of agitator which is very satisfactory has one pair of revolving blades which move up and down the vat, somewhat resembling the motion of the rake.

Exactly fifteen minutes after cutting, turn steam into the jacket of the vat, and raise the temperature gradually just 19° during the next twenty minutes to 104°, which temperature is maintained one hour and twenty-five minutes, until the whey is drawn.

Drawing the Whey, Matting, Cutting, and Turning the Curd. The agitator is left running until about two minutes before the whey is to be drawn, when it is removed, and the curd after settling for a few seconds, is pushed slowly away from the gate with one or two rakes. The whey strainer is placed inside the vat, and the hair sieve below the gate in the conductor, and the gate is opened at such a time as will permit the whey to be out and the first rack to be put in place at the time given in the schedule. When the whey is nearly all out, the gate end of the vat is lowered gradually, and a few seconds later the curd is pushed down toward the gate, leaving the upper third or half of the vat bottom bare and free from whey. In this process, the curd is always sufficiently firmed in the whey, not to need any stirring in the whey or on the rack. With reasonably brisk work, the curd can be transferred to the curd cloth on the rack with a curd pail or scoop, before it has time to become lumpy on the bottom of the vat. Each pail of curd as it strikes the rack should fall apart loosely and not show the presence of great lumps of curd matted together. Any such lumps should be lightly broken up with the hand, and if many lumps appear it indicates lack of skill and quickness.

The curd is piled evenly on the rack about four or five inches thick, and the top is leveled off with the hand in the usual manner, and covered with the curd cloth. More racks if necessary are put in place, and the vat is finally covered, leaving the curd to drain. The little curd gauge made of wood, devised during the course of these experiments, and illustrated in Figure 8, is a help in getting the layer of curd of the right thickness, and also gives a good square end to

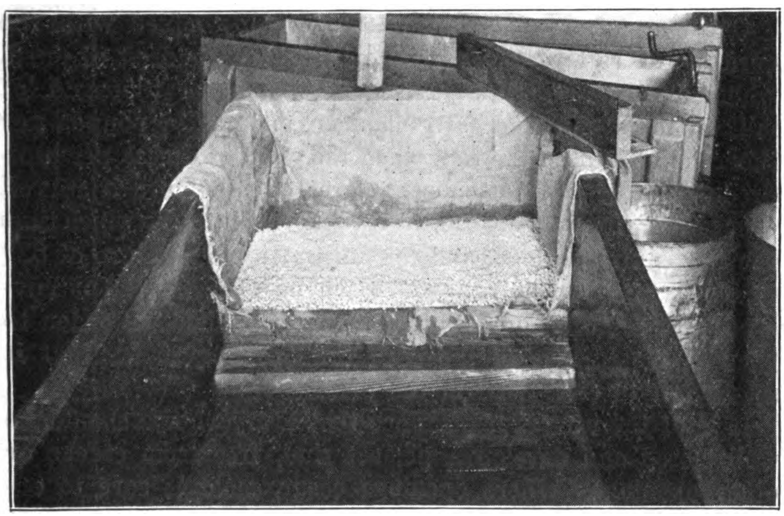

FIGURE 8. CURD ON THE RACK
Use of the gage shown on the upper corner of the vat insures even thickness.

the curd, which makes it easier to cut into blocks of uniform shape.

Just 15 minutes after the time scheduled for putting in the rack the curd gauge is removed and the cutting of the matted curd into blocks eight inches square or 6x12 inches is begun.

The blocks are turned over immediately after cutting and turned again 15 minutes later. They are then turned once in ten minutes, and piled two deep one hour after drawing the whey, and repiled every ten minutes until milled. In turning and piling, care is always used to turn the outer cooler surfaces toward the inside, in order that the entire mass of curd may remain at practically uniform temperature throughout, as in ordinary practice.

Milling, Salting, and Hooping the Curd. Exactly 1½ hours after the whey was drawn, the curd is milled. The milled curd is piled along the sides of the vat, so as to drain toward the middle.

It is stirred up with the hands from the bottom, turning the pile over, about once every 10 minutes after milling, so as to cool it somewhat, prevent matting, and allow free drainage. Little or no white whey ever escapes from the curd after milling or salting, when made by this process, although some clear whey or brine does drain away.

One hour after milling, salt is thoroughly mixed with the curd at the rate of two pounds of salt per hundred of curd, which amounts practically to two pounds per thousand of milk in the spring and early summer, and to 2¼ pounds per thousand of milk in the fall, when the yield of cheese per hundred-weight of milk is somewhat greater. The curd is stirred over several times during the next twenty minutes, by which time the salt is all dissolved, and the curd at a temperature of 82° to 86° is ready to be hooped. Each hoopful of curd is covered with a cloth and follower as soon as filled, in order to prevent the surface of the curd from cooling so far that it might fail to close well in the press.

It is of the utmost importance that every cheese should be well closed and develop a perfect rind, free from cracks or other openings. Where openings occur, mold is sure to enter during the curing process, and the flavor, especially, is apt to suffer as a result.

Pressing and Dressing the Cheese. Throughout the present set of experiments, the cheese have been pressed for about an hour, applying pressure with the hand lever only; and at first, only sufficient pressure is used to keep the drippings running from the hoops. After an hour, the cheese are dressed, and returned to the press, putting on the continuous pressure and leaving for the night.

In bandaging hoops, the usual starched circles are used under the heavy muslin or duck cap cloths, or if it is found that the circles are hard to remove for paraffining, they may be left out, and the cap cloths left on the cheese until paraffined. The cap cloths being of heavy cloth, can be stripped off rapidly without tearing, washed, and used many times.

The next morning, it is customary, as in cheese factories generally, to look over the cheese, straighten any bandages which may be faulty, and turn any crooked cheese over in the press, leaving them until noon to straighten.

Testing Cheese for Moisture When Dressed in the Hoops. With this process, the green cheese are found to differ very little in moisture content from day to day, as shown in Table XIX, column *B*.

TABLE XIX. COMPARISON OF MOISTURE DETERMINATIONS

Made (A) on samples taken when cheese was dressed, ¾ to 1 hour after pressing, and (B) on samples taken by trier from green cheese, next day, when removed from press.

Date	(A) Moisture content of cheese when dressed			(B) Moisture content after pressing			A—B= difference
	1st	2nd	Av.	1st	2nd	Av.	
Aug.	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
15	37.60	37.40	37.50	37.95	37.25	37.60	—0.10
16	38.50	38.70	38.60	38.50	39.00	38.75	—0.15
16*a*	33.50	38.90	38.70	38.05	38.50	38.27	+0.43
17	39.60	39.10	39.35	38.50	38.60	38.55	+0.80
17*a*	38.90	39.00	38.95	39.40	39.40	39.40	—0.45
18	37.80	37.75	37.77	37.75	37.95	37.85	—0.08
18*a*	42.25	42.25	42.25	41.25	41.40	41.32	+0.93
23	38.80	38.80	38.80	38.05	38.45	38.25	+0.55
23*a*	42.25	42.45	42.35	42.20	42.10	42.15	+0.20
24	39.35	39.05	39.20	39.70	40.30	40.00	—0.80
24*a*	44.25	44.30	44.27	43.15	43.30	43.22	+1.05
25	39.55	39.70	39.62	39.30	39.65	39.46	+0.16
25*a*	44.10	44.45	44.27	44.25	44.95	44.60	—0.33
26	38.95	39.10	39.02	38.80	39.00	38.90	+0.12
26*a*	44.30	44.60	44.45	42.80	43.00	42.90	+1.55

a Cheese was made in two vats, and each vat of curd was tested for moisture separately. Those marked *a* were made from raw milk.

The determination of moisture in cheese is not recommended as a part of the daily work in a factory. It is of great value, however, in experimental work, where it is desired to study the effect of different methods of handling curds on their moisture content, or the effect of different moisture content on the market value or keeping quality of cheese.

Moisture tests are easily made. It is objectionable however, to plug a new cheese every day, for a moisture test, because of the danger of admitting molds, etc., beneath the rind; and it has been found that the plugging of green cheese can be entirely avoided by sampling the cheese at the time it is dressed in the hoop about one hour after putting it to press. The trier hole made at this time will entirely close over night in the press, leaving the rind perfect. Samples of cheese taken from the curd when dressed, and tested for moisture, agreed closely in moisture content with samples taken with a trier from the same cheese the next day, after pressing about 20 hours, as shown in Table XIX. The moisture tests were all made by heating 10-gram portions of the curd for at least three hours in the Wisconsin High Pressure Steam Oven.[22] After three or four hours, there is practically no further loss of weight from samples of fresh curd, in 24 hours heating. Samples of cured cheese continue to lose weight with continued heating, much more noticeably than samples of fresh curd or cheese.

Drying, Paraffining, and Curing. The cheese taken from the press are stenciled with the brand, and date of making, or a reference number, and placed on shelves in a well ventilated room, to dry on the surface. The temperature of this room may be as high as 70°. Here they are turned over once a day.

The cheese should be paraffined when five to ten days old, or possibly earlier. The paraffine should be at 220° F., at least, and better at 230° to 250°. The thinnest possible coat of paraffine is the best, and the cheese should be held in it about five seconds, then drawn out and left to drain over the vat, on a rack, until they can be handled. A thin coating of paraffine is flexible, and less likely to crack, than a thick coating.

It is possible to cure this cheese at any temperature bebetween 34° and 75°. When it is desirable to cure the cheese as fast as possible, they may be cured at 75° without injury to the quality. However, at this temperature, there is considerable shrinkage, and it is necessary to wipe the cheese occasionally and turn them over to prevent them from getting moldy, and sticking to the shelves.

At 45° to 55°, the cheese cure well, with little shrinkage and a minimum amount of labor. Stored at 34° at the age of 1 week, the cheese cure well, and develop little or no mold on the surface; but owing to the extra cost, this temperature should be employed only where it is necessary to hold cheese for considerable length of time.

Branding Cheese Made From Pasteurized Milk. In order

[22] Wis. Expt. Sta. Bul. 154.

that customers may be sure that they are getting genuine pasteurized milk cheese, when called for, every cheese should be marked with the words, "Pasteurized Cheese," running all around the edge of the cheese. All persons making cheese according to the process here described, should use such a label, in order to distinguish this product from the ordinary cheddar cheese made in factories, generally, at the present time.

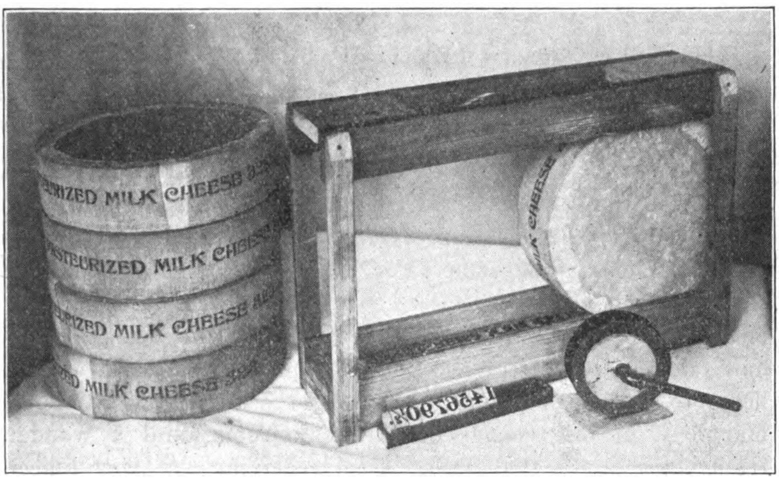

FIGURE 9. MARKER FOR PASTEURIZED CHEESE

All pasteurized milk cheese should be marked to identify and advertise them. The type is inked by the roller and the cheese are marked by rolling them through the frame over the type.

A large number of cheese can be rapidly marked with a rubber stamp, or by rolling the cheese over rubber type, set in a board, as shown in Figure 9. Narrow strips of wood on each side of the board prevent the cheese from rolling sidewise off the type.

Selling Cheese. In a new style of product, uniformity is a quality which consumers and dealers require. It is recommended that the maker of this style of cheese keep back one cheese from each day's make, when shipping, until the cheese have been accepted and paid for by the buyer. These sample cheese can then be sent along with the next shipment without plugging. If necessary the cheese can be plugged with a trier, and by this means the maker will be able to study any faults which may be observed by the buyer, and avoid them in the future. Names of leading cheese dealers, who have already received sample shipments of this cheese and found it suitable for their trade, can be obtained from the authors.

Where a maker doubts whether the buyer is giving him a square deal, it is recommended that each day's make be sent to two different dealers, whose criticisms, if any are received, can be compared by the maker at the factory.

III. TWO YEARS TRIAL OF THE NEW METHOD

INCREASED YIELD OF CHEESE OBTAINED BY NEW PROCESS

Apparatus and Methods of Study. In the year 1909–1910 it was found that an increased weight of cheese is regularly obtained after pasteurization, over the weight obtained by the regular factory methods. For the purpose of accurately studying the yield of cheese, two scales were used in 1911, one of 5000 pounds capacity, graduated on the beam to one-half pound; and one of 300 pounds capacity graduated on the beam to one-tenth pound. The larger scale was set up permanently in one corner of the make-room, and a wooden frame carrying a 300 gallon steel receiving vat was placed upon it. The outlet of the vat is of sanitary metal piping, suspended by wire to the vat, in such a way that the pipe and contents are weighed each time with the vat. The frame, vat, and pipe weighed 487½ pounds when empty. The separate weights and the scale on the beam were carefully tested by use of test weights. The entire set of weights agreed among themselves so closely that no difference could be detected in the equilibrium of the beam, when one weight was substituted for another in weighing a load. The error in a single weighing was not over ¼ pound with large or small loads. Except when weighing, the lever is kept up, thus relieving the knife edges from load and wear.

The method of using this apparatus is as follows: The vat being empty, with the pipes in place and stopcocks closed, the supply of milk is run into the vat through a conductor and cloth strainer. The strainer and conductor are then removed, the lever is lowered, and the weight of vat and contents determined. It is our habit to balance the scales exactly, giving neither "up" nor "down" weight. The lever is then raised, and the operator climbs up the ladder on the frame to the run board along side of the vat. With a dipper, he stirs the milk continuously and vigorously for 5 or 10 minutes, and continues stirring while a portion of the milk is being drawn out for use in one of the experimental cheese vats. The vat and the remaining milk are then weighed with the same precautions as before, after which another portion of the milk may be drawn off for use in another vat in the same manner.

The precautions mentioned above seemed sufficient to insure thorough mixing of the milk used in two vats, in making check and pasteurized cheese respectively, at the time it was drawn from the receiving vat; and accurate weighing of each lot with a total possible error of not over ½ pound in a vat of 200 to 2,000 pounds milk, that is, not over .25% at most.

The other new scale mentioned is a counter scale graduated on the beam to one-tenth pound and sensitive to 1/20 of a pound with any load up to 200 pounds. This was used for weighing cheese, throughout the work here described. The set of weights used agreed among themselves, and with the test weights used with the other scale.

With this scale, 20 to 200 pounds of cheese could readily be weighed with an error of not over .05 pound, or .25%, at most. On sixty-eight days during the season of 1911, the receiving vat of milk was divided into two accurately weighed portions, for this experiment. One of these was pasteurized, and made into cheese by the new method. The other portion was made into cheese by regular factory methods. The cheese were 13½ inches diameter by four inches high, the "daisy" size. The green cheese were always weighed as quickly as possible after being removed from the hoops. The daily record of weights of milk used, and of cheese obtained and the per cent of increased yield which resulted from pasteurization, are shown in Table XX. It will be noted that every day in the season, there was a larger yield of cheese from the pasteurized milk. From 250 to 1,700 pounds of milk was handled in each vat. The average yield of green cheese from raw milk was 9.815 pounds and from pasteurized milk was 10.337 pounds per 100 pounds of milk.

The daily increase in yield ranged from 0.6% to 12.0%, and in fifty cases (72%) lay between 3% and 8%, while the aver-

TABLE XX. INCREASED YIELD OF GREEN CHEESE OBTAINED BY THE NEW METHOD, FROM PASTEURIZED MILK

Date made	Pasteurized milk			Raw milk			Gain in yield by new process	Starter used in raw milk
	Weight		Yield of cheese per cwt milk	Weight		Yield of cheese per cwt. milk.		
	Milk used	Green cheese		Milk used	Green cheese			
1911	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Per cent.	Per cent.
Feb.								
23	538.0	53.20	9.89	380.0	35.40	9.31	6.23	0.00
24	504.5	51.00	10.11	380.0	36.60	9.63	4.98	0.00
27	1,026 5	106.20	10.35	600.0	57.80	9.63	7.48	0.00
28	800,0	82.20	10.27	400.0	38.30	9.57	7.31	0.75
March								
1	350.0	35.40	10.11	510.0	50.20	9.84	2.75	1.50
2	389 5	39.00	10.01	628.0	59.70	9.51	6.61	0.75
3	340.0	35.00	10.29	522.0	52.30	10.02	2.79	1.50
7	855.0	88.20	10 32	380.0	38.40	10.11	2.08	2.00
8	590.0	60.70	10.29	388.5	39.30	10.12	1.68	1.50
9	418.0	42.80	10.24	417.5	41.00	9.82	4.27	1.00
10	442.0	44.70	10.11	700.0	66.40	9.49	6.53	0.00
13	1.166.0	122.00	10.46	275.0	25.70	9.34	12.00	0.00
14	956.0	103.40	10 81	260.0	25.80	9.92	8.97	0.75
15	570.5	58.10	10.18	380.0	37.50	9.87	3.14	0.75
16	531.5	56.90	10.71	359.0	37.40	10.42	2.78	2.00
17	395.0	41.20	10.43	396.0	39.80	10.05	3.78	2.50
20	1.344.0	136.00	10.12	384.0	36.60	9.53	6.19	0.00
21	570.0	56.40	9.89	378.0	35.30	9.34	5.89	0.00
22	362.5	36.00	9.93	542.0	51.80	9.56	3.87	1.67
April								
5	585.0	60.80	10.39	390.0	37.70	9.67	7.45	0.75
7	508.0	51.15	10 07	339.5	32.50	9.57	5.22	0.75
11	549.0	55.00	10.02	549.0	52.60	9.58	4.59	0.75
13	364.0	35.70	9.81	364.0	34.55	9.49	3.37	0.75
17	800.0	80.25	10.03	600.0	55.50	9.25	8.43	0.00
18	720.0	71.15	9.88	540.0	49.80	9.22	7.16	0.00
24	1,254.0	122.80	9.79	660.0	61.90	9.38	4.37	0.75
27	570.0	55 30	9.70	380.0	35.70	9.39	3.30	0.75
28	420.0	40.85	9.73	420.0	40.05	9.54	1.99	0.75
May								
2	636.0	65.05	10.23	424.0	42.00	9.91	3.23	0.75
3	558.0	54.30	9.73	372.0	35.55	9.56	1.81	0.75
8	1,693.0	158.15	9.34	800.0	70.95	8.87	5.30	0.75
10	798.0	77.60	9.72	798.0	73.70	9.24	5.19	0.75
15	1,587.0	161.60	10.18	800.0	76 90	9.61	5 93	0.75
17	1,088.5	109.00	10.01	800.0	76.60	9.57	4.60	0.75
22	1,223.0	129.40	10.58	800.0	78.20	9.77	8.29	0.75
25	851.0	87.00	10.22	800.0	78.80	9.85	3.76	0.75
29	1,315.0	138.60	10.54	800.0	80.20	10.02	5.29	0.75
June								
1	798.0	83.50	10.46	800.0	83.10	10.39	0.67	0.75
2	799.5	82.85	10.36	800.0	79.50	9.94	4.23	0.75
7	790.5	79.65	10.07	800.0	76.60	9.57	5.22	0,75
9	800.0	82.30	10.29	800.0	78.15	9.77	5.32	0.75
13	1,090.0	119.70	10.98	800.0	80.20	10.02	9.58	0.00
15	795.0	85.50	10.75	800.0	80.70	10.09	6.54	0.75
16	800.0	83.45	10.43	800.0	78.95	9.87	5.67	0.75
19	810.0	87.60	10.81	800.0	79.65	9.96	8.54	0.00
21	798.5	81.75	10.24	800.0	77.70	9.71	5.46	0.75
26	770.0	80.65	10.47	770.0	75.45	9.80	6.84	0.00
27	801.0	83.50	10.42	800.0	79.00	9.88	5.46	0.75
28	801.5	85.90	10.73	800.0	82.00	10.25	4.68	0.75

TABLE XX Continued. INCREASED YIELD OF GREEN CHEESE OBTAINED BY THE NEW METHOD, FROM PASTEURIZED MILK

Date made	Pasteurized milk			Raw milk			Gain in yield by new process	Starter used in raw milk
	Weight		Yield of cheese per cwt. milk	Weight		Yield of cheese per cwt. milk		
	Milk used	Green cheese		Milk used	Green cheese			
1911	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Per cent	Per cent
July								
3	1,234.0	122.75	9.95	800.0	72.35	9.04	10.07	0.00
6	995.0	102.45	10.30	660.0	66.10	10.02	2.79	0.75
8	1,068.0	108.50	10.16	660.0	62.80	9.52	6.72	0.00
10	1,064.5	107.30	10.08	800.0	74.35	9.29	8.50	0.00
11	914.0	93.50	10.23	660.0	63.65	9.64	6.12	0.00
12	873.0	93.15	10.67	800.0	78.20	9.77	9.21	0.75
24	1,195.0	125.10	10.47	600.0	58.20	9.70	7.94	0.75
26	1,099.0	118.32	10.77	190.0	19.32	10.17	5.90	0.00
August								
29	294.5	31.58	10.72	290.0	30.50	10.52	1.90	0.75
30	344.0	35.82	10.41	340.0	34.05	10.01	4.00	0.75
Sept.								
1	322.0	34.10	10.59	320.0	32.60	10.19	3.92	0.75
5	291.5	31.00	10.63	292.0	29.65	10.15	4.73	0.75
6	276.0	28.95	10.49	275.0	27.20	9.89	6.46	0.75
7	286.5	31.03	10.83	286.5	29.48	10.29	5.24	0.75
8	292.0	31.50	10.79	292.0	30.25	10.36	4.14	0.75
20	263.0	29.15	11.08	263.0	27.80	10.57	4.82	0.75
22	265.0	29.20	11.02	266.5	28.05	10.52	4.75	0.75
25	748.0	83.90	11.22	250.0	26.40	10.56	6.25	0.75
October								
2	700.5	79.25	11.31	420.0	45.10	10.74	5.31	0.75
3	251.0	27.75	11.05	250.0	26.25	10.50	5.24	0.75
Average	....	....	10.337	....	....	9.815	5.374	....

age increase in yield by the new process on sixty-nine days was 5.37%.[23]

On forty-five days, the same proportion of skim milk starter (.75%) was used in both the raw and the pasteurized milk. On sixteen days, none was used in the raw milk and on eight days, 1% to 2½% (average, 1.71%) was used in the raw milk, while in every case, the pasteurized milk received .75% starter. If the use of starter affects the yield of cheese, the average yield from the pasteurized milk was raised about .75% on sixteen days; while the average yield from raw milk was raised on eight days about 1.71%. These two effects off-

[23] Both the median and the mode lie betwen 5% and 6%. The mode may be defined as the class which occurs with the greatest frequency. The median is the magnitude at the middle of the series, from largest to smallest.

See C. B. Davenport, Statistical Methods, N. Y., 1899; or E. Davenport, Principles of Breeding, p. 684.

set each other in Table XX, giving a slight advantage to the yield from the raw milk, so that the final average figure (5.37%) representing the average gain in yield of green cheese by the new process, is no higher and possibly a trifle lower than it would have been, if equal proportions of starter had been used in all cases.

Among the seventeen cases in Table XX, in which no starter was used in the raw milk vat, the average gain using .75% starter in the pasteurized milk vat, was 7.48%; and in eight cases, where more than .75% starter was used in the raw milk, the average gain in yield in the pasteurized milk vat was 3.00%. From this it would appear that the proportion of starter used does notably affect the yield of cheese, contrary to some recent statements.[24]

Search for Errors in Experiments on Yield of Cheese. Sources of error were carefully guarded against in the daily work on the yield of cheese. Before dividing milk from the receiving vat for use in the two make vats, the milk was thoroughly stirred four to ten minutes as already stated, and the stirring was continued while the milk was running out. The portion of milk drawn out first, was commonly used for making the raw milk cheese, but sometimes as on March 8, 9, 10, 17, 21, 22, and April 7, 11, 17, 18, and May 10, the portion drawn first was used for making the pasteurized milk cheese. The average gain in yield through pasteurization on these eleven days was 5.15%, so nearly equal to the figure 5.37% (see Table XX) as to indicate that the gain in yield is not due to any difference in composition of the milk, when divided into two lots. Carefully tested thermometers and the same pair of curd knives were used in every vat.

Usually, the vat of pasteurized milk was set with rennet five minutes before the vat of raw milk. The two vats were placed near each other, and conditions were such that one operator could stir them both at once, if desired. On eleven days, April 18, 24, 27, May 8, 10, 15, 17, August 29, 30, September 1, and October 2, the rennet was added to the raw milk first, and to the pasteurized milk five minutes later. The average gain in yield on the eleven days was 4.63%, indicating that the order of setting the vats had nothing to do with the gain in yield.

[24] VanSlyke and Publow, Theory and Practice of Cheesemaking, p. 69.

In order to ascertain what per cent of unavoidable error enters into the measurement of yield of cheese, and into the figure 5.37% (from Table XX), a special experiment was performed on thirty-four days. Each day, with all of the usual precautions, two lots of milk drawn from the receiving vat, were run through the pasteurizer, one after the other, and made up into cheese in separate vats marked *c* and *d* standing near each other, and handled by the same operator (Mr. Bruhn). The vats were heated up and set exactly five minutes apart by the watch, and the time schedule for each vat was strictly followed in every detail. The same curd knives and thermometer were used in both vats.

The pasteurizer and cooler are always rinsed with hot water at the beginning of the first run, but are wet with adhering milk at the close of the run, just before beginning the second run. Thus the actual weight of milk in the first vat might be slightly less than it should be. To avoid this source of error, the pasteurizer and cooler were allowed to drain each time into the vat for several minutes (until the stream of milk broke into single drops), and then the metal surfaces were carefully rinsed with two measured portions of clean water. Thus the surfaces of the pasteurizer and cooler were wet with water at the beginning of the second run, as well as the first. The milk content of the rinsings (see Table XXI) was found

TABLE XXI. WEIGHT AND CONTENTS OF RINSINGS OF PASTEURIZER AND COOLER

Date	Vat	Weight of rinsings	Fat in rinsings	Weight of fat in rinsings	Estimated weight of cheese in rinsings	Estimated weight of milk in rinsings
1911 April		Lbs.	Per cent	Lbs.	Lbs.	Lbs.
25..........	c	2.25	1.25	.028	.08	.8
25..........	d	2.25	1.25	.028	.08	.8
26..........	c	2.25	1.20	.027	.08	.8
26..........	d	2.25	1.20	.027	.08	.8

to be very small and uniform, amounting to about .8 pound of milk each time, which, if it were all lost from one vat but not the other, would cause a difference of yield of cheese from a 500 pound lot of milk (as in Table XXII) of about .16%. In order to avoid this source of error entirely, the rinsings from both runs were either thrown away, as on the first fifteen days listed in Table XXII, or the rinsings after each run were added to the respective vats, as on the last nineteen days.

The yields of cheese obtained in duplicate vats thus handled, were never exactly equal; and varied on the average of thirty-three days, by about .58% of the weight of the cheese, as shown in Table XXII. The milk in vat *C* was drawn first

TABLE XXII. YIELD OF CHEESE FROM DUPLICATE VATS OF PASTEURIZED MILK

Date	Vat C			Ratio of milk wts. in two vats	Vat D			Difference in yield obtained in two vats
	Weight of milk used	Weight of green cheese	Cheese per cwt. milk		Weight of milk used	Weight of green cheese	Cheese per cwt. milk	
1911 Mar.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Per cent
23	430.0	42.50	9.884	1 : 1	430.0	42.55	9.895	0.11
24	390.0	38.80	9.949	1 : 1	390.0	39.10	10.026	0.77
27	375.0	36.10	9.627	1 : 3	1125.0	109.20	9.707	0.83
28	350.0	36.60	10.457	1 : 2½	875.0	92.20	10.537	0.76
29	585.0	59.10	10.102	1½ : 1	390.0	39.45	10.115	0.13
30	495.6	50.10	10.121	1½ : 1	330.0	33.50	10.151	0.30
31	540.0	54.20	10.038	1½ : 1	360.0	36.15	10.042	0.04
April								
4	585.0	60.50	10.342	1½ : 1	390.0	40.55	10.397	0.53
6	534.0	54.15	10.140	1½ : 1	356.0	37.35	10.491	3.46*a*
10	1080.0	106.30	9.842	3 : 1	360.0	35.65	9.903	0.62
12	555.0	55.70	10.036	1½ : 1	370.0	37.60	10.162	1.25
14	380.0	38.10	10.026	1 : 1	380.0	38.40	10.105	0.79
19	400.0	40.30	10.075	1 : 1	400.0	40.60	10.150	0.74
20	370.0	36.75	9.932	1 : 1½	555.0	55.40	9.728	0.50
21	380.0	37.00	9.737	1 : 1½	570.0	55.45	9.728	0.09
25	420.0	41.00	9.762	1 : 1	420.0	40.90	9.738	0.25
26	370.0	36.20	9.784	1 : 1½	555.0	54.35	9.793	0.09
May								
4	420.0	42.10	10.024	1 : 1	420.0	42.50	10.119	0.95
5	531.0	51.40	9.680	1½ : 1	354.0	34.35	9.703	0.24
9	408.0	40.65	9.963	1 : 1½	612.0	60.80	9.935	0.28
11	410.0	41.50	10.122	1 : 1	410.0	41.80	10.195	0.72
12	795.0	78.25	9.843	1 : 1	795.0	79.50	10.000	1.59
16	800.0	80.30	10.037	1 : 1	800.0	80.65	10.081	0.44
18	600.0	63.80	10.633	1 : 1	600.0	62.70	10.450	1.75
19	600.0	62.20	10.367	1 : 1	600.0	61.95	10.325	0.41
23	600.0	64.00	10.667	1 : 1	600.0	63.75	10.625	0.39
24	612.25	64.35	10.510	1 : 1	612.25	65.15	10.641	1.24
30	600.0	61.30	10.217	1 : 1	600.0	60.75	10.125	0.91
31	600.0	62.10	10.350	1 : 1	600.0	62.12	10.353	0.03
June								
6	583.0	59.15	10.146	1 : 1	577.75	59.15	10.238	0.91
8	600.0	61.55	10.258	1 : 1	600.0	61.85	10.308	0.49
14	600.0	62.28	10.380	1 : 1	600.0	62.15	10.358	0.21
17	599.5	62.71	10.460	1 : 1	599.5	63.11	10.527	0.64
20	600.0	60.30	10.050	1 : 1	600.0	60.90	10.150	0.99
Ave.*a*	535.22	....	10.105	....	536.37	....	10.149	0.585*a*

*a*April 6 omitted from average.

from the receiving vat, and was pasteurized and set first in all cases, except where otherwise noted.

Among the thirty-four days' results obtained during the season on this question, (Table XXII) the difference in yield between duplicate vats exceeded 1.75% in only one case. On this day, (April 6), there was unusual difficulty in the work, because of unexpected failure of the supply of water for cooling, and although the direct cause of the exceptionally high figure, (3.46%) cannot be directly traced, it seems likely that some gross error occurred on that day, which was avoided ordinarily. Therefore this figure (for April 6) is omitted from the general average.

On twenty-eight days (82% of all cases) the variation in yield between duplicate vats lay below 1% and on thirty-three days, (omitting April 6) it averaged .58%. For present purposes, therefore, it may be considered that the figure 5.37%, from Table XX, representing the average increased yield of green cheese obtained through pasteurization, is correct within .58% or about one-ninth of its value.

The yield of cheese from pasteurized milk is thus capable of measurement with an average difference between duplicate determinations of .60% of the amount determined.

This degree of accuracy in manipulation is comparable with that attained in many analytical chemical processes, in which a limit of 1% of the amount determined is commonly set as the maximum allowable difference between duplicates.

The principal cause for the difference of .60% yield in making duplicate vats of cheese, does not lie in the weighing of the milk or cheese, because with the scales employed either the 500 pounds of milk used in one vat, or the 50 pounds of cheese obtained therefrom, could be weighed with an error of not over .10%. The per cent of difference in yield was not reduced when the weight of milk handled was doubled on March 24 and April 10. It appears likely, therefore, that there are small unavoidable differences of size of cubes, or in the manipulation of milk and curd, which cause an average difference in yield of about .50% to .60% between duplicate vats.

An effort was made, so far as time permitted, to determine whether any one of several causes was regularly or chiefly responsible for this average difference of about .50% to .60% in yield. The stirring of the vats was done by hand in all cases where the weight of milk in a vat was less than 400 pounds. For experiments with 400 to 800 pounds of milk in a vat, two vats of 800 pounds capacity were used. These were stirred with a pair of wooden rakes, exactly alike in shape and size.

Larger quantities of milk than 800 pounds were always handled in a vat of 2,400 pounds capacity, in which a two bladed, rotating and oscillating agitator was used, instead of the rake. Differences in yield between duplicate vats could not be traced to the methods of stirring. Thus on March 27, the agitator stirred vat *D* gave .83% greater yield than the hand stirred vat *C;* but on April 10, the hand stirred vat *D* gave .62% greater yield than the agitator stirred vat *C*. The average difference on twelve days in yield between duplicate rake-stirred vats, was .70%, and the average difference in yield between duplicate hand stirred vats (on nineteen days) was .52%, but the differences varied slightly ,whatever method of stirring was employed.

Handling different amounts of milk (by the new method) does not appear to affect the yield in duplicate vats. On twelve days, using 1½ to 3 times as much milk in one vat as in the other, the average difference in yield was .40% which is a little smaller than the average of the other days, showing that the quantity of milk handled by this method does not affect the yield. Since the same results are obtained in a small vat with 375 pounds of milk as in a large one with 1,125 pounds it is believed that the general results of this investigation are applicable to the largest sized vats of milk used in factories.

Shrinkage before Paraffining, and Yield of Paraffined Cheese. Since there is always some loss in weight of cheese, previous to paraffining, it is of interest to compare the shrinkage of ordinary cheese with that of new process cheese, and to determine whether there is an increased yield of pasteurized milk cheese, paraffined, corresponding to the increased yield observed in the same cheese when green. This can be done readily from Table XXIII, which shows the average results for the season and also the range of daily variation.

In practically every case in Table XXIII, the pasteurized milk cheese showed a greater shrinkage than the raw milk cheese, during the period before paraffining, which was seven to nineteen days. The shrinkage of raw milk cheese before paraffining, on the average of all sixty-five cases, was 4.08 pounds per hundred of green cheese, and for the pasteurized milk cheese was 4.55 pounds per hundred, nearly ⅛ greater than the raw. This excess shrinkage is observed, whether the cheese

TABLE XXIII. COMPARISON OF OLD AND NEW PROCESS CHEESE AS TO SHRINKAGE BEFORE PARAFFINING, AND YIELD OF PARAFFINED CHEESE

Date made	Age when paraffined	Cheese weighed when paraffined: Total shrinkage per 100 pounds of green cheese		Cheese weighed when paraffined: Yield per 100 pounds of milk		Gain in yield by new process
		Pasteurized	Raw	Pasteurized	Raw	
1911	Days	Pounds	Pounds	Pounds	Pounds	Per cent
Feb.						
23	19	5.92	5.23	9.30	8.83	5.32
24	18	5.98	5.05	9.50	9.14	3.94
27	15	5.32	4.67	9.79	9.48	6.64
28	14	5.23	4.57	9.74	9.14	6.56
Mar.						
1	13	5.36	4.88	9.57	9.36	2.24
2	12	5.26	4.35	9.49	9.09	4.40
3	15	5.71	5.35	9.71	9.48	2.43
7	11	5.21	4.43	9.78	9.66	1.24
8	10	4.45	4.58	9.83	9.65	1.86
9	9	5.49	4.82	9.68	9.35	3.53
10	8	3.58	3.35	9.75	9.17	6.32
13	12	5.08	4.28	9.93	8.95	10.95
14	11	5.13	4.26	10.26	9.50	8.00
15	10	3.96	3.73	9.78	9.50	2.95
16	9	4.22	3.61	10.25	10.04	2.09
17	8	3.88	3.27	10.03	9.72	3.19
20	12	5.37	4.37	9.58	9.11	5.16
21	11	4.42	3.68	9.46	8.99	5.23
22	10	4.72	3.86	9.46	9.19	2.94
Apr.						
5	10	4.36	3.58	9.94	9.32	6.65
7	8	4.10	3.85	9.66	9.20	4.60
11	10	5.09	4.56	9.51	9.14	4.05
13	8	4.62	4.05	9.35	9.11	2.63
17	12	5.11	4.23	9.52	8.86	7.45
18	11	4.85	4.42	9.40	8.81	6.70
24	12	5.05	4.11	9.30	8.99	3.45
27	9	3.98	3.64	9.32	9.05	2.98
28	8	2.82	2.62	9.45	9.29	1.72
May						
2	11	4.36	3.93	9.79	9.52	2.84
3	10	4.33	4.08	9.31	9.17	1.53
8	13	4.52	4.65	8.91	8.46	5.32
10	11	4.19	3.73	9.32	8.89	4.83
15	12	4.64	4.36	9.71	9.19	5.65
17	10	4.57	3.98	9.49	9.19	3.26
22	12	4.71	4.09	10.08	9.37	7.57
25	11	4.71	3.93	9.74	9.46	2.96
29	13	4.72	4.37	10.04	9.59	4.69
June						
1	10	3.92	3.67	10.05	10.01	0.40
2	9	4.22	3.92	9.93	9.55	3.98
7	7	4.21	3.66	9.66	9.22	4.77
9	8	3.80	3.58	9.90	9.42	5.09
13	10	5.26	4.74	10.40	9.55	8.90
15	8	4.49	3.82	10.18	9.70	4.95
16	7	4.43	3.64	9.97	9.51	4.84
19	12	4.85	4.27	10.29	9.53	7.97
21	10	4.46	4.18	9.78	9.31	5.05
26	12	4.53	4.17	10.00	9.40	6.38
27	11	4.19	3.80	9.99	9.50	5.16
28	10	4.02	3.41	10.30	9.90	4.04
July						
3	14	4.56	3.91	9.49	8.69	9.21
6	11	4.20	4.01	9.86	9.61	2.60
8	9	3.64	3.42	9.79	9.19	6.53
10	10	4.80	4.64	9.60	8.86	8.35
11	11	4.46	4.01	9.77	9.26	5.51
12	10	4.54	3.65	10.19	9.42	8.17

TABLE XXIII Continued. COMPARISON OF OLD AND NEW PROCESS CHEESE AS TO SHRINKAGE BEFORE PARAFFINING, AND YIELD OF PARAFFINED CHEESE

Date made	When paraffined	Cheese weighed when paraffined				Gain in yield by new process
		Total shrinkage per 100 pounds of green cheese		Yield per 100 pounds of milk		
		Pasteurized	Raw	Pasteurized	Raw	
1911	Days	Pounds		Pounds		Per cent
Aug.						
29	11	4.99	6.07	10.18	9.88	3.14
30	10	4.22	4.05	9.97	9.61	3.75
Sept.						
1	8	4.14	4.14	10.15	9.77	3.89
5	13	4.35	4.05	10.17	9.74	4.42
6	12	3.82	3.49	10.09	9.54	5.65
7	11	3.49	2.99	10.45	9.98	4.71
8	10	3,17	2.81	10.45	10.07	3.77
20	10	3.80	3.41	10.66	10.21	4.41
22	8	3.43	3.21	10.64	10.19	4.42
25	16	6.49	5.87	10.49	9.94	5,53
Average	....	4.546	4.078	9.833	9.388	4.761

were paraffined at seven or fourteen days of age, as shown in the Table XXIV.

On account of this excess shrinkage before paraffining, amounting to about ½ pound per hundred pounds of cheese, the average increased yield of 5.37 pounds per hundred of

TABLE XXIV. SHRINKAGE OF CHEESE WHEN PARAFFINED AT DIFFERENT AGES
Summary of Table XXIII

Age when paraffined	Cases averaged	Average shrinkage in weight per 100 pounds green cheese		Difference in shrinkage of pasteurized over raw	
		Pasteurized	Raw		
Days	Number	Lbs.	Lbs.	Lbs.	% of Raw
7 to 8	11	3.95	3.56	.39	11
9	5	4.31	3.88	.43	11
10	16	4.35	3.83	.52	13
11	12	4.52	4.10	.42	10
12	10	4.84	4.17	.67	16
13 to 19	11	5.29	4.78	.51	11
Total	65			Average	12

milk observed in the pasteurized cheese when green (Table XX) was reduced to 4.76 pounds (see Table XXIII), by the time the cheese are paraffined.

Shrinkage and Yield of Cured Cheese. The further shrinkage and yield of cheese after paraffining, was studied (1) with cheese cured at Madison at a temperature of 60° to 75°,

(2) with cheese cured at New Orleans, La., and weighed both at New Orleans[25] and also at Madison before shipment and after its return, (3) with cheese cured at New Orleans, La., or at Columbus, Ga., and weighed both by Crosby and Meyers at Chicago, and by us at Madison, and (4) with cheese at different ages after paraffining in cold storage, at 34°, at Waterloo, Wis. So far as possible, duplicate cheese from the same day's make were cured in the different ways stated.

These different methods of curing were chosen for study, as representing (1) curing conditions at Wisconsin factories; (2) and (3) conditions to which annually large amounts of cheese are subjected when shipped south for sale; or (4) when cured in cold storage as commonly practiced by dealers.

The shipments to New Orleans were sent on four dates between April 29 and July 24, 1911. Each shipment consisted of nine to twenty-five pasteurized milk cheese, and an equal number of raw milk cheese, for comparison. In order that the cheese stored might be as representative as possible, each pair of cheese represented a different day's make.

For each lot of cheese shipped away from Madison for storage, a duplicate lot, from the same days' make was kept at Madison. The method of designating these different lots of cheese is shown in Table XXV.

In addition to weighing each cheese separately, they were also weighed in lots of five and the close agreement of the weight of a lot of five with the sum of the five separate weights proved the accuracy of the weighing. This general method of double weighing was followed, in obtaining all the weights of cheese in the fourteen lots.

The tabulated results show the shrinkage of the different lots of cheese and the yield of green, paraffined and cured cheese per hundred pounds of milk. In addition to the average results for each lot of cheese, the individual variations in shrinkage and yield of the single cheese are shown, from which the extent of daily variations from the general average figures can be studied.

Cheese Stored at Madison. Lots 1A to 5A, fifty-two pairs

[25] The details of the work at New Orleans, La., connected with the storage, weighing and shipping of the cheese used in this test, were handled by W. L. Bleecker, Junior Dairyman of the Dairy Div., U. S. Dept. Agr. Our thanks are due to Mr. Bleecker for his very careful attention to the work.

of cheese, were cured at Madison at 60° to 70° and were weighed one or more times (ninety-two weighings in all) at dif-

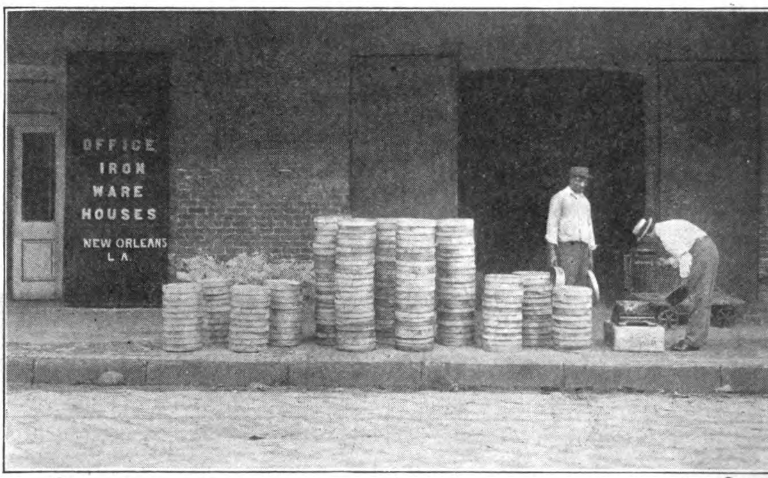

FIGURE 10. PASTEURIZED CHEESE WERE STORED IN NEW ORLEANS

It stands warm storage under market conditions with smaller loss of weight, flavor, and texture than ordinary cheese.

TABLE XXV. REFERENCE NUMBERS TO DIFFERENT LOTS OF CHEESE STORED IN 1911

Date made	Cheese Nos.	Cured at Madison	Shipped to New Orleans	Shipped to Crosby & Meyers	Cured in hot room at Madison	Shipped to Waterloo, Wis.
Feb. 23 to Apr. 16	171 to 207	1 A	1 B	....	....	....
Apr. 24 to May 17	211 to 227	2 A	2 B	....	....	....
May 22 to June 16	230 to 246	3 A	3 B	3 C	3 D	....
June 19 to July 12	248 to 263	4 A	4 B	4 C	4 D	....
July 13 to Aug. 21	264 to 283	5 A	....	....	....	5 E

ferent ages, from 21 to 117 days after paraffining. In every case there was a larger yield of pasteurized cheese than of raw cheese as shown in Table XXVI. The gain averaged 4.59%

TABLE XXVI. YIELD OF RAW AND PASTEURIZED MILK CHEESE, CURED AT MADISON

Date made	Time cured after paraffining	Weight of cured cheese per 100 pounds milk		Gain by pasteurization	
		Pasteurized	Raw		
1911	Days	Lbs.	Lbs.	Lbs.	Per cent
Apr. 24......	21	9.27	8.96	.31	3.46
Mar. 20......	26	9.52	9.06	.46	5.08
Mar. 21......	26	9.40	8.94	.46	5.15
Mar. 22......	26	9.37	9.12	.25	2.74
Mar. 20......	33	9.47	8.99	.48	5.34
Mar. 17......	32	9.87	9.63	.24	2.49
Mar. 16......	32	10.02	9.96	.06	0.60
Mar. 15......	32	9.68	9.38	.30	3.20
Mar. 14......	32	10.03	9.34	.69	7.38
Mar. 13......	32	9.72	8.80	.92	10.46
Mar. 2......	42	9.53	9.36	.17	1.81
Mar. 7......	42	9.57	9.49	.08	0.84
Mar. 8......	42	9.61	9.51	.10	1.05
Mar. 9......	42	9.55	9.29	.26	2.80
Mar. 10......	42	9.62	9.09	.53	5.83
Apr. 17......	42	9.30	8.73	.57	6.54
Apr. 18......	42	9.13	8.64	.49	5.67
May 15......	44	9.43	8.89	.54	6.07
May 17......	44	9.15	8.85	.30	3.39
June 13......	44	9.86	8.94	.92	10.29
June 15......	44	9.70	9.30	.40	4.30
June 16......	44	9.64	9.04	.60	6.64
Feb. 23......	45	9.12	8.63	.49	5.67
Feb. 24......	45	9.26	8.93	.33	3.69
Feb. 27......	45	9.51	9.00	.51	5.67
Feb. 28......	45	9.49	8.99	.50	5.56
Mar. 1......	45	9.57	9.08	.49	5.39
Mar. 2......	45	9.21	8.94	.27	3.02
Apr. 11......	50	9.29	8.98	.31	3.45
Apr. 13......	50	9.06	8.86	.20	2.26
May 10......	50	8.95	8.51	.44	5.17
June 7......	50	9.19	8.79	.40	4.55
June 9......	50	9.41	8.58	.83	9.67
July 3......	51	9.05	8.38	.67	8.00
July 6......	51	9.35	9.21	.14	1.52
June 1......	55	9.59	9.49	.10	1.05
June 2......	55	9.33	8.95	.38	4.24
May 29......	55	9.52	9.05	.47	5.19
Apr. 25......	56	9.62	9.07	.55	6.06
May 2......	58	9.32	9.06	.26	2.87
May 3......	58	8.82	8.66	.16	1.84
Apr. 7......	56	9.36	8.89	.47	5.28
May 25......	62	9.19	8.86	.33	3.72
May 22......	62	9.40	8.74	.66	7.55
May 26......	61	9.16	8.80	.36	4.09
May 27......	61	9.38	8.95	.47	5.25
May 28......	61	9.67	9.35	.32	3.42
May 19......	66	9.66	8.90	.76	8.54
May 21......	66	9.16	8.72	.44	5.05
Apr. 28......	65	8.97	8.82	.15	1.70
Apr. 27......	65	8.78	8.10	.68	8.40
Apr. 24......	65	9.01	8.68	.33	3.80
Mar. 10......	68	9.10	8.85	.25	2.82
Mar. 21......	68	9.15	8.67	.48	5.53
Mar. 20......	68	9.15	8.74	.41	4.69
Apr. 17......	72	9.03	8.47	.56	6.61
Apr. 18......	72	8.81	8.34	.47	5.63
Mar. 17......	74	9.43	9.28	.15	1.62

TABLE XXVI Continued. YIELD OF RAW AND PASTEURIZED MILK CHEESE, CURED AT MADISON

Date made	Time cured after pfg.	Weight of cured cheese per 100 pounds milk		Gain by pasteurization	
		Past.	Raw		
1911	Days	Lbs.	Lbs.	Lbs.	Per cent
Mar. 16......	74	9.72	9.55	.17	1.78
Mar. 15......	74	9.34	9.06	.28	3.09
Mar. 14......	74	9.62	8.99	.63	7.01
Mar. 14......	74	9.37	8.53	.84	9.84
Apr. 13......	80	8.76	8.58	.18	2.09
Apr. 11......	80	8.98	8.74	.24	2.74
Apr. 7......	86	9.09	8.68	.41	4.72
Apr. 5......	86	9.33	8.88	.45	5.07
Mar. 9......	84	9.24	8.94	.30	3.35
Mar. 8......	84	9.40	9.09	.31	3.41
Mar. 7......	84	9.39	9.13	.26	2.85
Mar. 3......	84	9.24	9.02	.22	2.44
Mar. 2......	87	8.93	8.64	.29	3.55
Mar. 1......	87	8.97	8.85	.12	1.35
Feb. 28......	87	9.25	8.71	.54	6.20
Feb. 27.....	87	9.28	8.78	.50	5.69
Feb. 24......	87	8.98	8.72	.26	2.98
Mar. 20......	98	8.94	8.62	.32	3.71
Mar. 21......	98	8.95	8.44	.51	6.04
Mar. 22......	98	8.91	8.69	.22	2.53
Mar. 17......	104	9.20	9.08	.12	1.32
Mar. 16......	104	9.51	9.35	.16	1.71
Mar. 15......	104	9.12	8.92	.20	2.24
Mar. 14.....	104	9.41	8.83	.58	6.57
Mar. 13......	104	9.14	8.46	.68	8.03
Mar. 9......	114	9.02	8.72	.30	3.44
Mar. 8......	114	9.14	8.88	.26	2.93
Mar. 7......	114	9.14	8.93	.21	2.35
Mar. 3......	114	9.06	8.85	.21	2.37
Mar. 2......	117	8.80	8.51	.29	3.41
Mar. 1......	117	8.86	8.75	.11	1.25
Feb. 28......	117	9.12	8.63	.49	5.67
Feb. 27......	117	9.15	8.69	.46	5.29
Feb. 24......	117	8.79	8.62	.17	1.97
Average......	....	9.289	8.907	.38	4.22%

among 10 pairs of cheese cured 20 to 30 days; averaged 4.58% among 37 pairs cured 30 to 60 days; averaged 4.38% among 28 pairs cured 60 to 90 days; and averaged 3.58% among 17 pairs of cheese, cured 90 to 117 days. On the average of all cases, the gain in yield of pasteurized over raw was 4.22% of the weight of the cheese.

Cheese Stored at New Orleans. Lots 1B to 4B, fifty-four days' make, represented by fifty-four raw and fifty-four pasteurized milk cheese were shipped to New Orleans in four lots at different times during the season (Figure 10). In every case, these cheese showed an increased yield for the new process cheese, as compared with the old. The average figures for each lot are given in Table XXVII.

Among the four lots, 1B to 4B, and in the summary at the bottom of the table, it will be seen that the per cent of gain in yield of pasteurized cheese over raw, fell off slowly as the green cheese were paraffined and shipped, on the average,

TABLE XXVII. AVERAGE YIELD OF CHEESE PER 100 POUNDS OF MILK AND ITS SHRINKAGE IN SHIPMENT AND STORAGE

Lot	Method of manufacture	Number of days' make	When green	When paraffined	When shipped to New Orleans	When received at New Orleans	After one month's storage	After two months' storage	When returned to Madison
No.			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1B	Pasteurized	25	10.19	9.69	9.55	9.52	8.85	8.38	8.31
"	Raw	25	9.67	9.26	9.16	9.14	8.36	7.85	7.78
"	Pounds gained by pasteurizing	......	.52	.43	.39	.38	.49	.53	.53
"	Per cent gained by pasteurizing	......	5.37	4.64	4.25	4.16	5.86	6.75	6.81
2B	Pasteurized	9	9.83	9.40	9.37	9.26	8.48	......	8.40
"	Raw	9	9.45	9.08	9.05	8.97	8.12	......	8.01
"	Pounds gained by pasteurizing	......	.38	.32	.32	.29	.36	......	.39
"	Per cent gained by pasteurizing	......	4.02	3.52	3.54	3.23	4.43	......	4.87
3B	Pasteurized	10	10.47	9.99	9.92	9.77	9.29	......	9.17
"	Raw	10	9.93	9.54	9.47	9.34	8.69	......	8.55
"	Pounds gained by pasteurizing	......	.54	.45	.45	.43	.60	......	.62
"	Per cent gained by pasteurizing	......	5.44	4.72	4.75	4.60	6.90	......	7.25
4B	Pasteurized	10	10.38	9.92	9.63	9.78	8.94	......	8.71
"	Raw	10	9.69	9.31	9.24	9.19	8.28	......	8.14
"	Pounds gained by pasteurizing	......	.69	.61	.59	.59	.66	......	.57
"	Per cent gained by pasteurizing	......	7.12	6.55	6.38	6.42	7.97	......	7.00
	Averages								
1-4 B	Pasteurized	54	10.22	9.74	9.64	9.57	8.89	......	8.56
"	Raw	54	9.68	9.29	9.21	9.16	8.37	......	8.03
"	Pounds gained by pasteurizing	......	.54	.45	.43	.41	.52	......	.53
"	Per cent gained by pasteurizing	......	5.58	4.84	4.67	4.47	6.21	......	6.60

from 5.58% to 4.47%. After these cheese had been in storage at New Orleans for one month, the raw milk cheese were found to have shrunk more than the pasteurized cheese in the majority of cases, raising the per cent of gain in average yield of pasteurized cheese to 6.21%. This was also observed in lot 1B after the second month of storage, and is confirmed both by the weights taken in New Orleans by Mr. Bleecker, and by our weights taken at Madison. It was expected that the pasteurized milk cheese, containing slightly more moisture than the raw milk cheese, would lose more in weight than the latter when stored at high temperatures. It was surprising to find that the reverse is true in most cases.

The mean daily temperature at New Orleans as reported by the U. S. Weather Bureau, varied from 71°, the average for April, to 83°, the average for June. It is likely that the temperature of the cheese in the warehouse was somewhat higher than the average figures given above, because the warehouse, although well ventilated, was necessarily open more or less during the hot days and closed during the cool nights.

Cheese Shipped to Crosby and Meyers. Forty cheese in lots 3C and 4C, including twenty pasteurized and twenty raw, were sent in two shipments to storage in the south through a firm of cheese dealers in Chicago, Crosby and Meyers, who weighed the cheese both before and after storage for one month.

In the first shipment, one cheese, No. 243-3 was lost during shipment and in the second shipment, 2 cheese, Nos. 254—1 and 254C1 were damaged so that their weights are not included below. In the first shipment, according to Crosby and Meyers' weights, nine pasteurized milk cheese weighed 172½ pounds before storage, and 162¼ pounds afterward. The loss, 10¼ pounds, is 5.94% of the original weight. In the same shipment, ten raw milk cheese, weighed 189¼ pounds before shipment, and 175 pounds afterward. The loss, 14¼ pounds is 7.53% of the original weight.

In the second shipment, nine pasteurized milk cheese weighed 176½ pounds before, and 159¾ pounds after storage for one month. The loss, 16¾ pounds, is 9.49% of the original weight of the cheese. In the same shipment, nine raw milk cheese weighed 161 pounds before and 144¾ pounds after storage. The loss, 16¼ pounds is 10.09% of the original weight. In both shipments the raw milk cheese lost a greater per cent of their weight than the pasteurized milk cheese. Comparing the individual cheese in pairs, shows that in most cases, the pasteurized cheese lost less than the raw milk cheese, although in a few cases the reverse was true.

Our own weights, taken at Madison on the same lots of cheese, 3C and 4C, gave the figures shown in Table XXVIII, agreeing substantially with the results obtained by Crosby and Meyers.

To further test the effect of storage at high temperatures, forty cheese, lots 3D and 4D, were stored forty-seven days in a warm curing room at Madison where the temperature was held at 75° to 85° with results shown in Table XXIX.

From these results with eight lots of cheese, 1B, 2B, 3B, 4B, 3C, 4C, 3D, 4D, it can be stated, with certainty, that the

TABLE XXVIII. YIELD OF CHEESE PER 100 POUNDS OF MILK AFTER STORAGE IN THE SOUTH

Lot	Method of manufacture	No. of days' make	Green	Paraffined	Shipped from Madison	Received at Madison after storage
No.			Lbs.	Lbs.	Lbs.	Lbs.
3 C......	Pasteurized..................	9	10.47	9.99	9.92	9.24
	Raw..........................	10	9.93	9.54	9.46	8.68
	Gain by pasteurizing, lbs...	....	.54	.45	.46	.56
	Gain by pasteurizing, per cent......................	....	5.44	4.72	4.86	6.44
4 C......	Pasteurized..................	9	10.38	9.92	9.84	8.83
	Raw..........................	9	9.69	9.31	9.24	8.24
	Gain by pasteurizing, lbs...	....	.69	.61	.60	.59
	Gain by pasteurizing, per cent......................	....	7.12	6.55	6.49	7.16

pasteurized milk cheese do not lose more in weight than raw milk cheese when stored in warm rooms, or in the South, after paraffining. On the contrary, the pasteurized cheese lose on the average a smaller per cent of their weight, in warm storage, than do the raw milk cheese. At first, this

TABLE XXIX. YIELD OF CHEESE PER 100 POUNDS OF MILK AFTER STORAGE IN WISCONSIN

Lot	Method	No. of days' make	When green	When paraffined	When put in warm room	When taken out of warm room
No.			Lbs.	Lbs.	Lbs.	Lbs.
3 D......	Pasteurized..................	10	10.47	9.99	9.91	9.37
	Raw..........................	9	9.93	9.54	9.46	8.88
	Gain by pasteurizing, lbs...	....	.54	.45	.45	.49
	Gain by pasteurizing, per cent......................	....	5.44	4.72	4.75	5.52
4 D......	Pasteurized..................	9	10.38	9.92	9.85	9.33
	Raw..........................	10	9.69	9.31	9.23	8.73
	Gain by pasteurizing, lbs...	....	.69	.61	.62	.60
	Gain by pasteurizing, per cent......................	....	7.12	6.55	6.72	6.87

fact seemed inexplicable, but the reason became clearly apparent, from inspection of the cheese kept in the warm curing room at Madison.

Within a few days, after going into the warm room, the raw milk cheese became very greasy on the surface, and the grease running on to the shelves and the floor, marked the spot where each raw cheese stood. The pasteurized milk cheese, standing beside them on the same shelves, did not exude grease, or only very slightly in a few cases, and the difference between the greasy raw milk cheese and the dry surface of the pasteurized milk cheese was so marked that there was no difficulty in picking out each kind by the sense of touch alone.

To further demonstrate the difference in this respect, the last lot of cheese put into the warm room were placed each on a piece of wire gauze in a shallow tin pan, so that the grease running from each cheese could be collected. A very little of the paraffine was scraped from the surface of each cheese by contact with the wire gauze in the bottom of the pan. The total weight of material, practically all paraffine, collected in ten pans, from ten pasteurized milk cheese, weighed .13 pounds; while the material collected from ten raw milk cheese, mostly fat, with a little paraffine, and mold, weighed 1.92 pounds, which is 1.2% of the weight of the raw cheese when placed in the store room.

At present we are unable to explain with certainty why the pasteurized milk cheese should lose fat less readily, when stored at 70° to 80°, than the raw milk cheese. Further study will be made of this phenomenon. The purpose of beginning these studies of losses of weight in warm rooms, was to determine whether the increased yield obtained by pasteurization would be offset by increased losses in weight, when pasteurized milk cheese are shipped to the South, and it is now fully demonstrated that the pasteurized milk cheese stored in the south, maintain their advantage as to increased yield.

Cheese Stored at 34°. The losses of weight observed in forty-two pasteurized milk cheese, (Lot 5E), put into cold storage[26] at 34° at different ages, are shown in Table XXX.

The cheese represent seven days' make during July and August, 1911.

Although the seven cheese put into storage at the age of one day showed only 3.22% shrinkage after three months, yet they were not well broken down, and required further curing at 60° to 70° to get rid of their curdy, lumpy texture. The cheese paraffined and stored when one week old, showed

[26] In warehouse at Waterloo, Wis., by the courtesy of The Roach & Seeber Co.

an average total shrinkage of 5.10%, and these were found to be thoroughly broken down when taken out of cold stor-

TABLE XXX. SHRINKAGE OF PASTEURIZED MILK CHEESE IN COLD STORAGE

Date made	Cheese	Weight green	When paraffined		When put into cold storage		When taken out of cold storage		Total shrinkage	
			Age	Weight	Age	Weight	Age	Weight		
1911	No.	Lbs.	Days	Lbs.	Days	Lbs.	Days	Lbs.	Lbs.	Per ct.
July										
19......	264-1	20.60	9	19.60	....	*a*	100	18.15	2.45	11.89
19......	264-2	21.11	1	20.70	1	20.70	100	20.38	0.73	3.45
19......	264-3	20.10	7	19.21	7	19.21	100	19.15	0.95	4.72
19......	264-4	21.07	9	20.05	14	20.04	100	19.85	1.22	5.79
19......	264-5	19.89	9	18.90	28	18.70	100	18.28	1.61	8.09
19......	264-6	20.45	9	19.44	41	18.95	100	18.65	1.80	8.80
21......	265-1	22.49	8	21.60	....	*a*	99	20.10	2.39	10.62
21......	265-2	17.98	1	17.58	1	17,58	99	17.45	0.53	2.94
21......	265-3	20.21	7	19.35	7	19.35	99	19.25	0.96	4.75
21......	265-4	18.86	8	17.98	14	17.92	99	17.75	1.11	5.89
21......	265-5	19.58	8	18.68	28	18.42	99	18.05	1.53	7.81
21......	265-6	19.25	8	18.40	28	18.13	99	17.68	1.57	8.16
21......	265-7	19.75	8	18.86	40	18.36	99	18.10	1.65	8.35
25......	267-1	20.82	11	19.86	....	*a*	95	18.50	2.32	11.14
25......	267-2	20.29	1	19.95	1	19.95	95	19.80	0.49	2.41
25......	267-3	19.97	7	19.11	7	19.11	95	18.90	1.07	5.35
25......	267-4	21.55	11	20.58	14	20.58	95	20.38	1.17	5.43
25......	267-5	20.23	11	19.25	29	18.98	95	18.58	1.65	8.15
25......	267-6	22.20	11	21.31	43	20.62	95	20.25	1.95	8.78
27......	269-1	18.70	9	17.80	....	*a*	93	16.45	2.25	12.03
27......	269-2	19.88	1	19.45	1	19.45	93	19.20	0.68	3.42
27......	269-3	19.85	7	19.01	7	19.01	93	18.95	0.90	4.53
27......	269-4	20.87	9	19.92	14	19.92	93	19.55	1.32	6.32
27......	269-5	18.80	9	17.91	27	17.60	93	17.22	1.58	8.40
27......	269-6	20.22	9	19.22	41	18.61	93	18.25	1.97	9.74
Aug.										
1......	272-1	21.91	11	20.65	....	*a*	89	19.00	2.91	13.28
1......	272-2	19.78	1	19.30	1	19.30	89	19.05	0.73	3.69
1......	272-3	19.40	7	18.55	7	18.55	89	18.22	1.18	6.08
1......	272-4	21.82	11	20.55	14	20.55	89	20.25	1.57	7.19
1......	272-5	21.80	11	20.57	29	20.26	89	19.90	1.90	8.71
1......	272-6	21.75	11	20.50	46	19.75	89	19.50	2.25	10.34
8......	276-1	19.90	11	18.63	....	*a*	81	17.20	2.70	13.56
8......	276-2	20.42	1	19.98	1	19.98	81	19.60	0.82	4.01
8......	276-3	20.44	7	19.50	7	19.50	81	19.30	1.14	5.57
8......	276-4	19.90	11	18.66	15	18.63	81	18.40	1.50	7.53
8......	276.5	19.70	11	18.45	28	18.21	81	17.75	1.95	9.89
22......	283.1	20.10	....	....	....	*a*	67	18.10	2.00	9.95
22......	283-2	19.90	1	19.50	1	19.50	67	19.38	0.52	2.61
22......	283-3	19.68	8	18.81	8	18.81	67	18.75	0.93	4.72
22......	283-4	18.80	11	17.90	15	17.70	67	17.40	1.40	7.44
22......	283-5	19.84	11	18.84	29	18.62	67	18.45	1.39	7.00
22......	283-6	18.65	11	17.62	....	....	67	16.80	1.85	9.92

No. of cheese..................	7	7	7	8	6	7
Age when stored.............	1 day	1 week	2 weeks	4 weeks	6 weeks	*a*
Average total shrinkage....	3.22%	5.10%	6.51%	8.29%	9.29%	11.78%

a Cured in the cellar at Madison, at 60°-70°.

age. This series appears to indicate that the quality of pasteurized milk cheese is not damaged by placing in cold storage at the age of one week, while the shrinkage (5.10%) is about half that of the duplicate cheese, cured in the cellar at Madison, (11.78%), as shown at the bottom of the table.

THE CAUSES OF INCREASED YIELD OF PASTEURIZED MILK CHEESE

Losses of Fat from Vat and Press. The increased yield of green cheese from pasteurized milk amounting to over 5% (Table XX) is due partly to the fact that about half of the fat lost in the whey and drippings by the old process, is retained in the cheese, by the new process of making. Also, it is found that a little more moisture can safely be incorporated in the new process cheese, without danger of spoiling, giving the cheese a moist, fat appearance which consumers generally like.

The loss of fat in the whey is occasioned partly by the passage of the curd knives through the curd in cutting, at which time a considerable proportion of fat is brushed away from the surface of the curd cubes. During the stirring and heating, some further fat globules are lost from the curd cubes. Further losses occur after milling and during pressing. In the new process of making cheese from pasteurized milk, the curd is so firm and elastic, (not brittle) at the time of cutting, that the loss of fat in the whey averages only about half that observed in cheesemaking by the ordinary process.

The average fat content of whey from good clean milk is stated[27] to be .30%, and from average cheesefactory milk, .36%. On a great many days during the past 2½ years, the milk supply in the receiving vat has been divided, and one half made up by regular methods, the other half by the new method. The quality and composition of the milk was thus the same in both vats. On the twenty-four days, listed in Table XXXI, the average fat content of the whey from the regular vats was .25%, and from the pasteurized milk vats, was .159%. In these cases the small amount of milk handled in each vat permitted hand stirring, and neither the rake nor agitator was used. By this means, the whey fat of the regular process vats was kept at a lower figure (.25%) than could have been done with large vats, as handled in a commercial factory, using the regular process.

[27] VanSlyke and Publow, The Science and Practice of Cheesemaking, pp. 189-190.

On twenty-two days, using 1200 to 2000 pounds of pasteurized milk in each vat, the per cent of fat in the whey at the time of drawing whey averaged .17%, as shown in Table XXXII. In these cases, the vats were stirred with an agitator.

TABLE XXXI. FAT IN WHEY BY NEW METHOD AND BY REGULAR METHOD OF CHEESE MAKING

Date	Fat in milk	New method		Regular method	
		Weight of milk used	Fat in whey when drawn	Weight of milk used	Fat in whey when drawn
1911 Aug.	Per cent	Lbs.	Per cent	Lbs.	Per cent
29	4.1	294½	.14	290	.17
30	3.6	344	.14	344	.26
Sept.					
1	....	322	.15	320	.20
5	4.0	291½	.17	292	.28
6	3.6	276	.19	276	.32
7	4.1	286½	.18	286½	.32
8	....	292	.16	795	.26
1909 July					
21	4.0	200	.15	200	.21
22	3.9	200	.12	200	.20
23	4.0	200	.15	200	.19
24	4.0	200	.12	200	.22
Aug.					
12	3.7	200	.16	200	.26
1908 July					
18	4.1	200	.12	200	.22
Oct.					
1	4.7	200	.20	200	.30
2	4.5	200	.18	200	.29
7	4.4	200	.14	200	.19
8	4.0	200	.15	200	.25
Sept.					
1	4.3	200	.17	200	.32
2	4.2	200	.18	200	.30
14	4.2	200	.18	200	.24
16	4.0	200	.13	200	.27
17	4.4	200	.19	200	.29
18	4.4	200	.18	200	.25
19	4.2	200	.17	200	.23
Average.....	....	....	.159	....	.25

Most of the loss of fat from curd occurs at the moment of cutting, as shown by the figures in Table XXXIII. On twenty-three days, samples of whey were taken daily from the vat as soon after cutting as it was possible to obtain any clear whey, that is in four to six minutes. The fat content of this whey, sampled five minutes after cutting, was .47%, on the average of twenty-three days; while the average test of samples taken from the same vats two hours after cutting, was .16% fat. The average weight of milk handled daily in the

TABLE XXXII. FAT CONTENT OF WHEY FROM LARGE VATS OF PASTEURIZED MILK CHEESE

Date	Fat in whey two hours after cutting	Weight of milk handled	Weight of cheese
1910 May	Per cent.	Lbs.	Lbs.
25	.14	1,234	139
26	.16	1,322	153
27	.18	1,337	144
June			
1	.17	1,578	166
6	.12	2,061	226
7	.15	1,427	159
8	.14	1,431	158
9	.18	1,360	147
10	.17	1,448	162
14	.20	1,398	148
16	.20	1,165	126
17	.20	1,320	152
20	.20	1,588	170
21	.23	1,292	144
22	.14	1,347	144
23	.16	1,329	139
24	.18	1,337	139
28	.24	1,277	130
29	.14	1,210	130
30	.17	1,243	131
July			
5	.18	1,242	125
6	.14	1,229	134
Average	.17	....	....

TABLE XXXIII. FAT CONTENT OF WHEY AT DIFFERENT PERIODS

Date	Time after cutting		Weight of milk handled	Weight of cheese
	4 to 6 min.	2 hours		
1910 April	Per cent fat	Per cent fat	Lbs.	Lbs.
8	.45	.16	1011	102
12	.46	.19	1011	104
13	.40	.15	967	98
14	.40	.14	1045	108
15	.50	.12	1001	100
18	.35	.13	993	103
19	.55	.22	906	97
22	.40	.16	755	77
25	.42	.19	1065	117
26	.52	.17	940	103
27	.52	.16	1004	109
28	.57	.15	972	102
29	.45	.14	796	102
May				
3	.65	.16	1041	122
4	.67	.16	1055	118
5	.52	.17	1119	129
6	.50	.20	917	97
10	.52	.16	1288	141
11	.50	.15	1285	138
18	.35	.15	1239	137
19	.40	.14	1186	130
23	.25	.12	2477	268
24	.45	.19	1454	154
Average	.47	.16	1110	119,8

vat was 1110 pounds. The average fat test of the milk used was 4.0%.

TABLE XXXIV. LOSS OF FAT IN DRIPPINGS, IN TWO HOURS, FIFTY MINUTES FROM DIPPING TO HOOPING PASTEURIZED MILK CURD

Date	Total weight of drippings collected	Fat in drippings		Weight of cheese
1910 April	Lbs.	Per cent	Lbs.	Lbs.
12	29	.27	.078	104
13	28	.27	.075	98
14	31	,30	.093	108
15	33	.25	.082	100
18	21	.20	.042	103
19	26	.10	.026	97
20	20	.15	.030	91½
21	25	.18	.045	95½
22	21	.12	.025	77
25	24	.20	.048	117
Total	258.0	....	.544	991

The reason for the decrease in per cent of fat in whey during the two hour period after cutting is that there was little fat lost from the curd during the time that whey was being

TABLE XXXV. LOSSES OF FAT IN DRIPPINGS BEFORE PRESSING PASTEURIZED MILK CURDS

Date	Drippings in 1¼ hours dipping to milling			Drippings in 1½ hrs. milling to hooping			Weight of cheese
	Weight	Fat content		Weight	Fat content		
1910 April	Lbs.	Per cent.	Lbs.	Lbs.	Per cent.	Lbs.	Lbs.
27	35	.02	.007	5.0	1.8	.090	109
28	24	.05	.012	5.0	1.8	.090	102
29	24	.02	.050	3.0	1.8	.054	84
May							
3	25	.08	.020	2.5	1.8	.045	122½
4	25	.05	.012	1.5	0.6	.009	118
5	29	.07	.020	3.0	1.7	.051	129
10	26	.07	.018	4.0	1.2	.048	141
11	24	.07	.017	3.0	1.6	.048	137½
13	25	.16	.040	3.0	2.0	.060	103
18	24	.06	.014	4.5	2.0	.090	137
19	25	.05	.012	5.0	1.4	.070	125
23	38	.04	,015	9.0	1.5	.135	268
24	26	.14	.036	5.0	2.0	.100	162
Totals	350	....	.273	53.5	....	.890	1,738
Calculated for 10 lbs. cheese	2.01	....	0.00157	0.3078	....	0.00512	....

expelled. The fat already lost in the whey at the moment of cutting was diluted about 3 times $\left(\frac{.47}{.16} = 3\right)$ by the water expelled from the curd during the two hour period.

Losses of Fat after Drawing the Whey. On several days, the whey drippings from the pasteurized milk curd, from the time the curd was all on the rack up to the time when it was taken from the press, were collected, weighed, and tested for fat. From this could be calculated the weight of fat lost in the drippings, as shown in Tables XXXIV to XXXVI.

TABLE XXXVI. LOSS OF FAT IN DRIPPINGS FROM PRESS FROM PASTEURIZED MILK CHEESE

Date	Total weight of cheese pressed	Total weight of drippings	Fat in drippings	
	Lbs.	Lbs.	Per cent	Lbs.
1910 May				
16-20	808	24	3.85	0.92
23-27	873	32	3.2	1.02
Totals	1,681	56	....	1.94
Calculated for 10 lbs. cheese	....	0.33	....	0.0115

Summary of Losses of Fat by New Method of Cheesemaking. The total loss of fat from cheese in the new process is about 1.6% of the weight of the cheese, as shown in Table XXXVII, a summary of the preceding tables.

TABLE XXXVII. LOSSES OF FAT FROM ABOUT 100 POUNDS MILK YIELDING 10 POUNDS CHEESE

	Total weight	Fat content		Loss of fat from cheese
	Lbs.	Per cent	Lbs.	Per cent
Whey when drawn	87.4	0.16	0.1400	1.400
Drippings from curd before milling	2.01	0.08	0.0016	0.016
Drippings from curd in vat, after milling	0.31	1.66	0.0051	0.051
Drippings from press	0.33	3.46	0.0115	0.115
Total	90.05	....	0.1583	1.58

The average total loss of fat from 100 pounds of milk, handled by the new process of cheesemaking, is seen to be, on the average, .158 pounds of fat, or a little less than 4% of the total fat content of milk containing 4% fat. The loss of fat from 100 pounds of milk, in ordinary cheesemaking, under average factory conditions, is .33 pound of fat, or .36% of fat in the whey, or 9% of the total fat content of the milk.[28] It will be seen

[28] VanSlyke and Publow, The Science and Practice of Cheesemaking, p. 189.

from these figures, that the loss of fat is reduced to less than half, by the new process of cheesemaking. It might be expected from this statement that each day's make of pasteurized milk cheese tested by the Babcock test, would show a higher per cent of fat, than the same day's raw milk cheese. In Table XXXVIII, however, it is seen that in fifteen cases

TABLE XXXVIII. FAT AND MOISTURE CONTENT OF PASTEURIZED AND RAW MILK CHEESE CURED AT MADISON

Date	Moisture content of cheese				Fat content of cheese			
	Pasteurized	Raw	Difference		Pasteurized	Raw	Difference	
1911 Feb.	Per cent	Per cent	+ Per cent	— Per cent	Per cent	Per cent	— Per cent	+ Per cent
24	30.50	30.15	.35	....	38.86	39.10	—.24	....
27	33.55	30.15	3.40	....	....	....	....	....
28	32.52	30.05	2.47	....	....	....	....	....
Mar.								
1	32.55	31.25	1.30	....	....	....	....	....
2	31.60	30.75	.85	....	....	....	....	....
3	31.05	31.47	....	—.42	....	....	....	....
7	31.90	29.75	2.15	....	37.44	38.16	—.72	....
8	32.37	30.17	2.20	....	37.99	38.16	—.17	....
9	32.77	31.32	1.45	....	38.61	38.04	....	+.57
10	32.45	31.45	1.00	....	....	....	....	....
13	33.15	30.00	3.15	....	....	....	....	....
14	33.51	31 95	1.56	....	....	....	....	....
15	31.62	30.90	.72	....	38.28	38.36	--.08	....
16	33.40	30.87	2.53	....	38.61	38.39	....	+.22
17	34.15	33.22	.93	....	38.01	37.97	....	+.04
20	32.72	31.58	1.14	....	....	....	....	....
21	32.90	30.10	2.80	....	....	....	....	....
22	34.00	32.20	1.80	....	....	....	....	....
April								
5	34.10	32.25	1.85	....	36.93	37.09	—.16	....
7	34.52	31.92	2.60	....	36.56	36.85	—.29	....
11	32.90	31.97	.93	....	....	....	....	....
13	31.78	30.17	1.61	....	36.84	37.02	—.18	....
17	33.47	31.55	1.92	....	36.81	37.94	—1.13	....
18	33.55	30.15	3.40	....	38.22	39.95	—1.73	....
24	32.28	32.68	....	—.40	39.18	38.86	....	+.32
27	31.80	32.70	....	—.90	38.64	38.66	--.02	....
28	34.17	33.22	.95	....	37.93	39.08	—1.15	....
May								
2	32.63	31.25	1.38	....	39.55	40.68	—1.13	....
3	31.02	30.87	.15	....	40.68	41.43	— .75	....
8	32.87	31.05	1.82	....	37.97	39.06	—1.09	....
10	31.65	30.45	1.20	....	39.28	39.27	....	+.01
15	33.47	32.25	1.22	....	37.97	38.66	— .69	....
17	31.87	32.58	....	—.71	38.10	37.67	....	+.43
Av.......	32.69	31.28	1.68	--.61	38.21	38.59	-- .65	+.26

out of twenty-one, the pasteurized milk cheese tested lower in fat (.65% lower, on the average) than the raw milk cheese.

Increased Moisture Content of Pasteurized Milk Cheese. This is due to the fact that there is an increased content of moisture as well as of fat in the new process cheese, and in most cases, the increase of moisture is greater than the increase of fat. On this account, the moisture content of the pasteurized cheese, listed in this table[29] is greater than that of the raw milk cheese in twenty-nine cases out of thirty-three, and on the average of all, 1.68% greater.

The combined effect upon the percentage composition of cheese, caused by increasing both the fat and moisture content, is shown in the following example. Ten pounds of raw milk cheese of the average percentage composition shown in Table XXXVIII, would contain the weights of fat, moisture, casein, etc., shown in Table XXXIX.

TABLE XXXIX. EFFECT OF PASTEURIZATION ON PERCENTAGE COMPOSITION OF CHEESE

Constituents	Composition of 10 lbs. raw milk cheese		Yield added by pasteurization	Composition if pasteurized	
	Per cent	Lbs.	Lbs.	Lbs.	Per cent
Fat	38.59	3.859	0.154	4.013	38.07
Moisture	31.28	3.128	0.391	3.519	33.37
Casein, etc	30.13	3.013	....	3.013	28.57
	100.00	10.000	....	10.545	100.00

If by pasteurization, the fat content of the cheese is increased about 4% of itself, and the moisture content is increased about 12½% of itself, there will be obtained 10.54 pounds of pasteurized milk cheese, instead of 10 pounds of raw milk cheese, a theoretical gain of 5.4% in the yield of cheese. (The actual gain shown in Table XX was 5.37%). The percentage composition of this pasteurized cheese will agree closely with the average composition of the pasteurized milk cheese, shown at the bottom of Table XXXVIII. The increased moisture content of pasteurized milk cheese, made by this process, is due to the effect of pasteurization on the properties of curd, as stated on page 156.

SCORES AND CRITICISMS OF PASTEURIZED AND RAW MILK CHEESE[30]

Cheese from every day's make during the season were

[29] The cheese listed in this table were the same as those in Table XXVI, and the testing for fat and moisture was done immediately after the last weights had been taken for the determination of yield and skrinkage. The samples of cheese weighed into the Babcock test bottles, were rapidly dissolved in a mixture of hot water and sulfuric acid, as suggested by one of us in Jour. Indus. and Eng. Chem. 1909, p. 604.

[30] The milk supply used at this Station is no better than average cheesefactory milk. Sunday's milk is delivered on Monday throughout the year, and is worse than usual.

scored by two judges, U. S. Baer, Asst. Dairy and Food Commissioner of the State of Wisconsin, and A. T. Bruhn, Junior Dairyman, U. S. Dept. of Agriculture, who during the past year have scored the cheese sent to the Wisconsin Monthly Scoring Exhibition, conducted by this College. The judges worked independently, and pinned their score sheets to each cheese without knowing even the numbers of the cheese, which were turned toward the wall. Their scores show close agreement with each other in most cases, and leave no doubt as to the relative quality of the cheese scored. After finishing about twenty of the cheese, they turned them around and added the cheese numbers to the sheets.

In general, a score of 92, or above indicates that the cheese is of good quality, and salable at full market price. A cheese scored below 92 is likely to be cut in price in a dull market.

Tables XL and XLI show the scores of both judges, as well

TABLE XL. SCORES ON SIXTY SIX CHEESE CURED AT MADISON
Scores given July 17, 1911, to lots 1A and 2A

Temp. of curing room at 8 A. M.	Date of making cheese	Cheese	U. S. Baer			A. T. Bruhn			Average		
			Flavor	Texture	Total	Flavor	Texture	Total	Flavor	Texture	Total
°F	1911 Feb.	No.	Score	Score	Score	Score	Score	Score	Score	Score	Score
....	24	172	41.00	26.00	92.00	40.00	26.50	91.50	40.50	26.25	91.75
....	24	172C	37.00	27.00	89.00	38.00	27.00	90.00	37.50	27.00	89.50
....	27	173	43.00	28.50	96.50	42.50	28.00	95.50	42.75	28.25	96.00
....	27	173C	38.00	27.00	90.00	40.00	27.00	92.00	39.00	27.00	91.00
....	28	174	41.00	27.00	93.00	41.00	27.50	93.50	41.00	27.25	93.25
....	28	174C	39.00	26.00	90.00	39.00	26.50	90.50	39.00	26.25	90.25
....	Mar.	175	41.00	27.00	93.00	40.00	26.00	91.00	40.50	26.50	92.00
....	1	175C	40.00	26.00	91.00	40.00	26.50	91.50	40.00	26.25	91.25
....	2	176	40.00	28.00	93.00	41.00	27.00	93.00	40.50	27.50	93.00
....	2	176C	37.00	27.00	89.00	39.00	27.00	91.00	38.00	27.00	90.00
....	3	177	40.00	27.00	92.00	40.00	26.50	91.50	40.00	26.75	91.75
....	3	177C	38.00	26.00	89.00	38.00	26.00	89.00	38.00	26.00	89.00
....	7	178	40.00	26.00	91.00	40.00	27.00	92.00	40.00	26.50	91.50
....	7	178C	38.00	27.00	90.00	39.00	27.00	91.00	38.50	27.00	90.50
....	8	179	40.00	27.00	92.00	41.00	27.50	93.50	40.50	27.25	92.75
....	8	179C	35.00	26.00	86.00	38.00	26.00	89.00	36.50	26.00	87.50
....	9	180	41.00	26.00	92.00	41.00	27.00	93.00	41.00	26.50	92.50
....	9	180C	39.00	26.00	90.00	40.50	26.50	92.00	39.75	26.25	91.00
....	10	181	41.00	26.00	92.00	42.00	27.00	94.00	41.50	26.50	93.00
....	10	181C	38.00	27.00	90.00	39.00	26.50	90.50	38.50	26.75	90.25
....	13	182	40.00	27.00	92.00	41.00	27.00	93.00	40.50	27.00	92.50
....	13	182C	41.00	26.00	92.00	40.00	27.00	92.00	40.50	26.50	92.00
....	14	183	40.00	26.00	91.00	40.00	26.50	91.50	40 00	26.25	91.25
....	14	183C	40.00	27.00	92.00	40.00	26.50	91.50	40.00	26.75	91.75
....	15	184	40.00	26.00	91.00	41.00	27.00	93.00	40.50	26.50	92.00
....	15	184C	40.00	27.00	92.00	41.50	27.00	93.50	40.75	27.00	92.75
60°	16	185	40.00	26.00	91.00	41.50	27.00	93.50	40.75	26.50	92.25
....	16	185C	35.00	26.00	86.00	41.00	27.00	93.00	38.00	26.50	89.50
62°	17	186	42.00	28.00	95.00	41.00	26.50	92.50	41.50	27.25	93.75
....	17	186C	41.00	28.00	94.00	41.00	27.00	93.00	41.00	27.50	93.50

TABLE XL Continued. SCORES ON SIXTY SIX CHEESE CURED AT MADISON
Scores given July 17, 1911, to lots 1A and 2A.

Temp. of curing room at 8 A. M.	Date of making cheese	Cheese	U. S. Baer			A. T. Bruhn			Average		
			Flavor	Texture	Total	Flavor	Texture	Total	Flavor	Texture	Total
°F	1911	No.	Score	Score	Score	Score	Score	Score	Score	Score	Score
	Mar.										
63°	20	187	43.00	27.00	95.00	41.00	26.00	92.00	42.00	26.50	93.50
....	20	187C	35.00	25.00	85.00	39.00	26.50	90.50	37.00	25.75	87.75
66°	21	188	43.00	28.00	96.00	41.00	27.00	93.00	42.00	27.50	94.50
....	21	188C	38.00	26.00	89.00	40.00	27.00	92.00	39.00	26.50	90.50
66°	22	189	43.00	27.00	95.00	42.00	28.00	95.00	42.50	27.50	95.00
....	22	189C	39.00	27.00	91.00	40.00	27.00	92.00	39.50	27.00	91.50
62°	Apr.	198	43.00	27.00	95.00	42.00	28.00	95.00	42.50	27.50	95.00
....	5	198C	41.00	27.00	93.00	41.50	28.00	94.50	41.25	27.50	93.75
....	7	200	42.00	27.00	94.00	42.00	27.00	94.00	42.00	27.00	94.00
64°	7	200C	35.00	25.00	85.00	40.00	26.00	91.00	37.50	25.50	88.00
....	11	202	42.00	26 00	93.00	42.50	27.00	94.50	42.25	26.50	93.75
....	11	202C	39.00	26.00	90.00	40.00	27.00	92.00	39.50	26.50	91.00
....	13	204	41.00	27.00	93.00	42.00	28.00	95.00	41.50	27.50	94 00
....	13	204C	39.00	26.00	90.00	40.00	27.00	92.00	39.50	26.50	91.00
....	17	206	41.00	27.00	93.00	41.00	27.00	93.00	41.00	27.00	93.00
....	17	206C	40.00	25.00	90.00	38.00	25.00	87.00	39.00	25.00	88.50
....	18	207	43.00	26.00	94.00	41.50	27.00	93.50	42.25	26.50	93.75
....	18	207C	42.00	25.00	92.00	40.00	25.00	90.00	41.00	25.00	91.00
....	24	211	43.00	26.00	94.00	42.00	27.00	94.00	42.50	26.50	94.00
....	24	211C	39.00	25.00	89.00	39.00	27.00	91.00	39.00	26.00	90.00
....	27	214	40.00	25.00	90.00	42.50	27.00	94.50	41.25	26.00	92.25
....	27	214C	37.00	24.00	86.00	37.00	26.00	88.00	37.00	25.00	87.00
....	28	215	42.00	27.00	94.00	42.00	27.00	94.00	42.00	27.00	94.00
60°	28	215C	37.00	25.00	87.00	38.00	26.00	89.00	37.50	25.50	88.00
....	May	216	41.00	26.00	92.00	40.50	26.00	91.50	40.75	26.00	91.75
58°	2	216C	37.00	25.00	87.00	38.00	26.00	89.00	37.50	25.50	88 00
....	3	217	42.00	28.00	95.00	41.50	27.00	93.50	41.75	27.50	94.25
62°	3	217C	37.00	25.00	87.00	40.00	26.00	91.00	38.50	25.50	89.00
....	8	220	41.00	27.00	93.00	42.00	27.00	94.00	41.50	27.00	93.50
62°	8	220C	34.00	25.00	84.00	39.00	25.00	89.00	36.50	25.00	86.50
....	10	222	40.00	25.00	90.00	40.00	27.00	92.00	40.00	26.00	91.00
63°	10	222C	37.00	25.00	87.00	40.00	26.00	91.00	38.50	25.50	89.00
....	15	225	40.00	26.00	91.00	42.00	28.00	95.00	41.00	27.00	93.00
64°	15	225C	38.00	26.00	89.00	39.00	27.00	91.00	38.50	26.50	90.00
....	17	227	41.00	26.00	92.00	41.00	27.00	93.00	41.00	26.50	92.50
67°	17	227C	35.00	24.00	84.00	37.00	25.00	87.00	36.00	24.50	85.50

as the average scores, which latter are used in the discussion. Raw milk cheese are in all cases indicated by the letter C, attached to the serial number.

Cheese Cured in the Cellar at Madison. This includes lots 1 A, 2 A, 3 A, and 4 A, fifty-three pairs in all. The temperature of the curing room showed about 3° to 5° difference between the daily maximum and minimum; it ranged from 60° to 73° from February to July, 1911; and, by opening windows at night only, it was kept at 60° to 70° from July to October.

The average score of all the pasteurized milk cheese is 92.75 and for the raw milk cheese is 89.09 as shown in Table XL.

In fifty-one cases out of fifty-three, the pasteurized milk cheese received a higher average total score than the raw milk cheese; but in two cases, the raw milk cheese scored ¼ to ½ point higher (Nos. 183 and 184). In the fifty-one cases

TABLE XLI. SCORES ON FORTY CHEESE CURED AT MADISON
Scores given Aug. 14, 1911, to lot 3A.

Temperature of curing room	Date of making cheese	Cheese	U. S. Baer			A. T. Bruhn			Average		
			Flavor	Texture	Total	Flavor	Texture	Total	Flavor	Texture	Total
° F.	1911	No.	Score	Score	Score	Score	Score	Score	Score	Score	Score
	May										
67°	22	230	43.00	27.00	95.00	41.50	26.50	93.00	42.25	26.75	94.00
	22	230C	40.00	26.00	91.00	37.00	25.00	87.00	38.50	25.50	89.00
66°	25	233	41.00	25.00	91.00	41.00	26.00	92.00	41.00	25.50	91.50
	25	233C	38.00	25.00	88.00	36.00	25.00	86.00	37.00	25.00	87.00
	29	234	42.00	27.00	94.00	42.00	27.00	94.00	42.00	27.00	94.00
	29	234C	39.00	25.00	89.00	37.00	25.00	87.00	38.00	25.00	88.00
	June	237	42.00	27.00	94.00	41.00	26.50	92.50	41.50	26.75	93.25
66°	1	237C	35.00	25.00	85.00	38.00	26.00	89.00	36.50	25.00	87.00
	2	238	40.00	26.00	91.00	41.00	26.50	92.50	40.50	26.25	91.75
66°	2	238C	37.00	26.00	88.00	37.00	25.50	87.50	37.00	25.75	87.75
	7	240	40.00	27.00	92.00	41.00	26.00	92.00	40.50	26.50	92.00
66°	7	240C	33.00	25.00	83.00	37.00	26.00	88.00	35.00	25.50	85.50
	9	242	39.00	27.00	91.00	41.50	26.00	92.50	40.25	26.50	91.75
70°	9	242C	39.00	26.00	90.00	38.00	26.00	89.00	38.50	26.00	89.50
	13	243	40.00	27.00	92.00	41.00	26.00	92.00	40.50	26.50	92.00
68°	13	243C	38.00	25.00	88.00	38.00	25.00	88.00	38.00	25.00	88.00
	15	245	41.00	27.00	93.00	41.50	27.00	93.50	41.25	27.00	93.25
66°	15	245C	37.00	26.00	88.00	40.00	26.00	91.00	38.50	26.00	89.50
	16	246	40.00	27.00	92.00	40.00	26.00	91.00	40.00	26.50	91.50
66°	16	246C	40.00	26.00	91.00	39.00	27.00	91.00	39.50	26.50	91.00
Scores given Sept. 18, 1911, to lot 4A											
68°	19	248	42.00	27.00	94.00	42.00	27.00	94.00	42.00	27.00	94.00
	19	248C	40.50	26.00	91.50	40.00	26.50	91.50	40.25	26.25	91.50
68°	21	250	40.00	26.00	91.00	41.00	26.50	92.50	40.50	26.35	91.75
	21	250C	37.00	25.00	87.00	38.00	25.00	88.00	37.50	25.00	87.50
70°	26	253	37.00	25.00	87.00	39.00	25.00	89.00	38.00	25.00	88.00
	26	253C	35.00	25.00	85.00	35.00	26.00	86.00	35.00	25.50	85.50
70°	27	254	41.00	27.00	93.00	41.00	27.00	93.00	41.00	27.00	93.00
	27	254C	37.00	26.00	88.00	37.00	26.00	88.00	37.00	26.00	88.00
70°	28	255	41.00	27.00	93.00	41.00	27.00	93.00	41.00	27.00	93.00
	28	255C	35.00	25.00	85.00	37.00	25.50	87.50	36.00	25.25	86.25
72°	July	258	40.00	27.00	92.00	40.50	26.50	92.00	40.25	26.75	92.00
	3	258C	35.00	25.00	85.00	35.00	25.00	85.00	35.00	25.00	85.00
72°	8	260	41.00	27.00	93.00	41.00	26.50	92.50	41.00	26.75	92.75
	8	260C	37.00	25.00	87.00	36.00	25.00	86.00	36.50	25.00	86.50
73°	10	261	40.00	25.00	90.00	39.50	26.00	90.50	39.75	25.50	90.25
	10	261C	38.00	27.00	90.00	38.00	27.00	90.00	38.00	27.00	90.00
73°	11	262	41.00	27.00	93.00	41.00	26.50	92.50	41.00	26.75	92.75
	11	262C	37.00	26.00	88.00	37.00	25.50	87.50	37.00	25.75	87.75
72°	12	263	40.00	26.00	91.00	40.00	26.00	91.00	40.00	26.00	91.00
	12	263C	35.00	26.00	86.00	35.00	26.00	86.00	35.00	26.00	86.00

just mentioned, the difference in total score between pasteurized and raw milk cheese, ranged from ¼ point to seven points, and averaged 3.82 points. In 4/5 of these cases, the difference in score was over two points. Forty-nine of the fifty-three raw milk cheese received an average score below

92 while thirty-nine of the fifty-three pasteurized milk cheese scored 92 or above. The distribution of the scores in each case is most clearly shown in Figure 11.

From this figure, it can be readily seen that 94% (50 out of 53) of the pasteurized cheese scores lie between 91 and 95, a range of four points, while the same proportion (94%) of the raw milk cheese scores are quite uniformly distributed between 85 and 92, a range of seven points.

The variation in quality of product from day to day is thus reduced nearly one-half by the new process. In scoring all

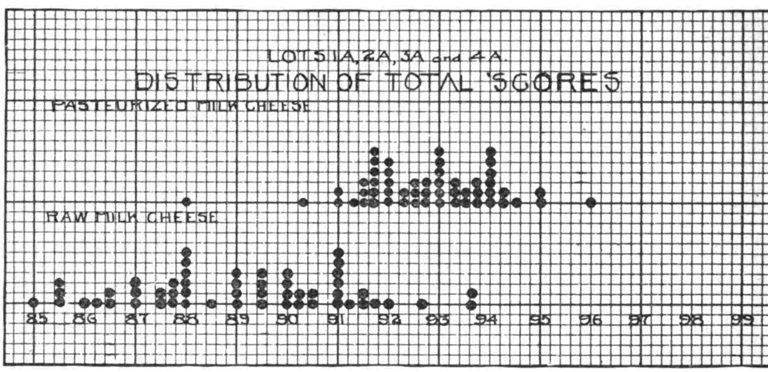

FIGURE 11. TOTAL SCORES GIVEN CHEESE STORED IN MADISON

Each dot represents a cheese stored about four months at 60° to 73° F. Note the wide range and low scores of those made from raw milk, while the pasteurized cheese are better and more uniform. This may be noted in the following graphs.

of these cheese, the color and make-up were always marked perfect, and the cheese were marked off only on flavor and texture. It is of interest, therefore, to consider the flavor and texture scores separately, in addition to the discussion of total scores given above.

The average flavor score for all of the pasteurized cheese is 41.05 and for the raw milk cheese is 38.13. In fifty cases out of fifty-three, the pasteurized milk cheese have a higher average flavor score than the raw, in two cases the scores are equal, and in one case the pasteurized cheese scored ¼ point less than the raw.

In the fifty cases just mentioned, the difference in flavor score between the two makes of cheese ranged from .5 to 5.5 points, averaging 3.1 points. The difference was equal to or greater than 1.25 points in forty-seven out of fifty cases showing that the improvement in flavor through pasteurization was not only unquestionable, but also consistent. Fifty-one out of fifty-three pasteurized milk cheese scored 40 or above on flavor, while forty-five of the fifty-three raw milk cheese scored below 40 in flavor.

Figure 12 shows that 94% (fifty out of fifty-three) of the pasteurized cheese flavor scores lie between 40 and 42½, a range of 2½ points; while the raw milk cheese flavor scores are quite evenly distributed over a range of five points (from 35 to 40 or 41). The range of variation is thus twice as great in the raw as in the pasteurized showing that the daily varia-

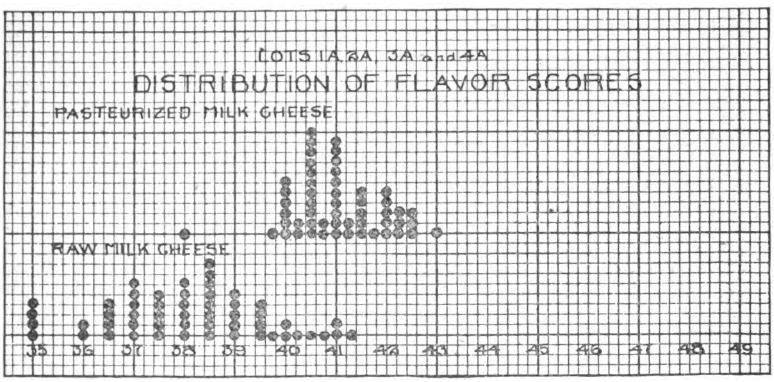

FIGURE 12. FLAVOR SCORES GIVEN CHEESE STORED AT MADISON

tion of flavor of product is reduced about one-half by the new process.

The average texture scores on all of the pasteurized milk cheese was 26.70; and on the raw milk cheese, was 25.96, showing some advantage for the new process cheese.

In forty cases out of fifty-three the pasteurized cheese scored higher than the raw; in five cases the scores were equal; and in eight cases, the pasteurized cheese scored .25 to 1.5 points (average .59 points) lower than the raw. Among the forty cases just mentioned, the differences in texture score between the two makes ranged from .25 to 2 points, and averaged 1.09 points. Figure 13 shows that 90% (forty-eight out of fifty-three) of the pasteurized milk cheese texture scores lie between 26 and 27.50, a range of 1.5 points; while 94% (fifty out of fifty-three) of the raw milk cheese scores are quite evenly distributed between 25 and 27, a range of two points, a distinct advantage in favor of the new process, both as to quality and uniformity of texture.

Cheese Stored Two Months in the South. Lot 1B (fifty cheese) was made on twenty-five days between February 23 and April 18, at Madison, was shipped to New Orleans April 29, where it arrived May 9, was stored there until July 3, and then shipped back to Madison. The temperatures at New Orleans given in Table XLIII, are taken from the U. S.

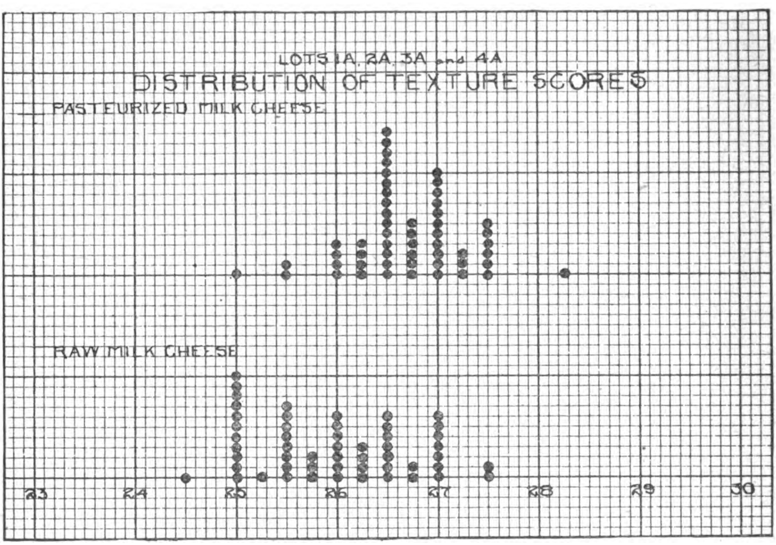

FIGURE 13. TEXTURE SCORES GIVEN CHEESE STORED AT MADISON

Weather Bureau monthly meteorological summaries, sent from New Orleans. The average daily mean for May was 75.8° and for June 83.2°. The quality for both raw and pasteurized cheese after returning from New Orleans, was very poor, as shown both by scores of judges, and by letters from dealers to whom they were afterward sold at a reduced price. The average score of the twenty-five pasteurized milk cheese was 85.10 and of the twenty-five raw milk cheese was 83.34, a difference of 1.76 points. In seventeen cases out of twenty-five, the pasteurized milk cheese scored higher; in three cases they equaled; and in five cases, they were less than the raw milk cheese. (See Table XLII). The highest average score given to

TABLE XLII. SCORES ON FIFTY CHEESE, LOT 1B, CURED AT NEW ORLEANS, TWO MONTHS AFTER MAY 9, 1911

Scored July 17, 1911, at Madison

Date of making cheese	Cheese	U. S. Baer	A. T. Bruhn	Average
1911	No.	Total score	Total score	Total score
February				
23	171	82	80	81.00
23	171C	87	87	87.00
24	172	83	79	81.00
24	172C	85	81	83.00
27	173	87	90	88.50
27	173C	85	86	85.50
28	174	90	85	87.50
28	174C	83	85	84.00
March				
1	175	86	87	86.50
1	175C	83	84	83.50
2	176	86	88	87.00
2	176C	83	84	83.50
3	177	88	84	86.00
3	177C	88	85	86.50
7	178	86	86	86.00
7	178C	86	85	85.50
8	179	91	90	90.50
8	179C	85	83	84.00
9	180	86	88	87.00
9	180C	85	85	85.00
10	181	90	88	89.00
10	181C	85	85	85.00
13	182	80	80	80.00
13	182C	80	80	80.00
14	183	79	79	79.00
14	183C	87	84	85.50
15	184	85	84	84.50
15	184C	85	82	83.50
16	185	85	89	87.00
16	185C	85	85	85.00
17	186	80	80	80.00
17	186C	80	80	80.00
20	187	79	80	79.50
20	187C	79	80	79.50
21	188	77	80	78.50
21	188C	80	80	80.00
22	189	86	83	84.50
22	189C	80	80	80.00
April				
5	198	92	89	90.50
5	198C	89	81	85.00
7	200	86	87	86.50
7	200C	82	85	83.50
11	202	85	88	86.50
11	202C	83	84	83.50
13	204	89	87	88.00
13	204C	84	84	84.00
17	206	89	86	87.50
17	206C	83	81	82.00
18	207	85	86	85.50
18	207C	83	84	83.50

TABLE XLIII. SCORES ON FIFTY EIGHT CHEESE, LOTS 2B, 3B, AND 4B CURED ONE MONTH AT NEW ORLEANS

Lot 2B, scored July 17, 1911 at Madison

Date of making cheese	Mean temp. at New Orleans	Cheese	U. S. Baer	A. T. Bruhn	Average
1911	F.	No.	Total score	Total score	Total score
April					
24	46	211	90	88	89.0
24	....	211C	85	86	85.5
27	60	214	92	90	91.0
27	....	214C	85	86	85.5
28	55	215	93	90	91.5
28	....	215C	85	84	84.5
May					
2	66	216	90	88	89.0
2	....	216C	85	86	85.5
3	60	217	91	89	90.0
3	....	217C	85	85	85.0
8	71	220	90	87	88.5
8	....	220C	85	85	85.0
10	73	222	92	94	93.0
10	....	222C	88	87	87.5
15	76	225	89	91	90.0
15	....	225C	87	85	86.0
17	76	227	92	92	92.0
17	....	227C	86	85	85.5
			Lot 3B, scored Aug. 14, 1911 at Madison		
22	78	230	89	88.0	88.5
22	....	230C	83	84.0	83.5
25	82	233	90	88.0	89.0
25	....	233C	79	80.0	79.5
29	84	234	91	90.0	90.5
29	....	234C	83	82.0	82.5
June	86	237	91	90.0	90.5
1	....	237C	80	81.0	80.5
2	86	238	91	90.0	90 5
2	....	238C	85	82.0	83.5
7	86	240	92	89.0	90.5
7	....	240C	80	79.0	79.5
9	87	242	93	92.5	92.75
9	....	242C	82	81.0	81.5
13	88	243	92	90.5	91.25
13	....	243C	86	85.0	85.5
15	88	245	90	91.0	90.5
15	....	245C	87	85 0	86.0
16	86	246	89	89.0	89.0
16	....	246C	86	82.0	84.0
			Lot 4B, scored Sept. 18, 1911, at Madison		
19	76	248	88.5	87	87.75
19	....	248C	83.0	85	84.00
21	74	250	81.0	82	81.50
21	....	250C	85.0	85	85.00
26	80	253	87.0	88	87.50
26	....	253C	87.0	85	86.00
27	82	254	89.0	89	89.00
27	....	254C	76.0	78	77.00
28	80	255	80.0	80	80.00
28	....	255C	78.0	77	77.50
	82	258	85.0	86	85.50
July					
3	....	258C	82.0	85	83.50
8	79	260	88.0	88	88.00
8	....	260C	86.0	83	84.50
10	82	261	82.0	80	81.00
10	....	261C	79.0	78	78.50
11	82	262	90.0	89	89.50
11	....	262C	85.0	85	85.00
12	79	263	87.0	86	86.50
12	....	263C	80.0	80	80.00

any cheese in the lot was 90.5; and the lowest, 78.50. The distribution of the scores is shown in Figure 14.

From this it can be seen that storage for so long a period as two months in New Orleans, at such temperatures, cannot be practised with either raw or pasteurized cheese without great loss of quality; however, the pasteurized cheese were somewhat better than the raw milk cheese when taken out of storage.

On account of the unmarketable quality of all the cheese when scored, it appears unnecessary to give the detailed scores and criticisms as to flavor and texture.

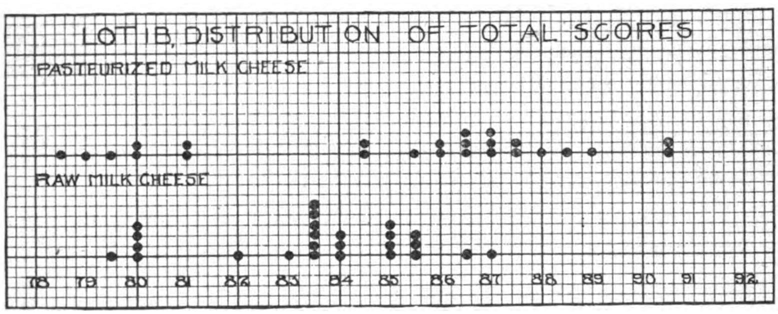

FIGURE 14. SCORES GIVEN LOT 1B AFTER TWO MONTHS' STORAGE IN THE SOUTH

Storage in a hot climate seriously injures the quality of both pasteurized and raw milk cheese but the pasteurized cheese show better scores.

Cheese Stored One Month in the South. Lots 2B, 3B, and 4B were stored at New Orleans for one month each, during parts of June, July, August, and September, 1911, and returned to Madison for scoring. The mean daily temperature during this period averaged 83.2° for June, 80.2° for July, 81.8° for August, and 82.6° for September. In lot 2B, the nine pasteurized milk cheese received an average total score of 90.44, and the raw milk cheese 85.56. The pasteurized were better in every case and averaged 3.88 points better.

In lot 3B, the ten pasteurized milk cheese scored the highest in every case, averaging 7.7 points higher. The average score of the pasteurized was 90.30 and of the raw was 82.60.

In lot 4B, the pasteurized milk cheese scored the highest in every case but one, and averaged 85.62 while the ten raw milk cheese averaged 82.10, a difference of 3.52 points.

From the results shown in Table XLIII, it is clear that after storage in the South for 1 month, the pasteurized milk cheese

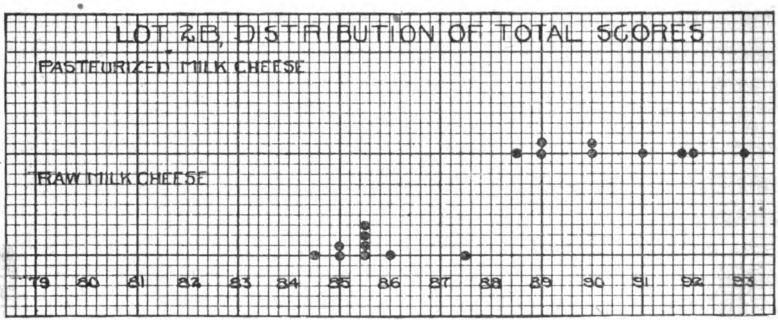

FIGURE 15. SCORES GIVEN LOT 2B AFTER STORAGE IN THE SOUTH

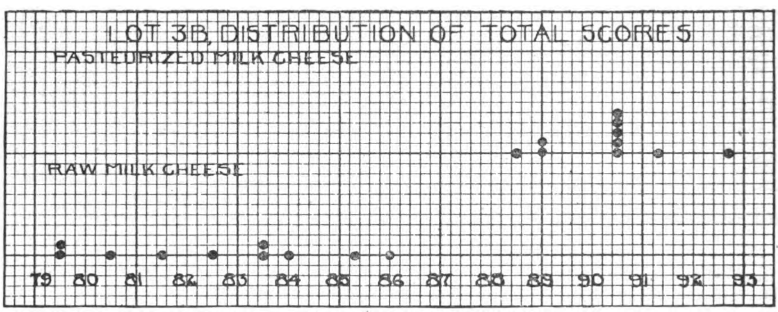

FIGURE 16. SCORES GIVEN LOT 3B AFTER STORAGE IN THE SOUTH

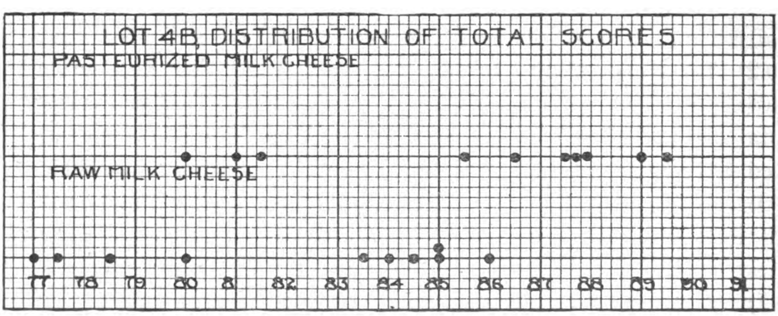

FIGURE 17. SCORES GIVEN LOT 4B AFTER STORAGE IN THE SOUTH

After one month's storage in a hot climate, the pasteurized cheese in each of these lots scored higher than the raw milk cheese.

came out better in quality than the raw milk cheese made from the same milk. It is not intended to suggest that cheese should be shipped to the southern states with the express intention of storing them for one month before they are sold, but it is clear that during the few days or weeks necessarily elapsing after market cheese reach their destination in the South, and before they are eaten, the pasteurized milk cheese are less likely to undergo serious deterioration, than the raw milk cheese.

The distribution of scores in lots 2B, 3B, and 4B is shown in Figures 15, 16, and 17.

Lots 3C and 4C, stored one month in the South by Crosby and Meyers, were scored at Madison. In lot 3C, the ten pasteurized cheese averaged 91.00; and the ten raw milk cheese, 84.85 in score as shown in Table XLIV. In every case, the pasteurized scored higher than the raw. In lot 4C, the ten pasteurized averaged 87.82 in total score, and the ten raw milk cheese, 85.07; and in every case but one, the pasteurized scored higher than the raw. All but two of these forty cheese scored below 92, and most of them were unsalable at full price, after storage as described. The temperature of the storage warehouse was not recorded.

Cheese in Warm Storage at Madison. Lots 3D and 4D were stored in a warm room at Madison, where the temperature ranged from 70° to 80° occasionally going up to 85°, during the months of July, August, and September, 1911. In lot 3D, the pasteurized cheese scored higher than the raw milk cheese in every case, averaging 90.55 while the raw milk cheese averaged 83.75, in total score. In lot 4D, the pasteurized cheese scored higher than the raw in every case but one, averaging 90.52 while the raw milk cheese averaged 86.15 in total score, as shown in Table XLV.

Cheese Kept in Cold Storage. Lot 4E. Much of the cheese made by the ordinary process is put into cold storage at about 34°, and most cheese dealers have cold storage warehouses. The effect of cold storage was therefore observed on a number of raw and pasteurized milk cheese. The milk supply was so short at the time, that raw milk cheese could be made on only a few days. Six or seven pasteurized milk cheese were made in one vat each day, and placed in the curing room at Madison, and single cheese were shipped to the cold storage warehouse of Roach & Seeber Co., at Waterloo, Wis., at different ages. After about three months, the cheese were all shipped

TABLE XLIV. SCORES ON FORTY CHEESE, LOTS 3C AND 4C, STORED ONE MONTH IN THE SOUTH, BY CROSBY & MEYERS, AND SCORED AT MADISON

Lot 3C, stored at Columbus, Ga., by Crosby & Meyers. one month before August 9, 1911. Scored at Madison, August 14, 1911.

Date of making cheese	Cheese	U. S. Baer	A. T. Bruhn	Average
1911	Number	Total score	Total score	Total score
April				
22	230	90	90	90.0
22	230C	87	86	86.5
25	233	90	89½	89.75
25	233C	85	84	84.5
29	234	94	94	94.0
29	234C	91	87	89.0
June				
1	237	92	89	90.5
1	237C	85	83	84.0
2	238	90	91	90.5
2	238C	84	85	84.5
7	240	92	91	91.5
7	240C	78	79	78.5
9	242	91	93	92.0
9	242C	85	87	86.0
13	243	lost	lost	lost
13	243C	85	82	83.5
15	245	91	90	90.5
15	245C	89	84	86.5
16	246	90	90.5	90.25
16	246C	88	83	85.5
Lot 4C, stored at New Orleans one month before September 13, 1911. Scored at Madison, September 18, 1911.				
19	248	90	89.5	89.75
19	248C	85	86.0	85.5
21	250	88	88.0	88.0
21	250C	85	85.0	85.0
26	253	86	87.0	86.5
26	253C	86	85.5	85.75
27	254	90	89.5	89.75
27	254C	80	83.0	81.5
28	255	89.5	89.5	89.5
28	255C	83	85.0	84.0
July				
3	258	87	88.0	87.5
3	258C	86	86.0	86.0
8	260	89	90.0	89.5
8	260C	87	86.0	86.5
10	261	83	84.0	83.5
10	261C	87	86.0	86.5
11	262	85	85.0	85.0
11	262C	85	85.0	85.0
12	263	90	88.5	89.25
12	263C	85	85.0	85.0

back to Madison at once, and examined by the judges. One cheese from each day's make was kept at Madison during the entire period.

In every case, the pasteurized milk cheese put into cold storage at the age of one day were criticised by the judges as being flat, low, and not developed in flavor; and the texture was described as curdy, new, not broken down, not cured, etc. They received an average score of 90.84, as shown in Table XLVI.

TABLE XLV. SCORES OF FORTY CHEESE, LOTS 3D AND 4D, STORED IN HOT ROOM AT MADISON

Lot 3D, scored at Madison, August 14, 1911

Date of making cheese	Cheese	U. S. Baer	A. T. Bruhn	Average
1911	Number	Total score	Total score	Total score
May				
22	230	87	87.0	87.00
22	230C	85	86.0	85.50
25	233	90	89.5	89.75
25	233C	81	80.0	80.50
29	234	93	94.0	93.50
29	234C	85	85.0	85.00
June				
1	237	94	94.0	94.00
1	237C	80	80.0	80.00
2	238	90	91.0	90.50
2	238C	85	86.0	85.50
7	240	94	94.0	94.00
7	240C	79	79.0	79.00
9	242	92	92.5	92.25
9	242C	85	85.0	85.00
13	243	90	89.0	89.50
13	243C	85	86.0	85.50
15	245	87	88.0	87.50
15	245C	85	86.0	85.50
16	246	88	87.0	87.50
16	246C	87	85.0	86.00
Lot 4D, scored at Madison, September 18, 1911.				
19	248	91.0	91.5	91.75
19	248C	85.0	85.0	85.00
21	250	86.0	86.0	86.00
21	250C	86.0	85.0	85.50
26	253	88.0	88.0	88.00
26	253C	85.0	86.0	85.50
27	254	91.0	92.0	91.50
27	254C	80.0	82.0	81.00
28	255	92.0	92.5	92.25
28	255C	89.5	89.5	89.50
July				
3	258	92.0	92.0	92.00
3	258C	87.0	86.0	86.50
8	260	91.0	92.0	91.50
8	260C	86.0	86.5	86.25
10	261	85.0	85.0	85.00
10	261C	89.0	87.0	88.00
11	262	94.0	94.0	94.00
11	262C	86.0	88.0	87.00
12	263	93.0	93.0	93.00
12	263C	86.0	89.0	87.50

The cheese put into cold storage at the age of one week received an average score of 91.93. They were found to be well cured and they had less mold on the surface (practically none) both when put into storage and when taken out, than any of the later lots. The cheese put into storage at two weeks,

TABLE XLVI. SCORES ON CHEESE PUT INTO COLD STORAGE AT WATERLOO AT DIFFERENT AGES

Date of making cheese	Cheese	Age when shipped to Waterloo	Lot 4E, scored October 30, 1911, at Madison								
			U. S. Baer			A. T. Bruhn			Average		
			Flav.	Text.	Total	Flav.	Text.	Total	Flav.	Text.	Total
1911 July	No.		Score	Score	Score	Score	Score	Score	Score	Score	Score
20	264.1	....	42.00	28.00	95.00	42.50	27.00	94.50	42.25	27.50	94.75
20	264.2	1 day	41.00	26.50	92.50	40.50	27.00	92.50	40.75	26.75	92.50
20	264.3	7 days	40.00	26.00	91.00	40.50	27.00	92.50	40.25	26.50	91.75
20	264.4	14 days	41.00	28.00	94.00	41.00	27.50	93.50	41.00	27.75	93.75
20	264.5	28 days	41.00	28.00	94.00	42.00	28.00	95.00	41.50	28.00	94.50
20	264.6	6 weeks	41.00	28.00	94.00	42.00	27.50	94.50	41.50	27.75	94.25
21	265.1	....	41.00	27.00	93.00	41.00	26.50	92.50	41.00	26.75	92.75
21	265.2	1 day	40.00	27.00	92.00	41.00	26.50	92.50	40.50	26.75	92.25
21	265.3	1 week	42.00	28.00	95.00	42.00	28.00	95.00	42.00	28.00	95.00
21	265.4	2 weeks	40.00	27.00	92.00	40.00	27.00	92.00	40.00	27.00	92.00
21	265.5	4 weeks	40.00	27.00	92.00	40.00	27.00	92.00	40.00	27.00	92.00
21	265.6	4 weeks	40.00	27.00	92.00	41.00	27.00	93.00	40.50	27.00	92.50
21	265.7	6 weeks	41.00	28.00	94.00	42.00	27.00	94.00	41.50	27.50	94.00
25	267.1	....	41.00	28.00	94.00	42.00	27.00	94.00	41.50	27.50	94.00
25	267.2	1 day	40.00	26.00	91.00	40.00	26.00	91.00	40.00	26.00	91.00
25	267.3	1 week	41.50	27.00	93.00	41.50	27.50	94.00	41.50	27.25	93.75
25	267.4	2 weeks	40.00	27.00	92.00	41.00	27.00	93.00	40.50	27.00	92.50
25	267.5	4 weeks	41.00	27.00	93.00	40.50	27.00	92.50	40.75	27.00	92.75
25	267.6	6 weeks	42.00	27.00	94.00	42.00	27.50	94.50	42.00	27.25	94.25
25	267C1	....	36.00	26.00	87.00	36.00	26.50	87.50	36.00	26.25	87.25
25	267C2	1 day	38.00	27.00	90.00	39.00	27.00	91.00	38.50	27.00	90.50
25	267C3	2 weeks	38.00	27.00	90.00	38.50	27.00	90.50	38.25	27.00	90.25
27	269.1	....	40.00	27.00	92.00	41.00	26.50	92.50	40.50	26.75	92.25
27	269.2	1 day	40.00	27.00	92.00	40.50	26.50	92.00	40.25	26.75	92.00
27	269.3	1 week	40.00	27.00	92.00	40.50	26.50	92.00	40.25	26.75	92.00
27	269.4	2 weeks	41.00	27.00	93.00	40.00	26.50	91.50	40.50	26.75	92.25
27	269.5	4 weeks	41.00	27.00	93.00	42.00	27.00	94.00	41.50	27.00	93.50
27	269.6	6 weeks	42.50	28.00	95.50	42.50	27.50	95.00	42.50	27.75	95.25
27	269C1	2 weeks	34.00	23.00	82.00	32.00	25.00	82.00	33.00	24.00	82.00
Aug. 1	272.1	....	35.00	23.00	83.00	36.00	25.00	86.00	35.50	24.00	84.50
1	272.2	1 day	36.00	25.00	86.00	36.00	25.00	86.00	36.00	25.00	86.00
1	272.3	1 week	37.00	25.00	87.00	39.00	24.00	88.00	38.00	24.50	87.50
1	272.4	2 weeks	38.00	25.00	88.00	38.00	25.00	88.00	38.00	25.00	88.00
1	272.5	4 weeks	35.00	25.00	85.00	36.00	24.00	85.00	35.50	24.50	85.00
1	272.6	6 weeks	37.00	24.50	86.50	38.00	25.00	88.00	37.50	24.75	87.25
8	276.1	....	37.00	25.00	87.00	39.00	26.00	90.00	38.00	25.50	88.50
8	276.2	1 day	40.00	26.00	91.00	40.00	26.00	91.00	40.00	26.00	91.00
8	276.3	1 week	40.00	25.00	90.00	39.50	25.50	90.00	39.75	25.25	90.00
8	276.4	2 weeks	40.00	24.00	89.00	39.00	25.00	89.00	39.50	24.50	89.00
8	276.5	4 weeks	40.00	27.00	92.00	39.50	26.50	91.00	39.75	26.75	91.50
22	283.1	....	41.00	27.00	93.00	41.50	26.50	93.00	41.25	26.75	93.00
22	283.2	1 day	40.00	26.00	91.00	40.50	26.00	91.50	40.25	26.00	91.25
22	283.3	1 week	42.00	27.00	94.00	41.00	27.00	93.00	41.50	27.00	93.50
22	283.4	2 weeks	40.50	27.00	92.50	41.00	26.50	92.50	40.75	26.75	92.00
22	283.5	4 weeks	42.00	27.00	94.00	41.50	27.00	93.50	41.75	27.00	93.50
22	283.6	....	42.00	27.00	94.00	42.00	26.50	93.50	42.00	26.75	93.75

four weeks, and six weeks of age, were given average scores of 91.36, 91.82, and 91.46, respectively; while the others kept at Madison the entire period scored 91.39.

So far as this short series indicates, there is no objection to putting pasteurized milk cheese into storage at 34°, at the age of one week, immediately after paraffining. It is planned to make a more extensive trial of the use of cold storage for pasteurized milk cheese during the season of 1912.

Exceptional Cases. It is of interest to collect in one place all of the cases recorded in the tables, where the pasteurized milk cheese were scored lower than the raw, in order, if possible to locate the cause for such difference. Table XLVII shows such cases.

TABLE XLVII. EXCEPTIONAL SCORES FOR CHEESE MADE FROM RAW AND FROM PASTEURIZED MILK

Lots 1A, 2A, 3A and 4A		Lots 1B, 2B, 3B, and 4B		Lots 3C and 4C		Lots 3D, and 4D	
Cheese No.	Total score	Cheese No.	Total score	Cheese No.	Total score	Cheese No.	Total score
....	....	171	81.00	....	....	....	....
....	....	171C *a*	87.00	....	....	....	....
172	91.75	172	81.00	....	....	....	....
172C	89.50	172C *a*	83.00	....	....	....	....
177	91.75	177	86.00	....	....	....	....
177C	89.00	177C *a*	86.50	....	....	....	....
183	91.25	183	79.00	....	....	....	....
183C *a*	91.75	183C *a*	85.50	....	....	....	....
184	92.00	184	84.50	....	....	....	....
184C *a*	92.75	184C	83.50	....	....	....	....
188	94.50	188	78.50	....	....	....	....
188C	90.50	188C *a*	80.00	....	....	....	....
250	91.75	250	81.50	250	88.00	250	86.00
250C	87.50	250C *a*	85.00	250C	85.00	250C	85.50
261	90.25	261	81.00	261	83.50	261	85.00
261C	90.00	261C	78.50	261C *a*	86.50	261C *a*	88.00

*a*The cases in which the raw milk cheese scored higher than the pasteurized milk cheese. The scores of duplicate cheese in the other lots, are given for comparison.

The fact that pasteurized and raw cheese from the same milk may occasionally score exactly alike or nearly alike would appear to indicate that where the milk supply is excellent, the quality of cheese produced is not improved by the new process. With so small a difference in score as occurred in Nos. 184 in lot A, and Nos. 177 in lot B, it is doubtful whether there was any difference between the two cheese which could be ascribed with certainty to the effect of the pasteurization process.

The most adverse criticism on the process that can be based upon the ten cases tabulated is the following. It is entirely possible that some harmful bacteria or their enzymes, occasionally present in dirty milk, may not be destroyed by the pasteurization process, and that such infections damage the quality of pasteurized milk cheese as well as raw milk cheese. In this year's work, it has been noticed that on a few occasions, when the raw milk was very ripe, the quality of cheese produced, even after pasteurization, was not so good as from milk of fairly good quality. For example, the poorest pasteurized milk cheese in Table XLVII is No. 261, and the milk used for making this was of .28% acidity before pasteurization. In Table XLVI, showing scores of cheese shipped to Waterloo, Nos. 272 and 276 are the poorest in quality, and these were made from milk which titrated .275% and .31% acidity, respectively, before pasteurization. Of course, such milk should not be accepted at any cheese factory.

No claim is made that the pasteurization process is a cure for all the troubles of the cheese factory, or that it reduces the responsibility resting on factory patrons to improve the sanitary quality of their milk, so far as possible. It would be most unfortunate, if any process could be used for making cheese, or any other article of food, which would relieve the milk producer or the factory man of the necessity for cleanliness.

Summary of Discussion of Scores. The scores of lots 1B, 2B, 3B, 4B, 3C, 4C, 3D, and 4D, all show that cheese either raw or pasteurized, stored for one or two months at about 80°, are often seriously injured, so as to be unsalable at the ruling market price. The pasteurized cheese come out of such storage, better in quality than the raw milk cheese in about 90% of all cases observed. It is clear that the pasteurized milk cheese are better suited to stand exposure to high temperature than raw milk cheese. This fact may find useful application in two ways. While it is never advisable to store market cheese for any great length of time in the South, yet several days or weeks may often elapse before cheese shipped South are finally sold to the consumer, and it appears that pasteurized milk cheese should stand this exposure with less damage in quality than raw milk cheese. It is likely too, that pasteurized milk cheese can be cured at ordinary curing room temperatures below 70° in Wisconsin, without the use of ice or mechanical refrigeration, thus avoiding part of the expense for cold storage. The quality of the fifty-three raw milk cheese in lots 1A, 2A, 3A, and 4A, cured at 60° to 73° at Madison is represented by the average total score of 89.09, and would no doubt have been greatly improved if the cheese had been cured in cold storage. In fifty-one cases out of fifty-three the pasteurized milk cheese in these lots, scored higher than the raw, and on the average of all, 3.8 points higher, the average total score of the pasteurized being 92.75 points, which indicates that cold storage for the pasteurized cheese was not necessary.

In a short series of cheese placed in cold storage at 34° F., at different ages, it was found that those stored at the age of one day, were curdy and uncured at the age of three months, while those placed in storage at the age of one week were free from this fault and scored as high or a very little higher; and showed less mold on the surface than those put in storage when older than one week. From this, it appears that pasteurized milk cheese can safely be put in cold storage at the age of one week, immediately after paraffining. It is planned to try cold storage with both raw and pasteurized milk cheese during 1912.

THE SALE OF PASTEURIZED MILK CHEESE DURING 1910 AND 1911

One of the objects of the work during 1909, 1910, and 1911 was to sell the cheese to consumers as widely as possible, and learn whether it would meet with favor and continued demand. It was felt necessary thus to establish its suitability for the market, before recommending that cheesemakers take up the new process.

The amount of cheese sold each year was limited by the output of the factory, at which place it was impossible to secure a larger supply of milk. Much more cheese could have been sold to the purchasers listed below, and doubtless to others, if we had had the cheese to sell. In nearly all cases, the cheese were sold at the current price ruling on the Plymouth cheese board, f. o. b. Madison, without discount.

During 1910, 137 sales, aggregating 4,815½ pounds of pasteurized milk cheese, valued at $711.16 were made to nineteen representative and leading grocery stores, hotels, restaurants, and delicatessen stores in Madison, Wis. Nearly every purchaser re-ordered it several times, and three of the leading retailers re-ordered it 15, 20, and 49 times respectively during the season. The average price paid for all of this cheese was 14¾ cents per pound. During 1909, 1910, and 1911, forty-one shipments of pasteurized milk cheese, weighing 10,126 pounds in all, valued at $1,382.93, were sent to twenty-seven leading cheese dealers, including a few retail stores, in New York, Boston, Philadelphia, Chicago, St. Louis, Minneapolis, and San Francisco, and at various Wisconsin points, outside of Madison, including Plymouth, Sheboygan, Fond du Lac, Marshfield, Richland Center, Waterloo and Milwaukee. Samples of the cheese were also shipped to experiment station workers in the leading dairy states, for their examination.

OPINIONS OF PURCHASERS OF NEW PROCESS CHEESE

No written opinions were asked from dealers in Madison, handling this cheese, neither were they urged to purchase a second time. The University delivery wagon, making two trips daily among retail stores, took such orders as were given. The fact that a dealer bought this make of cheese only once may be due to a variety of causes, such as business relations with other wholesale cheese dealers in the city. The fact that several of the leading grocers sold this cheese continuously for several months, and repurchased it every week or oftener, and always without reporting any complaint from consumers, is taken to indicate that it was satisfactory to the retail trade in this city.

An effort was made to obtain a written opinion from every firm outside of Madison, to whom the cheese were sold. It was usually impossible to send many shipments to a single purchaser, because it was desired to distribute the available supply of cheese as widely as possible.

The letters received from dealers outside of Madison show that all, except a very few, found the cheese entirely satisfactory, and salable at the full market price. Here again, the occasional disapproval of cheese may be due to an oversupply in the buyer's warehouse, or other causes than the quality of the cheese itself. It is interesting to note that the cheese shipped to two firms, who apparently disliked them, were the same day's make as those shipped on the same date to three other firms who praised their quality, and pronounced them satisfactory.

In every case, dealers were informed that the cheese "were made by special process, which we are trying at Madison, by which it is hoped that cheese of cleaner flavor and greater uniformity can be obtained." In no case were dealers informed as to the nature of the process, or that the milk was pasteurized. The purpose was to excite the dealers' interest, and secure careful examination of the cheese, but not excite prejudice for or against it.

The very general expression of approval of the product in the letters from dealers and experiment stations, appears to warrant further trial of the method on a larger scale than heretofore.

EXTRA COST OF MAKING PASTEURIZED MILK CHEESE

The extra cost in making pasteurized milk cheese is given in the following figures which are estimated for an outfit handling 2000 pounds of milk per hour, and operated one hour per day. It is of course true that the charges against one pound would be reduced, if the capacity of the outfit or the daily time of operating it were increased. The figures are regarded as expressing the maximum extra costs of making cheese by the new method, as compared with the old.

The additional outfit required for making cheese by the new process consists of a receiving vat, a pasteurizer and cooler, and an acidulator, which latter can be home-made. It is assumed that the boiler and pump in the factory are large enough to furnish the necessary steam and water supply for heating and cooling the milk. The costs for additional outfit are therefore:

Steam receiving vat, capacity 300 gallons, freight, etc.	$60.00
Pasteurizer, with pump or elevating device for milk; capacity, 2000 pounds per hour; cooler of the same capacity	285.00
Acidulator, partly home made	5.00
Total cost of additional outfit	$350.00

If it be considered that this outfit need be replaced only once in ten years, it will be fair to charge 10% for depreciation and 6% for interest on the investment, per year, or 16% on $350, which amounts to $56.00 per year or about 16 cents per day.

The cost of steam heat for pasteurizing will vary with the price of fuel. According to experiments carried on at the Royal Experiment Station, Copenhagen, Denmark, ninety pounds of steam are required to heat 1000 pounds of milk from 90° to 185° F. McKay and Larson[31] have calculated, that with coal at $4.00 per ton, and allowing fifteen pounds of coal, to produce ninety pounds of steam, the cost of steam for pasteurizing one thousand pounds of milk is three cents.

During 1910, a number of determinations were made of the amount of condensed steam which ran from the heating disks of a Farrington Duplex pasteurizer, during the pasteurization of weighed quantities of milk at 160° to 165° F. The figures are shown in Table XLVIII.

TABLE XLVIII. WEIGHT OF STEAM USED FOR PASTEURIZING MILK, FOR CHEESEMAKING

Date	Milk used	Condensed steam		Pounds steam per 1,000 pounds milk
	Weight	Weight	Temperature	
1910	Lbs.	Lbs.	F.	Lbs.
May				
23	2,611	265	108°	....
24	1,454	150	111°	....
25	1,284	135	112°	....
26	1,322	135	110°	....
27	1,337	133	111°	....
30	2,082	195	102°	....
June				
1	1,578	142	111°	....
3	1,449	141	110°	....
6	2,061	204	114°	....
7	1,427	144	113°	....
8	1,431	140	117°	....
9	1,360	130	114°	....
15	1,190	113	120°	....
Average	1,586	156	112°	98.36

From these determinations, the weight of steam required to pasteurize milk for cheesemaking appears to be a little less than 100 pounds per 1000 pounds of milk. It should be stated that the steam used was drawn from a main line at 160 pounds pressure expanding through a valve directly into the pasteurizer, and all condensed water was first drawn out of

[31] Principles and Practice of Buttermaking, p. 183.

the main connections through a drip cock before turning on the steam.

The amount of coal required to evaporate 200 pounds of water in the boiler, for pasteurizing 2000 pounds of milk, may be estimated at 15 to 30 pounds, according to conditions, costing, at $5.00 per ton, about eight cents, which must be charged against the pasteurized cheese.

The cost of pumping water for cooling the pasteurized milk will vary, of course, in different places. In several experiments with the Farrington Duplex pasteurizer, the water flowing from the cooling discs during exactly three minutes was collected in a tank and weighed, and at the same time the temperatures of the water and milk flowing into and out of the machine were noted. The average rate of flow of milk through the pasteurizer was found to be 33 pounds per minute, the rated capacity being 2000 pounds per hour. The milk at 160° was cooled by lake water which entered the first set of discs at 81° and flowed out at 105°, at the rate of 83 pounds per minute. In the second set of cooling discs, well water was used, entering at 58°, and escaping at 70°, at the rate of 63 pounds per minute. The weight of water used was thus about 4½ times the weight of the milk handled. This quantity would have been smaller, if the machine were so constructed as to let the well water flowing at 70° out of the cooler, second set of discs, enter the first set of discs instead of running into the drain, thus avoiding the use of lake water entirely. There were seven discs of 20 inches diameter in each set.

Using the Reid pasteurizer, and vertical disc cooler, having one set of 9½ discs, 14 inches in diameter, milk flowing at the rate of 1000 pounds per hour was cooled from 170° to 70° by water flowing in at 54° and out at 82°, using 67 pounds of water for 16 to 17 pounds of milk. These quantities of water were entirely sufficient, but it is possible that the work might be done with less.

Under these conditions about four pounds of cooling water were used per pound of milk pasteurized, or 8000 pounds of water for cooling 2000 pounds of milk. If this amount of water is pumped up 30 feet per minute, an eight-horse-power pump, will be needed; or if pumped up in an hour, a 1/7 horse power pump will be required. A small gasoline engine uses about 1/10 gallon of gasoline, worth 2 cents, per horse-power-hour. The cost of pumping, figured in this way, is very small. In the city of Madison, the charge made to large users of water is about nine cents per 1000 gallons, and this price is used in the table of costs given below.

The cost of chemically pure hydrochloric acid in carboys, for acidulating pasteurized milk, is seven cents a pound. One pound of the acid as purchased makes, by adding water, about ten pounds of "Normal acid", ready to be added to the milk. If the milk has an average acidity of .18%, when received at the factory, 2000 pounds of milk will require 7/9 of 20, or 15.6 pounds of "normal acid", or about 1.6 pounds of acid as purchased, costing 12 cents.

The total additional cost of making pasteurized milk cheese by this process, over the cost by the ordinary process, may be calculated as follows, for handling 2000 pounds of milk per day.

Interest and depreciation on receiving vat and pasteurizer	$0.16
Coal at $5.00 per ton, for heating milk, in pasteurizer	.08
Water, per 1000 gallons (city of Madison price)	.09
Hydrochloric acid, 1.6 pounds at seven cents	.12
Total added cost per 2000 pounds of milk	$ .45

If 200 pounds of cheese were obtained from the 2000 pounds of milk, the charges listed above would amount to about ⅕ cent per pound of cheese. With cheese selling at 12 cents per pound, an increased yield of 1 pound in 60, or 1⅔% by weight, would pay for the cost of pasteurization; and any additional yield obtained beyond this would be pure profit for the seller of the cheese.

THE SAVING AND PROFIT IN MAKING PASTEURIZED MILK CHEESE

In making cheese by the new process, only two ounces of rennet are required for 1000 pounds of milk, instead of four ounces, as in the ordinary factory. There is thus a saving, per day, on 2000 pounds of milk, of about four cents' worth of rennet.

Since the new process cheese can be cured without cold storage, the usual charges for the cold storage of 200 pounds of cheese for three months, at ½ cent a pound, may be avoided. This saves $1.00 per 2000 pounds of milk.

There is an increased yield of cheese by the new process, amounting to 4.75%, (See Table XXIII), at the time the cheese are paraffined. This is an increase of 9.5 pounds of cheese from 2000 pounds of milk. With cheese at 12½ cents a pound, the gain in yield is worth $1.19 cents.

It is impossible to calculate how much of the money now lost through the production of cheese of inferior quality, or through reduced yield, because of defective milk, can be saved through the use of the new process.

The savings figured above, for 2000 pounds of milk, are

Rennet	$0.04
Cold storage for three months	1.00
4.75% gain in yield of cheese	1.19
Total saving per 2000 pounds of milk	$2.23
Deducting the costs, estimated above	.45
Profit due to pasteurization of 2000 pounds milk	$1.78

At a factory where 10,000 pounds of milk are handled daily, the extra profits, by the new process, would amount at this rate, to $8.90 per day, which would more than pay for the factory supplies (estimated at ¾ of a cent per pound of cheese) or for the labor of two men, or a man and helper.

If the item for cold storage be omitted from the above estimate, leaving 78 cents profit on 2000 pounds of milk, this would amount to $3.90 on 10,000 pounds of milk per day, or $117 per month.

FURTHER TRIALS OF THE NEW PROCESS IN CHEESEFACTORIES

The results described in this bulletin appear to indicate that the new method of cheesemaking is an improvement over the regular process now commonly used. Working with the milk supply available at Madison, the new method is unquestionably an improvement over the old. It is a fact well known to cheesemakers however, that the milk supplies found at different factories do not always behave alike in the cheese vat, so that the regular process must frequently be modified to suit the conditions encountered in different localities. It remains therefore to test the new method at several factories in different cheesemaking districts before it can be recommended for use generally. Cheesemakers are advised to await the publication of results of further trials before undertaking to use the new method on a commercial scale.

It is hoped that the new method will receive careful attention and criticism by such cheese experts at Experiment Stations in different parts of the country, as may be able to give it a trial. The authors will be glad to correspond with anyone interested, and to aid in such trials so far as circumstances permit.

SUMMARY

Preliminary and Comparative Work with the Old and New Methods. The continued improvement of the cheesemaking industry calls for more economical factory management. Large well-equipped factories should replace many of the small, poorly supported factories of the present time. A new method of cheesemaking is needed, by means of which milk of variable quality from many farms, can be brought into practically uniform condition for cheesemaking at the factory, and be made up into cheese in a uniform, routine manner daily, without variations of time or method of handling. The new method should produce cheese of greater uniformity and avoid the present common losses in yield and quality, due to defective milk.

During the years 1905–1906, experimental cheese were made, omitting the starter, and in its place, adding various commercial acids to the raw milk. The method of adding acid to milk was perfected, and a two weeks' trial of the process was finally made in a commercial factory at Muscoda, Wis. It was shown that the addition of hydrochloric acid to milk is entirely practicable at cheesefactories, and that the quality of the cheese is not in any way injured by such addition; but it was also found that the quality of cheese obtained from overripe or tainted milk was no better than by use of the ordinary factory methods. Therefore, there was no reason for recommending the use of hydrochloric acid to cheesemakers, at that time.

Most of the defects observed in cheese factory milk are of bacterial origin. In other branches of the dairy industry than cheesemaking, pasteurization is successfully employed to overcome these faults. The desirability of pasteurization of milk for cheesemaking, if possible, has often been pointed out.

In 1907, a few lots of milk were pasteurized in a discontinuous pasteurizer, and then acidulated with hydrochloric acid, and the cheese obtained were such as to demonstrate the importance of further study.

In 1908, equally good results were obtained by use of the continuous pasteurizer. Heating to 160° to 165° was found sufficient to check effectually the bacterial action in milk for cheese making purposes. Bacterial counts showed that over 99% of the total baterial content of the milk was destroyed at this temperature. The use of higher temperatures was shown to be objectionable, on account of the effect upon the quality of the cheese.

In 1909, cheese were made almost daily both by the regular factory process, and by the new process from pasteurized milk. The regular milk supply was thoroughly mixed each day and divided into two lots, for the two different processes. After curing, the cheese made from pasteurized milk were found to be cleaner in flavor and superior in texture to the raw milk cheese. The difference was more marked the poorer the quality of the milk supply. Many of the details of the process were studied and improved.

In 1910, the making of cheese by the two methods, for comparison, was continued, and the entire output of pasteurized milk cheese was sold to retail grocers, mostly in the city of Madison, in order to determine how these cheese would suit the trade. They met with ready and continued sale. It was noticed also that the yield of cheese was, regularly, somewhat greater by the new process, than by the old.

In 1911, better facilities were provided for weighing large quantities of milk and cheese, quickly and accurately, and the yields of cheese obtained from raw and pasteurized milk were carefully determined. The accuracy of the experimental methods was such that in making duplicate vats of cheese from pasteurized milk, the yields differed by only .58% on the average. A greater yield of cheese was always obtained from the pasteurized milk than from raw milk; and during the year 1911, the average gain in yield of green cheese was

5.37%. The green pasteurized milk cheese shrank a little more than the raw milk cheese, so that when paraffined, the average gain in yield from pasteurized milk was 4.76%. After curing at 60° to 70° F., for about 100 days, the gain in yield of pasteurized milk cheese over raw was 4.22%.

The average loss of fat in whey from pasteurized milk is about .17%, measured at the time the whey is drawn from the vat. This is less than half the loss in average factories using raw milk. The total loss of fat in whey and drippings from vat and press,using pasteurized milk, averaged 1.58% of the weight of the cheese, or less than half that of the usual loss in handling raw milk.

In addition to this saving of fat, it is found that a somewhat larger proportion of moisture is incorporated in pasteurized milk cheese than in ordinary cheese, without damage to the quality. The gain in yield of pasteurized milk cheese is therefore due partly to fat and partly to moisture.

Scores and criticisms given by competent cheese judges show that the pasteurized milk cheese varied less in quality, and averaged better by 3.7 points of total score, than the raw milk cheese made from portions of the same milk supply. The pasteurized milk cheese scored higher than the raw milk cheese in 96% of all cases.

Duplicate sets of cheese were cured at New Orleans, for one month, at 70° to 83° (monthly average figures during the summer), and here the raw milk lost more in weight than the pasteurized, so that the average gain in yield of pasteurized over raw rose to 6.21%. From other cheese cured at Madison, in a warm room, it was learned that the raw milk cheese lose considerable amounts of fat, at 75° to 85°, while the pasteurized milk cheese lost none.

Storage for a month at 75° to 80°, average temperature, as at New Orleans, is not recommended for any cheese, yet it was found that the pasteurized milk cheese averaged three to eight points better in total score, after such storage, than the raw milk cheese.

Since pasteurized milk cheese can be cured without injury at 70°, it is likely that in many cases, the expense of cold storage for these cheese can be avoided.

Pasteurized milk cheese can be put into cold storage at 34° at the age of one week and possibly earlier, without injury.

The earlier they can be put in storage, if this is done at all, the greater will be the gain in yield by the new process. It is planned to study the cold storage of these cheese further.

During 1910–1911, about $2,100 worth of pasteurized milk cheese was sold to about fifty dealers, both wholesale and retail, in various large cities, from New York to San Francisco. The cheese sold readily for the ruling market prices, and often above. Very few dealers offered any objections to them, and several wished to buy them regularly. A great many were sold throughout the South. In general the cheese passed the market without exciting special comment, selling for full price, and giving satisfaction. They were not labeled or marked, except with a serial number to distinguish different days' make. There appears to be no reason why pasteurized milk cheese can not be sold regularly in any market, with entire satisfaction, excepting possibly, to the limited trade that demands very high flavored cheese.

Outline of the New Method. In the method here described, a principle is applied to the cheese making process which has already been found useful in many other lines of manufacture, namely: The raw material, milk, is first treated by a preparatory process to bring it into uniform condition before it enters the manufacturing process proper. Material of uniform quality, thus prepared, is made up into the finished product by a uniform routine process, without daily variations of the time schedule or other details, and the product is more uniform in quality, has better keeping qualities, etc., than the product obtained by the older process.

The difficulties met hitherto, in making American cheddar cheese from pasteurized milk are (1) that heated milk coagulates poorly with rennet, and (2) the curd, when obtained, does not expel moisture precisely as a raw milk curd does, this effect being more marked, the higher the temperature of pasteurization. The quality and behaviour of pasteurized milk curd suggest that it lacks the acid, which is normally produced in raw milk curds by the action of bacteria on milk sugar.

The first of these difficulties, but not the second, can be overcome by adding calcium chloride solution to pasteurized milk. This method has been tried experimentally, but is not recommended for use in American cheese factories. Both difficulties are overcome by adding an acid, preferably hydrochloric acid, to the pasteurized milk. Hydrochloric acid is normally present in the human stomach during the process of digestion, in larger proportion than that added to milk in this process of cheesemaking. Further, 95% of the added acid passes out of the cheese into the whey, during the process of manufacture. On this account, no objection can be made, on sanitary grounds, to the use of this acid, in the manner and for the purposes described.

Among different lots of cheese, part of which were made with hydrochloric acid, and part with calcium chloride, added to portions of the same milk after pasteurization, those made with acid were found to be more uniform in moisture content and superior both in flavor and texture to those made with calcium chloride.

The losses of fat in the whey are reduced by use of the acid. Pasteurization and acidulation of milk for cheesemaking appear to be complementary processes. Used together, they furnish a means for bringing milk daily into uniform condition, both as to acidity and bacterial content, for cheesemaking purposes.

The acidulation of milk with hydrochloric acid after pasteurization is accomplished without difficulty or danger of curdling, by running a small stream of the acid, of normal concentration, into the cooled milk, as it flows from the continuous pasteurizer, into the cheese vat. One pound of normal-strength acid is sufficient to raise 100 pounds of milk from .16% to .25% acidity (calculated as % of lactic acid). The amount of acid needed each day to bring the milk up to .25% acidity is read from a table, or calculated from the weight of the milk and its acidity, determined by use of Manns' acid test (titration with $^{N}/10$ NaOH and phenolphthalein). The preparation of standard strength acid in carboy lots for this work, and the acidulation of milk present no great difficulty to any one who is able to handle the Manns acid test correctly.

After milk is pasteurized and acidulated, .75% of first-class starter is added, and the vat is heated to 85°. It is set with rennet, using two ounces rennet per thousand pounds milk, so that the milk begins to curdle in seven minutes, and is cut with 3/8 inch knives in twenty-five minutes. All portions of the day's work, after adding rennet, are carried out in routine manner, according to a fixed time schedule, every day. As soon as the rennet has been added, the cheesemaker is able to calculate the exact time of day, when each of the succeeding operations should be performed, and the work of making cheese is thus simplified and systematized.

It is possible that the routine process here described may be varied somewhat, with advantage, at different factories. For example, some experienced cheesemakers may prefer to mat the curds on the bottom of the vat instead of on racks, or may find the use of the "curd gage" unnecessary, and local conditions may be found in different factories making other adjustment of details desirable. However, the experience already had with the process indicates that the routine of daily operations found suitable at any factory can be practiced there throughout the season without variation.

The extra cost of making pasteurized milk cheese is being studied, with a view to finding out accurately what the net profit is in making this cheese, compared with the regular process.

Preliminary estimates show that the maximum extra cost may be 45 cents for 2,000 pounds of milk, with many chances for reducing the cost, in handling larger quantities.

Because of the increased yield of cheese, the saving in rennet, and in cold storage charges, there is a saving of about $2.23, in handling 2,000 pounds of milk. Deducting the extra costs of making from this figure, leaves a net profit of $1.78, as a result of using the pasteurization process here described instead of the usual raw milk process. This is equal to a gain of 7/8 of a cent a pound on the selling price of cheese.

Allowing $1.00 for cold storage charges on 200 pounds of cheese, there is yet a profit of about 3/8 of a cent a pound through pasteurization. The profits per pound will be increased where larger quantities of milk are handled and the losses in yield, quality, and selling price, which factories often suffer, because of defective milk, will also be avoided through pasteurization.

It should not be supposed that sanitary conditions of milk production may be neglected on the farm, as a result of using this process at the cheese factory. In all cases, it is to be expected that the better the milk used, the better the quality of the cheese will be.

It is the intention to give the new process a thorough trial in different cheesefactories in various localities, to test its applicability to different milk supplies, before recommending it for general use by cheesemakers. These trials will show whether new difficulties may arise, which were not encountered heretofore. Cheesemakers are therefore advised to await the publication of results of further trials of the method by the writers, before undertaking to use the new process at their factories.

This process should interest the farmer, because of the increased yield of cheese, and the avoidance of the usual losses in yield and quality, due to defective milk. It should interest the cheese maker, because the process of making is systematized to such a degree, that it is conducted upon a fixed time schedule for all operations. It should interest the dealer because the cheese is more uniform in quality, and there is less need for cold storage, in curing. Finally the cheese should interest the consumer, because it is more uniform in flavor than most of the cheese to be found on retail counters, being made from pasteurized milk; and is a more sanitary product than ordinary American cheese, made from raw milk.