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Article 1

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A Bacteriological Study of the College Creamery Milk Supply

A Case of Putrid Butter

Purification of Milk by the Centrifugal Separator

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A BACTERIOLOGICAL STUDY OF THE COLLEGE CREAMERY MILK SUPPLY.

BY C. H. ECKLES.

For several years the Dairy Department has been making experiments in cream ripening and its relation to butter flavor. In the course of this work certain important facts have developed regarding the causes of variation in quality of butter from season to season.

It is a fact understood by all buttermakers that under natural conditions, most of the difficulty experienced in securing the right butter flavor occurs during the winter season. The annual loss to the dairies and creameries of the state due to this fact is undoubtedly very large.

In Bulletin No. 40 of the Iowa Station, the writer called attention to these facts and gave an explanation as the result of experimental work. It was shown that the chief difference between winter and summer butter is not due to the character of the feed given the cows but to a difference in fermentations occuring in the milk.

In the summer conditions are such that the milk ordinarily sours with a pure acid taste, due to the large proportion of acid bacteria present at that time. In the winter when the poorest quality of butter is made this kind of fermentation is present in much smaller quantities, and most of the milk shows a disagreeable impure acid taste when fermented and this condition extends to the butter made at that time.

This explanation has been confirmed by recent work along the same line. In order to further study this question and others regarding the bacteriological condition of milk as received under average creamery conditions a second series of experiments were made beginning in February, 1900.

On each Wednesday for a period of a year, beginning at that time, pint samples were taken from the mixed milk of

each patron bringing milk to the college creamery that day. Pint Mason jars were used for the purpose, sterilized before using by steaming three-quarters of an hour in a steam-oven.

After taking a sample as mentioned, a small measured amount was taken and placed in another jar which was kept in ice and salt. An equal sample from each patron's milk was added to this jar which represented, when complete, a composite or average sample of the milk brought to the factory that day.

The college creamery is supplied with milk by farmers of the neighborhood who furnish milk of a quality which is about typical of that used at the creameries of the state.

THE FERMENTATION TESTS.

The jars containing the milk samples were left in the laboratory with no attempt made to control the temperature. After coagulation each sample was examined for gas bubbles, then the character of the taste and smell was noted. This is practically the fermentation test of Gerber except the milk was kept at a somewhat lower temperature than he recommended.

In order to get as fair a comparison as possible the samples were, with a very few exceptions, examined by the writer. It is impossible to divide a number of milk samples accurately into the good and the bad or into any other groups based upon taste and smell alone as some will always be near the dividing line.

The classification which was finally adopted seemed to suit the conditions as well as any and was as follows:

1. Pure acid.
2. Fair acid.
3. Impure acid.

The "pure acid" class includes those samples which soured with a clean acid taste and showed nothing objectionable either in taste or smell. These the writer would consider suitable for making the best kind of natural starters for cream ripening.

The "fair acid" class includes those having nothing especially objectionable but still lacking in some degree the desirable qualities of those put into the first class.

The "impure acid" division includes those showing an undesirable smell or taste which is not that of pure souring. This group includes therefore all degrees from those slightly bad to some which are very offensive. It has been found by

observation and experiment that the quality of the butter flavor made under natural conditions can be judged largely by the natural fermentation which takes place in the milk from which it was made.

If the milk sours with a pure acid taste and smell the conditions are favorable for making a good quality of butter or cheese, while if a decided impure fermentation develops, the quality of the cheese or butter is apt to be inferior.

For these reasons the fermentation test is of considerable value as a means of selecting good milk for natural starters and to locate the source of injurious fermentations.

EXAMINATION OF THE COMPOSITE SAMPLE.

From the average sample taken as mentioned previously culture plates were made to estimate the number of bacteria and to find something in regard to the kinds present.

In doing this the ordinary methods used in such work were adopted. The milk was diluted with a known volume of sterilized water and a small measured portion put into the liquified media. The amount used varied with the age and condition of the milk. The intention was to have from 500 to 1500 colonies on a Petri dish, but of course the condition of the milk could not be judged with sufficient accuracy to come within these limits in all cases. The amount of dilution used varied from 1:600 to 1:20,000. All the media used contained 2 per cent milk sugar, as media without this is entirely unsuitable for the purpose as has been shown by the writer.*

One set of Petri dish cultures was made by using lactose agar. After this was solidified a second tube of the same material was melted and poured on the surface to cover all bacteria which might have been on or near the surface. Wherever a gas producing colony was developed a gas bubble was found. By this means the number of gas producing bacteria present in the milk was estimated.

From the average of the number developing on the lactose agar cultures the total number per cubic centimeter was estimated. The number of gelatin liquifiers was found from the gelatin cultures.

When the colonies were well developed on the agar cultures a portion of the dish was marked off which contained about 45 or 50 colonies. From each colony to be formed within this space an inoculation was into a sterile milk tube.

*Iowa Acadamy of Science Vol. VIII. 1900.

These tube cultures were examined after about three days growth in the incubator.

Three divisions were made of the cultures based upon their relation to the milk as follows:

Class I. Producing an acid curd with or without gas and showing no dissolving of the curd.

Class II. Coagulating milk without producing acid or showing a dissolving effect on the curd. This class may also be called the enzyme class as to a substance of this nature is the action mentioned due.

Class III. Having no visible effect on the milk.

While this class do not coagulate or appear to change milk at all it is probable they do cause some changes in certain constituents of the milk.

The number of gas producing and gelatin liquifiers was determined for each week and is given in the table showing summary by months.

In examining the part of the table coming under the head of fermentation tests the columns marked pure acid and impure acid probably have the greatest significance. As indicated before the adaptability of certain milk for butter or cheese making can be judged very well by observing if it undergoes a pure acid fermentation or not.

January. During this month the milk is generally poor in quality, nearly two-thirds of the samples showing impure acid fermentation and only 28 per cent pure acid. Out of 5 sets of samples taken the composite sample of 3 showed impure and 2 fair. This month was warmer than usual and the milk probably showed slightly better quality than usual for this season.

February. According to the fermentation tests as well as by common observation the milk during February is the worst of the year. The composite sample showed impure in every case and 4 out of 5 sets of samples developed no pure acid coagulations. The samples showed very offensive odors in many cases, especially after the milk had been coagulated 2 or 3 days.

March. The milk during this month was somewhat better than that of February and about the same as that of January. As a whole the quality was very poor with about 50 per cent impure samples and 20 per cent pure acid.

April. During April the quality of milk improved somewhat over March but still showed about one-half impure acid

TABLE NO. I.

Date	No. Patrons Represented	Results of Fermentation Tests				Examination of Composite Sample			
		% Pure Acid	% Fair Acid	% Impure Acid	Fermentation of Composite Sample	Total No. Bacteria per Cubic Centimeter	% Acid Bacteria	% Enzyme Producing Bacteria	% Bacteria Producing No Effect
Jan. 2	29	7	7	86	Impure acid	4,961,200	42	22	36
" 9	26	16	8	76	" "	2,806,000	37	9	54
" 16	26	30	11	59	" "	8,811,000	45	5	50
" 23	26	57	9	34	Fair "	4,270,000	50	8	42
" 30	14	50	10	40	" "	1,411,000	37	9	54
Feb. 6	29	3	17	80	Impure "	218,000	30	20	40
" 13	25	0	20	80	" "	195,000	26	27	47
" 20	19	0	0	100	" "	3,632,000	36	17	47
" 27	24	0	3	97	" "	6,990,000	40	15	45
" 28	19	0	16	84	" "	2,750,000	64	36	
Mch. 7	37	36		63	" "	2,536,000	60	40	
" 14	25	20	40	40	Fair "	4,095,000	58	42	
" 21	17	23	23	54	" "	6,316,000	57	43	
" 28	35	6	12	82	Impure "	7,190,000	72	28	
Apr. 4	35	28	15	57	Fair "	11,311,000	58	42	
" 11	29	17	34	49	Impure "	4,368,000	62	38	
" 18	35	11	31	58	Fair "	30,705,000	77	23	
" 25	23	26	40	34	" "	20,947,000	70	30	
May 2	42	33	34	33	" "	20,411,200	.....	.....	.....
" 9	43	44	33	23	Pure "	22,584,400	68	32	
" 16	49	59	29	12	" "	20,790,000	87	13	
" 23	46	74	22	4	" "	12,898,000	76	24	
" 30	47	48	27	25	" "	27,970,000	62	7	31
June 6	55	42	49	9	" "	14,176,000	86	5	9
" 13	52	50	37	13	" "	15,543,000	66	5	29
" 20	47	51	24	25	" "	16,837,000	60	5	35
" 27	47	42	31	27	" "	16,440,000	50	8	42
July 5	52	59	15	26	" "	10,420,000	70	none	30
" 11	52	55	41	4	" "	10,824,000	83	none	17
" 18	49	75	19	6	" "	18,572,000	76	7	17
" 25	49	65	16	19	Fair "	17,424,000	55	10	35
Aug. 1	52	30	41	29	" "	12,592,000	.....	.....	.....
" 8	55	29	33	38	" "	31,700,000	47	6	47
" 15	55	64	24	12	Pure "	19,600,000	56	8	36
" 22	45	33	47	20	Fair "	83,712,000	.....	.....	.....
" 29	48	45	22	33	" "	32,498,000	78	11	11
Sep. 5	45	24	41	35	" "	47,512,000	.....	.....	.....
" 12	44	61	17	22	" "	16,900,000	70	10	20
" 19	35	71	29	00	Pure "	3,850,000	.....	.....	.....
" 26	32	93	7	00	" "	13,728,000	45	8	47
Oct. 3	32	77	8	15	" "	193,424,000	69	2	29
" 10	38	96	2	2	" "	10,890,000	59	4	37
" 17	39	79	14	7	" "	3,684,000	40	2	58
" 24	36	83	15	2	" "	67,376,000	87	3	10
" 31	10	80	10	10	" "	61,248,000	82	4	14
Nov. 7	17	94	6	0	" "	4,092,000	70	13	17
" 14	15	73	7	20	" "	425,000	.....	.....	.....
" 21	19	64	0	36	Fair "	329,280	36	14	36
" 28	13	84	8	8	" "	1,871,000	58	6	36
Dec. 5	15	80	14	6	Pure "	2,868,000	44	4	52
" 12	12	45	19	38	Fair "	1,711,000	26	7	67
" 19	15	60	10	46	" "	6,757,000	38	8	54
" 26	11	18	37	18	" "	1,266,000	41	12	47

TABLE NO. II. SUMMARY BY MONTHS.

Months	Fermentation Tests				Examination of composite samples					
	Total number samples	Per cent. pure acid	Per cent. fair acid	Per cent. impure acid	Number bacteria per cubic centimeter	Per cent. acid bacteria	Per cent. Enzyme producing bacteria	Per cent. bacteria producing no effect	Number gelatin liquifiers per c c.	Number gas-producing bacteria per c.c.
Jan.	121	28	10	62	4,452,000	47	10	43	182,900	182,930
Feb.	116	2	8	90	2,705,000	45	19	36	110,200	15,500
Mar.	114	19	32	49	5,032,000	61	38		148,700	126,000
April	122	30	22	48	16,830,000	66	33		287,000	102,990
May	227	61	17	22	20,930,000	73	26		188,470	372,200
June	201	52	25	23	15,749,000	66	6	28	253,200	661,500
July	202	66	18	16	14,310,000	71	7	22	145,000	699,900
Aug.	255	52	22	26	36,020,000	60	8	31	290,000	887,700
Sept.	155	61	21	18	20,490,000	55	12	33	339,500	222,300
Oct.	155	83	8	9	47,324,000	63	8	29	256,300	226,180
Nov.	65	76	6	18	1,679,000	54	12	34	81,800	47,270
Dec.	53	50	13	37	3,150,000	37	8	55	113,430	113,600

while the composite sample was impure in some cases and fair in others but not pure in any.

May. During May a great improvement was noticed over April. The impure acid samples decreased to 20 per cent and the pure acid increased from 30 to 61 per cent and the composite sample was generally pure.

June. This is generally considered the best month of the year regarding quality of milk but these tests would not indicate that the milk was in any better condition than during May, and not quite equal to July, September and October. The month during which these samples were taken was not quite typical weather for that time of the year, being dry and hot. It is probable that during most years June would show better results. In every case, however, the composite sample showed a pure acid fermentation proving the milk to be in good condition as a rule.

July. This month was rather favorable for good quality on account of the dust being less than usual. The composite sample showed pure except at the last when an excessive amount of gassy milk caused it to be classed as fair. Two-thirds of the samples showed a pure acid coagulation and about one-sixth impure. The large number of samples classed as fair was due to the large amount of gassy milk.

August. Like July this month was favorable on account of being quite free from dust although abnormally hot. The impure samples were in but slightly larger proportions than

during the preceeeding month and the proportion of pure acid samples the same as for June. The large number of gas germs was responsible for so many samples being classed as fair.

September. This month showed about typical weather for that period. As usual the milk improved somewhat over that of August. It contained a large number of gas germs as during the preceeding months. Towards the end of the month the quality improved greatly giving one of the best set of samples for the year with 93 per cent pure acid and none impure.

October. This month showed the best quality of milk for the year. This is borne out by practical observations which indicate the best quality of milk to be produced during October and June. The per cent of pure acid samples reached 83 for the month and the impure only 9. The quality of the composite sample was uniformly pure.

November. This is generally a favorable month in this state and in this case was about typical of the usual conditions. The milk showed very good quality as a rule and very little gas, ranking in general quality about the same as July and May.

December. The milk this month showed the effect of winter conditions especially in the latter part. The general quality however was fair and the conditions quite good.

The most prominent fact shown by the results is the difference in the character of the winter and the summer fermentations. The worst condition of milk, according to the fermentation tests, occurs in the latter part of the winter, especially during February. The best quality is found either in the fall or the early summer. The periods when the best and the poorest butter is made under natural conditions corresponds with the results of the fermentation tests. These facts show why a starter for cream ripening is of so much more importance in the winter than in the summer. It is also easily seen how at certain times of the year an exceptionally good quality of butter can sometimes be made under the most primitive conditions and by a maker who knows little or nothing of the process. A discussion of the reasons for these variations in quality will be found in another part of this article.

THE NUMBER OF BACTERIA.

As would be expected by anyone familiar with such work

the number of bacteria found in a cubic centimeter was very great. However, few would have estimated the number high enough as practically all estimates of this character made heretofore have been for milk sold at retail where the conditions are quite different. The media used was more suitable for such work than that generally used on account of the addition of milk sugar. This is one important reason for the high numbers found.

As would be expected the number varied with the conditions of weather and age of the milk. The samples of milk being in all cases from a mixture from several sources, changes due to individual treatment of the different lots was largely done away with. Except for this there would be even more variation.

The highest number of bacteria it will be observed occurred in October. This is accounted for by the milk being 2 days old and the weather very hot for that time of the year. When this milk was mixed as received in the creamery it had a noticeable sour taste and smell. The highest number for milk one day old occurred as would be expected in August. The lowest numbers occurred in November and February. For a monthly average November showed the least, followed by February. October in these experiments showed the greatest average for the month, due as mentioned to the milk being brought to the creamery only every other day and the weather being very hot. August comes next and probably most years would be first, while June, July and September were much the same. May and April stand above June and July, due no doubt to the milk being partly two days old.

While the kinds of bacteria present are of more importance than the number still the number has some important relations to practical work.

It will be seen at once that the fermentations are so far advanced in the summer months that it is diffiult to control them by the use of starters. If this immense number of bacteria found in the summer season were of the kind predominating in the winter, instead of being mostly of the desirable class it would be impossible to produce even a fair quality of butter or cheese.

On account of the comparatively few bacteria present in the winter it is possible to control the fermentation quite easily and to make butter almost if not quite equal to that produced in the summer. When we use an acid starter in winter we are imitating summer conditions.

THE KINDS OF BACTERIA.

As already mentioned the bacteria present in the cultures made from the composite samples were classed according to their effect on milk.

The first class, the acid producing, were the most numerous in most cases but varied greatly with the condition of the milk and the season. Most of these in this class are of a single species, the typical bacterium of sour milk. The gas producers, mostly of the *Bacterium aerogenes* type, are also included and at some periods constituted a considerable portion of the whole. It will be seen that the per cent of acid bacteria corresponds as a rule with the fermentation tests.

When the milk is in the poorest condition, in January and February, the per cent of acid germs is the lowest of the year. In October and May when the milk is in the best condition the per cent of acid bacteria reaches the highest point. For the entire year the acid bacteria constituted an average of 58 per cent of the total number.

The next group in importance is the enzyme producing, which have the power of curdling milk sweet or dissolving the curd. As a rule the injurious fermentations belong to this group. They are especially common in stables and contamination from this source is the common way by which they get into milk. They work mostly on the casein and albumen, producing a variety of substances such as those giving the common bitter taste to milk or cream, the taste of over-ripened cream and a great variety of taints.

This group is present in the largest proportion during the period when the quality of milk is most inferior. At this time they constituted about one-fourth of the total number. In the summer they were generally less than one-tenth of the whole and when the milk was in the best condition of the year they where about 2 per cent of the whole.

The third class, those producing no visible effect, were always numerous, making up from 20 to 55 per cent of the whole. Most of these bacteria probably have some effects on the milk which are not visible but it is not thought they have very much influence either good or bad on the quality of butter or cheese made.

THE GELATIN-LIQUIFIERS.

The bacteria that belong to the enzyme class are mostly included here. As seen by Table II this class is always pres-

ent and the number does not vary so much as does the total number of bacteria. In the period of poor quality milk the proportion of gelatin liquifiers was greatly increased while the number per c. c. was not changed to the same extent.

The proportions of these classes given, it must be kept in mind, are for the milk when brought to the factory and they change rapidly when the cream is ripened. As shown in Bulletin 40 this change is mostly an increase in the acid bacteria.

GAS PRODUCING BACTERIA.

Almost every lot of milk contains more or less germs of this kind. Although at certain times they are much more numerous than at others. The smallest number was found in February, November and December and the largest number in August with June and July close behind. In August we have nearly a million per c. c. for the average of the month. In one of the weekly trials the number exceeded one million per c. c. When milk is used for butter-making the presence of a large number of gas bacteria is not especially injurious. When pure culture starters of these are used in pasteurized cream the butter is of good quality but not of the very best. Their injurious effects on cheddar cheese-making are undoubtedly overestimated.

THE CAUSES OF THE VARIATION IN QUALITY.

Most of the variations both in number and kind of bacteria can be explained by taking into account the conditions of that particular time of the year.

The great increase in numbers during the summer months is due directly to the higher temperature of that period. This effect from higher temperature is not alone on the milk after being milked but also affects the contamination from several other sources especially the utensils by making it possible for the germs left by careless cleaning to increase very greatly before the milk comes in contact with them.

The low number found in November and early part of December is due to the fact that the cows in this state are not as a rule confined in stables much of the time during this period. The condition of the ground is not such as to cause much dust and the temperature is cool enough to check the development after the milk is drawn.

The higher number found later in the winter under much colder conditions is due to the more contamination taking

place from the cow's body during milking and from the stable. That milk is more contaminated in the latter part of the winter than in the early part can be seen by anyone who will examine the character of separator slime at intervals for a year.

About the time the cows are turned out to pasture the condition of the milk improves greatly due not in any great extent to the grass but again to the conditions surrounding it. In the early summer and in the fall we have similar conditions. The cows are usually clean from being in the pastures and the milking is done in a cleaner atmosphere than in the winter while the heat is not so severe as in the middle of the summer Another factor the importance of which seems to be generally overlooked as a means of contamination is the dust of the pastures and roads Some of the dust which gathers on the body of the cow drops into the milk-pail, carrying and immense number of germs of various kinds in even the smallest portion. An Italian investigator has found 78 million germs in a single gram (1-28 of an oz.) of road dust. The writer has repeatedly noticed that when the weather is dry and the pastures and lanes dusty the quality of milk is very inferior. If the dust is settled by a rain the condition at once improves even when the temperature remains the same.

Numerous references are seen in the dairy press which refer evidently to the effects of contamination from dusty summer conditions although the writer has never seen the conditions connected with what seem to him to be the real cause.

Contamination from cows wading into stagnant ponds fouled with their own excreta is another common occurance which is closely connected with the dusty conditions as both are liable to occur at the same time.

THE QUALITY OF MILK AS AFFECTED BY BEING DELIVERED ONCE IN TWO DAYS.

One of the reasons often assigned for the poor quality of butter made at creameries during the winter is that the milk is not delivered at the factory often enough. This is undoubtedly a condition to be guarded against but too much weight should not be given this factor. During a part of September and October and one week in May some of the patrons brought milk every day and the others once in two days. This gave a fairly good comparison of milk under the two plans but of course such a comparison may or may not hold good for the winter season.

It will be seen by Table III that there was very little difference in the quality of the milk as shown by the fermentation tests which probably gives as fair an idea of the condition of the milk for butter-making as any. If the number of bacteria was determined for the two divisions it is probable the older would show more although it is common for milk which is held longer to be cooled better. For this reason it might not show so much difference as would be expected. If no starter was used it would not seem that it should make so

TABLE NO. III.

Date	Age Milk	No. Samples	No. pure acid	No. fair acid	No. impure acid
May 2	1 day	14	6	3	5
	2 days	28	9	10	9
Sept. 26	1 day	19	18	1	0
	2 days	13	12	1	0
Oct. 3	1 day	17	13	1	3
	2 days	15	12	1	2
Oct 10	1 day	5	5	0	0
	2 days	33	31	1	1
Oct. 17	1 day	4	4	0	0
	2 days	34	26	5	3
Oct. 24	1 day	5	5	0	0
	2 days	31	25	5	1

Summary	Age Milk	No. Samples	Per cent. pure acid	Per cent fair acid	Per cent. impure acid
	1 day	64	80	8	12
	2 days	154	74	14	12

very much difference as to the age of the milk as the natural fermentation is allowed to develop anyway. If starters are used the fewer bacteria there are in the cream the better can the ripening be controlled.

From the results shown in the tables we conclude that every other day delivery is not necessarily injurious Other conditions are generally responsible for the poor conditions of winter butter.

SUMMARY.

The fermentation test shows when milk is in suitable condition for making good butter and cheese.

This test applied to the milk from the patrons of the college creamery shows a great variation in quality during a year.

This difference in fermentations is probably due to the

conditions under which milk is handled during the different seasons of the year.

The average quality of butter made under natural conditions corresponds with the quality of milk as shown by these tests and is dependant upon the condition of the milk. The principal reason for the fine quality of butter made in the summer and the poorer quality in winter is this difference in the fermentations in the milk.

The number of bacteria found in milk as brought to the creamery varies with the temperature, season of the year, etc. In the winter on an average each cubic centimeter contains from 1 to 5 million. In the summer from 15 to 30 million although these limits may be passed either way. The few bacteria found in milk during the winter makes it possible to control the fermentation to a large extent by the use of starters.

The acid producing bacteria are always present in quite large numbers and make up from 25 to 85 per cent and average for the year about 58 per cent of the total number. This class is present in smallest numbers when the quality of the milk is the poorest and in greatest numbers when the milk is the best.

The class of bacteria (enzyme producing) which coagulate milk sweet or dissolve the curd contains most of those injurious to butter-making. They are present at all times of the year but in far greater proportion when the milk is of the poorest quality.

Bacteria having no visible effect on milk are always present in large numbers and make up from 20 to 55 per cent of the entire number.

Gelatin liquifiers are almost always present in milk and in the largest numbers in milk of a poor quality especially during the winter months.

Gas producing germs belong mostly to the *Bacterium aerogenes* type and are found in milk at all seasons but in far greater number during the hottest weather of summer.

Milk brought to a factory once in two days is not necessarily injured in quality for butter-making and this can not be considered as the chief cause of bad milk and poor butter in winter.

A CASE OF PUTRID BUTTER.

BY C. H. ECKLES.

In August 1900 the manager of a creamery visited the Experiment Station bringing two samples of butter representing two days manufacture at his factory. For about a week previous to this time the butter made at this factory had possessed a strong disagreeable taste with a putrid smell. This fault was so pronounced that the local sale of the butter was entirely stopped and what had been sold was returned.

This condition lasted in all about two weeks and was the cause of a heavy loss to the company. Some of this butter was sent to the New York market and the official scorer there scored it 78, 22 points being taken off in flavor. Up to and after this time the creamery made butter that sold as first grade or "Western Extras." This butter as graded by the official scorer would be classed as "Creamery Thirds," or fourth class and the value would be about 10 cents per pound less than the first grade. It would not have been salable at any price for table use.

It was learned from several correspondents familiar with the conditions that the factory was kept in good condition regarding cleanliness, but the buttermaker was compelled to receive all the milk offered without regard to condition as the supply was limited and competition strong.

The buttermaker, however failed to make use of the means always available for combating a condition of that kind, that is pasteurization, sterilization of patrons cans, starters, etc.

The manager was given the following suggestions for the buttermaker prepared by Prof. McKay and the writer:

Make certain that no uncleanliness exists in the factory.

Reject any milk showing indications of this rotten condition.

Thoroughly wash and steam all the patrons cans at least once.

Pasteurize the skim milk before returning from the factory.

Use a heavy starter, 15 to 20 per cent, grown from a good acid culture (which was furnished).

When the manager returned these suggestions were put into practice. About the same time the dry period which had existed for some time was broken by heavy rains. As a result of some or all of these conditions the butter improved at once and no further trouble was had.

EXAMINATION OF THE BUTTER.

The butter samples showed an extremely disagreeable putrid smell rendering the butter entirely unfit for table use. The taste though strong was not as bad as the odor. A small piece of the butter was added to a flask of sterilized milk which produced such a putrid smell within 2 or 3 days that it had to be removed from the laboratory.

This fact showed the source of the trouble was some injurious fermentation which had developed in the cream or butter. If the bad odor had come from the feed of the cows direct it would not increase in quantity and cause the same smell in other milk. This view was further sustained by the fact that two other creameries were getting milk from the same locality, in some cases from adjoining farms and they had no special trouble at the time.

Gelatin and agar Petri dish cultures were made from both samples of butter to find, if possible, the bacteria causing the trouble. The gelatin cultures from the spoiled butter showed a striking contrast to similar cultures made a few days later for comparison from good butter made in the college creamery. This difference is shown by the illustrations No. 1 which is one of the cultures from the spoiled butter shows about 50% of gelatine liquifiers which appear in the illustration as large irregular spots. The cultures from the other samples of spoiled butter were in about the same condition.

In No 2 which shows the condition of good creamery butter, but one of this class of ferments is present, the remainder showing as small white colonies are mostly of the acid producing class.

The condition as shown in No. 2 is typical of any good butter as far as the writer has observed The class of bacteria which liquify gelatin are sometimes called the putrefac-

NO. 1. SHOWING CONDITION OF SPOILED BUTTER.

NO. 2. SHOWING CONDITION OF GOOD CREAMERY BUTTER.

tire class and they usually decompose the casein and albumin of milk, and as a rule are the ones which are injurious.

The presence of such a large proportion of this injurious class shows at once that the conditions were abnormal and that a serious contamination had taken place somewhere from the time the milk was drawn until the butter was made.

From these plate cultures all the kinds of bacteria that could be found were taken and studied. Among these were as would be expected the typical acid bacterium, although in smaller nnmbers than usual, also a great many of the gas producing class and some others which apparently have no effect on milk. All these were discarded as having no particular relation to the putrid condition. The kinds that produce an injurious effect on milk were preserved and finally reduced to four species. Of these three produce very bad effects on milk and are thought to be the cause of the butter fault.

No. 50. This bacterium which was present in large numbers is of the least importance as its injurious properties are not very marked. In milk it dissolves the casien and produces a bitter taste.

No. 51. This bacillus produced a very strong rancid bitter taste in milk. In butter it produces a bad flavor and no aroma whatever.

No. 52. This bacterium produces a very strong smell in milk, and butter made from cream ripened with it has the same odor. It is considered to be with the next the chief cause of the putrid smell.

No. 56. This is the common *Bact. fluorescens liquefaciens*. In milk it produces a greenish yellow color and a very sickish disgusting odor. In butter it produces a marked injurious effect, but no as bad as No. 52. This kind of bacteria is common in decomposing substances of all kinds and in impure water.

As the writer could not visit the factory at the time the trouble occurred it was impossible to learn for certain where the contamination occurred.

*Two other creameries in the same locality had but little trouble at the same time although one reported the qualito of the milk delivered at that period generally poor in quality. This poor condition of the milk and the inferior butter probably was partly due indirectly to the condition of the weather.

*A sample of cream affected with the same injurious fermentations was received from another creamery in the same part of the state after the above was prepared for publication, July 1901.

The dusty condition due to dry summer weather often is a serious source of contamination as mentioned elsewhere and in this case this condition was present. It is also possible that the trouble may have come from the cows wading in stagnant water as the bacteria which were undoubtedly the cause of the trouble are such as are common in such places.

CONCLUSIONS.

It is quite certain the putrid condition of the butter was brought about by contamination of the milk in some way and not from the feed the cows were receiving

This contamination probably took place before the milk was received at the factory but could have been checked by the factory operator by using proper methods.

The principal difference between the spoiled butter and good creamery butter in regard to the bacteria contained was an abnormal number of gelatin liquifiers in the former which included some forms found to have a very injurious effect on butter.

PURIFICATION OF MILK BY CENTRIFUGAL SEPARATION.

C. H. ECKLES. S. E. BARNES.

*Among the various methods which have been tried for purifying milk that of centrifugal separation holds a prominent place. It is now in use for this purpose in a number of establishments which supply milk to city retail trade. The value of this method has been tested by a number of investigations but the conclusions are far from uniform.

Prof. Fjord, of Denmark, and †Fleischman, of Germany, are among those who claim centrifugal separation has but little value as a means of purification.

‡Grotenfelt and Hueppe, other prominent investigators hold the process is of value on account of the large proportion of injurious germs which are thrown out with the separator slime.

§Backhaus found 95 6 per cent of the dirt present to be removed by the centifugal process and also found the slime to contain a large part of the bacteria originally in the milk, and the cream to contain more than the skim milk.

The effect of centrifugal separation upon the disease producing bacteria liable to be found in milk has been carefully tested by ‖Moore. He finds that while most of the germs of tuberculosis and hog cholera are thrown out into the separator slime the process cannot be relied upon to free milk from these germs. His results showed both skim milk and cream to contain the bacteria in small quantities, when they had been added to the milk before separation.

*This article is condensed from a thesis for the degree of Master of Science in Agriculture presented by S. E. Barnes The work was planned and directed by C. H. Eckles.

†Fleischman, The Book of the Dairy, p. 98.

‡Principles of Modern Dairy Practice, p. 183.

§Milch Ztg., 26:358, 1897.

‖Year Book U. S. Dept. of Agriculture, 1895, p. 431.

The experiments made by the writer were for the purpose of finding to what extent the germ content can be reduced by running milk through a separator, how they are distributed in the skim milk, cream, and separator slime and finally what effect separation has on the keeping qualities of milk.

It should be kept in mind that when the centrifugal separator is used as a purifier the skim milk and cream are again mixed together.

The experiments were made from time to time throughout the year in order to give different conditions of milk, etc. Some tests were made from fresh milk, others from old milk. In some cases the milk had a low bacterial content, in others very high.

KEEPING QUALITIES.

The first set of experiments was made to compare the keeping qualities and the bacterial content of milk before and after it had been run through the centrifugal separator. In going about this two samples were taken, one from the whole milk before it was separated, and then while the milk was running through the separator a bottle was held under the skim milk outlet and one under the cream outlet, and both held there for the same length of time. Then the skim milk and cream thus caught were mixed together, making whole milk which had gone through the separator. Then culture plates were made from each sample and both then set away and kept at the same temperature. The acidity being tested at the end of 24 hours.

The following is a table showing the results obtained from the culture plates.

TABLE NO. I.

No. of Experiment	Number of bacteria per cubic centimeter		
	Before Separation	After Separation	Per cent of Difference
Experiment No. I.....	12,742,388	10,773,000	15
" " II.....	1,303,695	1,067,635	18
" " III.....	2,782,080	2,034,120	26
" " IV.....	54,000	27,480	49
" " V.....	261,550	143,600	45
" " VI.....	361,200	168,600	47
" " VII.....	92,500	44,640	51

Experiment No. I. At the end of 24 hours the separated sample showed .17% of acid while the nonseparated sample

TABLE NO. II.

No of Experiment	Product	No. bacteria per c. c.	Per cent of bacteria found in skim milk, cream and slime
No. 1	Whole milk	58,050	
	Skim milk	16,200	23
	Cream	98,000	27
	Slime	37,595,250	49
No. 2	Whole milk	207,200	
	Skim milk	81,375	33
	Cream	255,780	16
	Slime	33,226,929	49
No. 3	Whole milk	206,350,480	
	Skim milk	67,190,000	27
	Cream	215,488,000	19
	Slime	3,964,713,800	52
No. 4	Whole milk	167,040	
	Skim milk	57,960	30
	Cream	283,576	18
	Slime	57,028.246	51
No. 5	Whole milk	234,608	
	Skim milk	207,360	15
	Cream	469,800	26
	Slime	87,051,000	56
No. 6	Whole milk	220,800	
	Skim milk	64,800	25
	Cream	520,968	34
	Slime	55,424,000	40
No. 7	Whole milk	93,000	
	Skim milk	45,000	39
	Cream	124,200	26
	Slime	13,583,300	35
No. 8	Whole milk	54,000	
	Skim milk	21,400	32
	Cream	83,520	26
	Slime	11,600,000	41

showed .18%, making a difference of .01% of acid and the table shows a decrease of 15% in bacteria.

Experiment No. II. At the end of 23 hours the separated sample showed .19% acid and the nonseparated sample .20%, making a difference of .01% and the table shows a decrease of 18% in bacteria.

Experiment No. III. At the end of 24 hours the separated sample showed .02% less acid than the nonseparated sample and the table shows a decrease of 26% in bacteria.

Both samples coagulate about the same time but the nonseparated samples shows a disagreeable odor and some dirt settled in the bottom which was absent in the separated sample.

Experiment No. IV. At the end of 24 hours the separated sample showed .07% less acid than the nonseparated sample and the table shows a decrease of 49% in bacteria. The nonseparated sample showed some dirt settled in the bottom of the jar which was absent in the separated sample.

Experiment No. V. At the end of 24 hours the separated sample showed .03% less acid than the nonseparated sample and the table shows a decrease of 45% in bacteria. Considerable dirt was settled in the bottom of nonseparated sample and practically none could be seen in the separated sample.

Experiment No. VI. At the end of 24 hours the separated sample showed .03% less acid than the nonseparated sample and the table shows a decrease of 47% in bacteria. This milk was fresh when samples were taken—only about one hour old.

Experiment No. VII. At the end of 24 hours the separated sample showed .06% less acid than the nonseparated sample and the table shows a decreased of 51% in bacteria.

A number of other similar experiments were made by the writer at different times, taking the samples from several different kinds of separators used in the Dairy School. These showed practically the same results as given above.

The writer made eight other experiments to determine in which product (skim milk, cream or slime) the most bacteria were thrown during separation. In doing this the milk was carefully weighed before beginning and each division (skim milk, cream and slime) weighed separately after separation. Then a culture plate was made from each and the number of germs per cubic centimeter was determined. Then as we knew the per cent of skim milk, cream and slime we

had in 100 parts of whole milk we determined the per cent of the bacteria in the whole milk going into each.

Table No. II shows the number of germs per cubic centimeter in each of the products—whole milk, skim milk, cream and slime, and also the per cent of the whole number of germs found in each.

In all the experiments the skim milk contains the lowest number of germs per cubic centimeter, but in five experiments out of the eight it contained next to the highest in per cent of the whole.

The cream contains more germs per cubic centimeter than the whole milk or skim milk, but a less proportion of the whole than the skim milk in all but three of the experiments.

The skim milk contains an average of 29% of the whole number of germs, while the cream contains about 24% of the whole, thus leaving about 47% in the slime.

From this we would judge that running the milk through the separator would increase the keeping qualities of the milk and it seems strange that it does not increase it very much. But when we consider that bacteria are capable of reproducing themselves every half or three-quarters of an hour under favorable conditions, it can be explained. For example, if one sample contains 100 germs per cubic centimeter and another one 50 germs per c. c. In one half hour one would contain possibly 200 germs while the other would contain 100. Now if the fermentation of the first is stopped and the second allowed to continue it would take only about one-half hour for the second to contain the same number as the first. This probably shows why removing about one-half of the total number of germs by centrifugal separation has so little influence on the keeping quality.

SUMMARY.

1. The centrifugal separator removes practically all the solid impurities from milk.

2. From 37 to 56 per cent of the total number of germs were thrown out with the slime.

3. An average of 29 per cent of the total number of germs went into the skim milk, 24 per cent into the cream and about 47 per cent into the slime.

4. The keeping qualities of the milk are improved but little if any by centrifugal separation.