Scientific Treatises
in Honor of
Bernard Wernick Hammer

Further Observations on the Quantitative Changes in the Microflora of Cream and Butter During Manufacture, Storage and Shipment[1]

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A STUDY was made in the summer of 1927 in connection with investigations to determine the changes in the microflora of cream and butter during the processing of the cream and the manufacture, storage and shipment of the butter and in an attempt to ascertain whether mold, yeast or bacterial counts of cream or butter could be used as indices of the market grade or keeping quality of the butter.

With the co-operation of an Eastern buyer, the studies were made at nine typical Minnesota co-operative creameries and at the terminus on the Eastern seaboard. The creameries were grouped into three sets, each set consisting of three creameries selected because shipments from them were made in the same car. The observations were made during the month of August, and a member of the Dairy Husbandry staff was assigned to each creamery to make the necessary laboratory tests and to record other pertinent information such as manufacturing records, temperature readings and scorings.

At each creamery, during the week of observation, each lot of cream was subjected to analyses from the time it was received until the butter was placed in the car for shipment. All laboratory tests, chemical and microbiological, were made at the creamery, where the necessary equipment had been provided from the University laboratories. The raw cream was tested for fat, acidity, mold, yeast and bacterial counts and then graded. Immediately after pasteurization and cooling, samples were taken for mold, yeast and bacterial counts. Where flash pasteurization was used, a composite sample was collected during the process. When

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starter was used, an additional sample was taken for analysis just before the cream was pumped to the churn. A sample of the finished butter was taken from the churn, following working, for complete Kohman analysis and microbiological examination. The day the butter was shipped a sample was taken from each churning for analysis. Each churning of butter was scored when fresh and when shipped.

The butter in all creameries was printed, wrapped in parchment and placed in 60-pound boxes for shipment. The print from which the sample was taken before shipment was marked and placed in a regular box for examination in the East.

A maximum-minimum registering thermometer was fastened securely in a separate box, which was placed near the center of the refrigerator car before the car door was sealed.

Complete manufacturing records for each churning, temperature of atmosphere inside and outside the creamery, and of the butter storage room during the day, were kept. Observations were also made daily on the weather.

At the Eastern market, when the butter arrived, samples were taken by the author from each churning for scoring, chemical analysis and mold, yeast and bacterial counts. The readings of the thermometers in the cars were also recorded.

All plates were poured with whey agar and acidulated with tartaric acid in the case of mold and yeast analyses. For mold and yeast counts incubation was at room temperature for three days; for bacterial counts, seven days.

The data showing the changes in the microflora during manufacture, storage and shipment are presented in tables 1-3.

Table 1 shows that pasteurization (165° F. at creameries 1, 4, 6, 7, 8 and 9, 145° F. in coil vats at creameries 2 and 3, and 180° F. flash at creamery 5) was especially efficient in destroying molds in the cream at creameries 1, 2, 3 and 4, ranging from 99.6 to 100 percent effective. Results were fair in this respect at creameries 6 and 8 but least satisfactory at creamery 5, where the flash system was used. With the high-acid cream at creameries 7 and 9 the percentage reduction of molds was marked where the original counts were high, but the final counts were not as low as might be desired. As indicated in table 2, creameries 1, 2, 3, 4 and 6 had the best records for the destruction of yeasts by pasteurization. The remarkable reduction in bacterial counts as a result of pasteurization is clearly demonstrated in table 3. Altogether it is apparent that proper pasteurization may be relied upon to reduce the numbers of molds, yeasts and bacteria in cream in a striking manner.

Tables 1 and 2 indicate that certain creameries using starter were carrying cultures notably contaminated with molds and yeasts.

The data definitely demonstrate that the churn was a very important source of molds, yeasts and bacteria because in the majority of cases the

TABLE 1. *Changes in mold counts of cream and butter*

Creamery number	Percent acidity of cream	Mold counts — number per ml.						Score of butter at market
		Raw cream	Pasteurized cream	Pasteurized cream + starter	Fresh butter	Butter when shipped	Butter at market	
1	.16	170	0	....	1	4	0	91
1	.16	170	0	....	20	8	3	92
1	.16	190	0	....	2	1	3	91½
1	.14	70	0	....	0	2	1	91½
1	.14	70	0	....	10	9	5	92½
1	.15	270	0	....	3	3	1	91
1	.15	270	0	....	6	3	4	91½
1	.16	160	0	....	5	3	4	91
1	.14	600	0	....	1	2	0	90
1	.14	600	0	....	10	3	2	91
2	.16	1200	1	0	2	3	2	92
2	.16	1100	0	0	1	0	0	91½
2	.16	1100	0	0	0	0	1	90½
2	.13	70	0	....	1	1	0	92
2	.14	20	0	....	10	0	0	91
2	.14	20	0	....	0	2	0	93
2	.15	110	0	0	12	2	2	92
2	.13	180	0	0	2	18	24	92
3	.20	270	0	13	3	5	10	92
3	.20	270	0	6	0	6	20	92½
3	.20	60	0	....	2	0	2	92
3	.17	90	0	10	70	8	10	92
3	.17	90	0	4	70	8	6	91
3	.19	700	0	4	4	3	20	92
3	.19	50	0	....	460	3	1	90½
4	.14	190	0	0	5	6	2	92
4	.20	1600	0	....	5	9	1	91½
4	.22	1700	1	....	10	2	3	91
4	.14	180	0	....	3	10	5	92½
4	.14	600	1	....	6	49	8	91
4	.17	330	0	....	1	6	3	92
4	.13	330	0	....	26	28	1	91½
4	.21	230	0	....	12	14	2	90½
4	.23	230	1	....	6	21	9	90
4	.13	480	0	....	0	15	2	92
5	.17	120	4	4	20	190	4	91
5	.19	100	70	60	14	170	3	91
5	.12	90	1	10	180	56	11	92½
5	.12	90	0	....	19	9	2	92½
5	.11	300	5	....	760	120	4	92
5	.13	400	0	1	0	80	4	90½
5	.11	90	1	....	4	10	2	92

TABLE 1. (Continued)

Creamery number	Percent acidity of cream	Mold counts — number per ml.						Score of butter at market
		Raw cream	Pasteurized cream	Pasteurized cream + starter	Fresh butter	Butter when shipped	Butter at market	
6	.16	30	1	....	3300	4610	1700	92
6	.12	30	0	....	2200	2460	900	92½
6	.12	70	0	....	....	....	....	.....
6	.10	230	0	....	....	3630	1860	92
6	.12	.....	0	....	3200	3300	6	91½
6	.10	250	3	....	4200	2670	2	92
7	.28	5500	0	....	5	1	3	92
7	.34	2900	80	....	11	14	7	92
7	.32	2900	0	....	40	2	2	91
7	.30	5000	1	....	0	4	2	92
7	.26	1400	0	....	4	2	5	92
7	.30	4300	1	....	6	10	12	92
7	.28	5200	15	....	7	6	0	92
7	.32	4500	4	....	4	1	2	92
7	.32	4000	0	....	7	4	4	91½
7	.32	7800	2	....	1	1	1	92
8	.19	700	0	....	12	15	21	92
8	.19	90	0	....	11	8	4	92
8	.19	480	1	....	5	10	3	92
8	.14	6	0	....	9	10	4	92
8	.20	380	10	....	13	19	10	92
8	.21	110	0	....	9	13	11	92
8	.24	170	0	....	16	38	11	92
9	.26	3900	5	....	8	2	....	.....
9	.33	6700	7	....	8	1	....	.....
9	.39	22500	8	....	10	3	....	.....
9	.25	1000	0	....	4	2	....	.....
9	.27	1000	2	....	1	6	....	.....
9	.29	500	4	....	4	50	....	.....
9	.30	2600	3	....	7	3	....	.....

fresh butter gave higher mold and yeast counts and in some instances higher bacterial counts than the cream from which the butter was made. The very bad condition of the churn in creamery 6 is particularly impressive.

It will be noted that there is no consistency in the changes taking place in the mold, yeast or bacterial counts from the time the butter was made until it reached the market.

An interesting relationship between the acidity and the mold, yeast and bacterial counts of the raw cream is revealed in table 4. It is clear that there is the expected correlation between the total number of microorganisms and the acidity. The important fact is, however, that even so-

Creamery number	Percent acidity of cream	Yeast counts — number per ml.					
		Raw cream	Pasteurized cream	Pasteurized cream + starter	Fresh butter	Butter when shipped	Butter at market
1	.16	370	0	.....	15	15	11
1	.16	370	0	.....	2,500	45	56
1	.17	420	0	.....	150	20	7
1	.14	380	0	.....	27	31	47
1	.14	380	0	.....	29	16	28
1	.15	820	0	.....	30	25	23
1	.15	820	0	.....	70	19	155
1	.16	1,550	0	.....	7	1	2
1	.14	620	0	.....	0	4	2
1	.14	620	0	.....	11	4	11
2	.16	600	0	0	40	3	58
2	.16	450	0	0	0	2	7
2	.16	450	0	0	0	1	14
2	.13	2,020	0	.....	5	11	51
2	.14	160	0	.....	120	7	23
2	.14	160	0	.....	6	13	11
2	.15	700	0	0	65	0	86
2	.13	1,290	0	0	13	2	17
3	.20	240	0	620	51	63	198
3	.20	240	0	76	18	16	216
3	.20	510	0	.....	8	2	28
3	.17	880	0	280	290	10	115
3	.17	880	0	19	30	34	66
3	.19	200	0	14	26	17	310
3	.19	350	0	.....	600	90	200
4	.14	700	0	0	250	270	98
4	.20	2,300	0	.....	39	10	14
4	.22	1,800	7	.....	6	126	15
4	.14	230	0	.....	34	480	41
4	.14	1,700	0	.....	11	70	14
4	.17	540	0	.....	3	4	0
4	.13	580	0	.....	15	7	29
4	.21	790	0	.....	5	7	0
4	.23	790	0	.....	4	12	2
4	.13	1,200	0	.....	17	5	7

TABLE 2. (Continued)

Creamery number	Percent acidity of cream	Yeast counts — number per ml.					
		Raw cream	Pasteurized cream	Pasteurized cream + starter	Fresh butter	Butter when shipped	Butter at market
5	.17	1,320	0	0	74	100	110
5	.19	820	10	10	10	70	55
5	.12	750	0	0	780	66	20
5	.12	850	0	.....	37	22	15
5	.11	610	6	.....	510	460	220
5	.13	1,290	3	0	0	580	340
5	.11	120	0	.....	16	33	10
6	.16	750	0	.....	150	30	130
6	.12	79	0	.....	510	130	200
6	.12	120	0	.....	.....	.....	.....
6	.10	590	0	.....	.....	140	160
6	.12	.....	0	.....	4,500	320	32
6	.10	370	0	.....	200	220	65
7	.28	4,000	0	.....	20	9	150
7	.34	1,500	20	.....	3	5	1,680
7	.32	200	0	.....	70	5	25
7	.30	100	8	.....	1,400	1	20
7	.26	300	0	.....	20	4	10
7	.30	1,900	0	.....	5	3	13
7	.28	1,200	4	.....	20	4	30
7	.32	4,400	70	.....	18	1	10
7	.32	1,700	0	.....	12	24	36
7	.32	4,500	0	.....	0	3	10
8	.19	320	8	.....	45	16	45
8	.19	1,500	8	.....	6	10	9
8	.19	1,400	1	.....	11	2	28
8	.14	430	2	.....	1	10	37
8	.20	1,100	0	.....	6	19	48
8	.21	330	0	.....	0	38	61
8	.24	430	0	.....	3	23	60
9	.26	3,200	0	.....	3	0	.....
9	.33	6,200	0	.....	2	0	.....
9	.39	20,000	0	.....	15	1	.....
9	.25	700	0	.....	4	0	.....
9	.27	600	2	.....	0	0	.....
9	.29	840	10	.....	1	0	.....
9	.30	2,800	7	.....	4	0	.....

TABLE 3. *Changes in bacterial counts of cream and butter*

Creamery number	Percent acidity of cream	Bacterial counts — number per ml.					
		Raw cream	Pasteurized cream	Pasteurized cream + starter	Fresh butter	Butter when shipped	Butter at market
1	.16	127,000,000	26,000	.....	2,800	200	600
1	.16	127,000,000	26,000	.....	6,500	1,800	3,250
1	.17	134,000,000	300	.....	2,100	500	366
1	.14	44,000,000	5,300	.....	3,600	400	630
1	.14	44,000,000	5,300	.....	2,700	400	2,300
1	.15	78,000,000	28,900	.....	5,500	200	1,100
1	.15	78,000,000	28,900	.....	9,800	2,600	21,200
1	.16	67,000,000	28,000	.....	6,700	900	1,120
1	.14	175,000,000	20,500	.....	3,100	700	70
1	.14	175,000,000	20,500	.....	9,600	2,300	850
2	.16	90,000,000	1,300,000	1,100,000	1,130,000	1,000,000	82,000
2	.16	30,000,000	.....	1,500,000	970,000	1,000,000	48,000
2	.16	30,000,000	.....	580,000	1,860,000	1,000,000	740,000
2	.13	32,000,000	1,950,000	.....	26,200	12,500	5,600
2	.14	101,000,000	1,100	.....	1,700	2,200	1,900
2	.14	101,000,000	1,100	.....	1,100	45,000	1,100
2	.15	86,000,000	200	2,800,000	32,000	500	34,000
2	.13	560,000,000	240,000	10,700,000	17,000	9,900	12,200
3	.20	246,000,000	7,300	.....	217,000	6,900	2,300
3	.20	246,000,000	7,300	.....	132,000	8,500	33,000
3	.20	118,000,000	.....	.....	240,000	29,100	20,000
3	.17	92,000,000	2,200	.....	930,000	8,500	26,000
3	.17	92,000,000	2,200	.....	110,000	77,000	21,400
3	.19	189,000,000	1,800	.....	169,000	29,300	128,000
3	.19	167,000,000	23,600	.....	16,000	9,600	14,200
4	.14	62,000,000	3,800	73,000	1,300	2,400	6,100
4	.20	534,000,000	9,500	.....	5,400	1,800	3,800
4	.22	446,000,000	4,600	.....	3,700	1,200	10,200
4	.14	56,000,000	1,300	.....	900	2,200	12,100
4	.14	145,000,000	6,100	.....	4,900	1,400	2,100
4	.17	171,000,000	2,600	.....	.....	.....	.....
4	.13	75,000,000	.....	.....	11,300	4,500	1,300
4	.21	391,000,000	3,100	.....	2,600	400	100
4	.23	393,000,000	2,000	.....	380	600	330
4	.13	119,000,000	100	.....	400	100	290

TABLE 3. (Continued)

Creamery number	Percent acidity of cream	Bacterial counts — number per ml.					
		Raw cream	Pasteurized cream	Pasteurized cream + starter	Fresh butter	Butter when shipped	Butter at market
5	.17	304,000,000	25,100	40,000,000	940,000	96,000	13,600
5	.19	206,000,000	1,000	100,000,000	1,000,000	520,000	2,700
5	.12	87,000,000	10,000	2,300,000	12,200	10,800	7,600
5	.12	40,000,000	4,000	.....	3,700	3,000	1,700
5	.11	68,000,000	12,000	.....	4,700	2,900	5,600
5	.13	93,000,000	800	100,000,000	1,000,000	182,000	4,800
5	.11	500,000,000	1,000,000	.....	560,000	12,600	6,000
6	.16	218,000,000	10,800	.....	88,000	1,500	30,000
6	.12	11,000,000	300	.....	27,200	3,300	37,000
6	.12	19,000,000	9,800	.....	.....	.....	.....
6	.10	7,000,000	400	.....	39,000	2,900	52,000
6	.12	.....	100	.....	26,500	600	6,000
6	.10	9,700,000	20,500	.....	24,800	3,500	14,000
7	.28	500,000,000	2,000	.....	4,100	15,400	8,300
7	.34	400,000,000	384,000	.....	82,000	14,000	460,000
7	.32	500,000,000	500	.....	4,000	7,800	8,700
7	.30	300,000,000	2,400	.....	208,000	7,600	8,600
7	.26	224,000,000	1,200	.....	2,800	1,000	1,900
7	.30	390,000,000	1,500	.....	2,500	2,400	2,500
7	.28	480,000,000	73,000	.....	8,100	3,400	1,800
7	.32	480,000,000	1,000,000	.....	187,000	12,700	3,400
7	.32	292,000,000	200	.....	2,000	5,300	2,800
7	.32	460,000,000	24,600	.....	300	700	1,400
8	.19	172,000,000	3,700	.....	3,900	900	6,100
8	.19	150,000,000	11,000	.....	5,800	600	7,000
8	.19	208,000,000	9,500	.....	3,900	400	5,500
8	.14	51,000,000	19,600	.....	5,600	2,000	4,800
8	.20	288,000,000	15,700	.....	26,500	37,000	104,000
8	.21	144,000,000	1,000	.....	1,400	300	2,500
8	.24	233,000,000	22,100	.....	10,700	16,000	34,000
9	.26	330,000,000	2,000	.....	1,200	200	.....
9	.33	267,000,000	13,200	.....	1,900	.....	.....
9	.39	370,000,000	700	.....	500	200	.....
9	.25	211,000,000	4,600	.....	600	200	.....
9	.27	156,000,000	800	.....	2,000	200	.....
9	.29	208,000,000	29,000	.....	12,000	100	.....
9	.30	252,000,000	1,000,000	.....	81,000	200	.....

TABLE 4. *Relation between acidity of cream and numbers of microorganisms*

Number of samples	Percent of acidity	Mold count per ml.			Yeast count per ml.			Bacterial count per ml.		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
41	.10-.20	6	1,600	304	79	2,300	762	7,000,000	560,000,000	145,000,000
6	.21-.25	110	1,700	573	330	1,800	807	144,000,000	446,000,000	303,000,000
9	.26-.30	500	5,500	3,265	100	4,000	1,660	156,000,000	500,000,000	315,000,000
7	.31-.39	2,900	22,500	7,330	200	20,000	5,500	267,000,000	500,000,000	396,000,000

called "sweet cream" below 0.20 percent acidity contained large numbers of bacteria.

Table 5 indicates that there was a greater tendency for samples of butter with higher salt contents to show decreasing mold and yeast counts immediately after manufacture. On the other hand, this salt effect was largely lost after a few days. In the case of bacterial counts, the salt effect is not as noticeable in the early stages but becomes more pronounced with the passage of time. The bacterial counts showed a tendency to decrease in the fresh butter regardless of the salt content, while the survivors later were apparently under the influence of the brine. These data agree in general with those presented by others and offer some suggestive explanation for changes in the microflora of butter.

An analysis of the data to determine any possible relationships between the temperature of creamery coolers, or of refrigerator cars in transit, and the changes in the microflora or quality of the butter did not yield any positive relationships. The temperatures in creamery coolers ranged from 30-45° F. during the period of investigation, while the minimum-maximum temperatures of the refrigerator cars from the time they

TABLE 5. *Effect of salt content of butter on the quantitative changes in the microflora during storage and shipment*

Number of samples	Salt percentage	Mold counts: Percent of samples showing changes in count — Fresh butter to time of shipment: Increase	Decrease	No change	From time of shipment to arrival at market: Increase	Decrease	No change
7	1.0-1.9	71.4	28.6	0.0	0.0	100.0	0.0
26	2.0-2.4	46.2	50.0	3.8	30.4	60.9	8.7
28	2.5-2.9	53.6	38.6	7.8	18.5	77.8	3.7
10	3.0-3.4	33.3	55.6	11.1	40.0	30.0	30.0
		Yeast counts					
7	1.0-1.9	42.9	42.9	14.2	75.0	25.0	0.0
26	2.0-2.4	42.3	53.9	3.8	65.2	34.8	0.0
28	2.5-2.9	39.3	60.7	0.0	59.3	40.7	0.0
10	3.0-3.4	33.3	66.7	0.0	90.0	10.0	0.0
		Bacterial counts					
7	1.0-1.9	28.6	71.4	0.0	100.0	0.0	0.0
26	2.0-2.4	12.0	88.0	0.0	59.1	40.9	0.0
28	2.5-2.9	14.8	85.2	0.0	61.5	38.5	0.0
10	3.0-3.4	30.0	70.0	0.0	40.0	60.0	0.0

left the siding at the creamery until they reached the market were as follows: 48-50° F., 46-52° F., 47-59° F., 42-63° F. and 35-65° F. The butter reached the market from 8 to 15 days after it was made.

Scorings of the butter upon its arrival at the market proved that the quality of the butter at that time was slightly better in those cases where the mold, yeast and bacterial counts of the raw cream were low. The scores showed a tendency to be somewhat higher when the butter was made from cream of the lower acidities. On the other hand, there was no relation (a) between the final butter quality and the mold, yeast or bacterial counts of the pasteurized cream nor (b) between the mold, yeast or bacterial counts of the fresh butter and the change in score during storage or transit. The changes in mold, yeast or bacterial counts of the butter were not influenced by the days in storage before shipment nor the days in transit.

SUMMARY

1. Data were obtained at nine Minnesota creameries and at an Eastern market on the quantitative changes in the microflora of cream and butter during manufacture and shipment.

2. Pasteurization of the cream was effective in most instances in reducing the numbers of microorganisms.

3. The churn in many cases was shown to be an important source of contamination.

4. Changes in the microflora of the butter did not follow any consistent pattern.

5. The number of microorganisms was usually greater in the more acid cream, although the number present in so-called "sweet cream" was often remarkably high.

6. The amount of salt in the butter often influenced the trend of the mold, yeast and bacterial counts but this effect was not uniform.

7. No positive relationship was established between the temperature of the creamery coolers or refrigerator cars involved in these studies and the changes in the microflora or market grade of the butter.

8. Neither a mold, yeast nor bacterial count of the butter would have served as a reliable index of the market or keeping quality of the butter made at these creameries. There was a tendency toward higher scores, however, when the butter was made from cream which was low in mold, yeast or bacterial count before pasteurization.