Issued June 10, 1909.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 114.
A. D. MELVIN, CHIEF OF BUREAU.

THE INFLUENCE OF ACIDITY OF CREAM ON THE FLAVOR OF BUTTER.

BY

L. A. ROGERS,
Bacteriologist, Dairy Division,
AND
C. E. GRAY,
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., March 29, 1909.

SIR: I have the honor to transmit herewith, with the recommendation that it be published as a bulletin of this Bureau, a paper entitled "The Influence of Acidity of Cream on the Flavor of Butter," by L. A. Rogers and C. E. Gray.

The deterioration in quality and the development of objectionable flavors in butter kept in cold storage cause considerable loss to the trade, and the causes and nature of these changes have not been understood. The Dairy Division of this Bureau has been making a study of these problems during the past three years, and the present paper reports investigations in which quantities of butter were made from cream of varying degrees of acidity and stored at different temperatures. It is believed that the results will be of practical value to the butter manufacturers of the country.

The authors wish to express their appreciation of the services of the various persons whose cooperation has made this work possible. They are especially indebted to the director and members of the staff of the University of Wisconsin Agricultural Experiment Station, who kindly allowed the use of their creamery and laboratories for part of the work. They are also under obligations to the manager of the creamery at Bloomer, Wis., and to the several persons who kindly scored the butter.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE INFLUENCE OF ACIDITY OF CREAM ON THE FLAVOR OF BUTTER.

INTRODUCTION.

Although much has been written about butter, there is yet very little known about the changes taking place in its chemical composition, the relation of these changes to the changes in flavor, the causes which produce them, or the factors which control their progress. It becomes necessary, therefore, to work out one by one the various conditions which cause or control the changes in the composition and flavor of butter. The difficulty of controlling conditions exactly and at the same time making normal butter renders it hard to determine the part played by any one factor. However, it is only by limiting the variations so far as the circumstances will permit to one factor that any definite conclusions can be reached.

A factor in the manufacture of butter, the variations of which can be controlled, is the acidity developed in the cream. This factor has long been recognized as important in determining the flavor of butter and as having a decided influence on the constancy with which butter retains its desirable flavors in storage.

It is generally taught by instructors and writers on dairy subjects that to produce good butter it is necessary to develop a certain amount of acid in the cream. The reason for this is twofold—first, to develop a desirable flavor, and, second, to improve the keeping quality by suppressing the undesirable bacteria. McKay and Larsen[a] state that in the ripening of cream the lactic-acid bacteria suppress other bacteria which, if carried into the butter, would produce undesirable changes. It is recognized, however, that if the fermentation is carried too far the keeping quality of the butter is injured. McKay and Larsen also state that in overripened cream undesirable bacteria may gain the ascendency and cause deterioration of the butter.

Michels[b] states:

> It has been found that butter with the best keeping quality is obtained from well-ripened cream. It is true, however, that butter made from cream that has been ripened a little too far will possess very poor keeping quality. An acidity of 0.5 per cent should be placed as the limit when good keeping quality is desired.

[a] George L. McKay and C. Larsen. Principles and Practice of Butter-making. P. 194. 1906.

[b] John Michels. Creamery Butter Making. P. 70. 1904.

These statements by recognized authorities may be taken as an expression of the opinion of instructors, investigators, and butter-makers in general. This opinion seems to be based, not on the results of actual experiment, but on experience in buttermaking. The little experimental evidence available on this question is conflicting and inconclusive. Patrick, Leighton, and Bisbee,[a] and Patrick, Leighton, and Heileman[b] concluded that butter made from sweet cream retained its flavor better than butter made from sour cream. The opposite conclusion was reached by Dean.[c] Unpasteurized cream was evidently used in these experiments.

The Dairy Division of the Bureau of Animal Industry therefore planned to include in a general investigation of the changes in storage butter a scientific and carefully controlled study of the influence of the acidity of the cream on the keeping quality of the butter in order to determine, if possible, the proper conditions under which butter intended for storage should be made. Obviously, results obtained from pasteurized cream could not properly be applied to butter made from unpasteurized cream, and vice versa. Therefore the investigation was planned to include butter made from both pasteurized and unpasteurized cream with varying degrees of acidity.

EXPERIMENTS WITH BUTTER MADE FROM CREAM WITH VARYING ACIDITY.

The first lot of butter in this investigation was made in the creamery of the University of Wisconsin dairy school at Madison in the summer of 1906. Owing to the fact that it was necessary to obtain part of the cream from another creamery it was impossible to control conditions as exactly as was desired, since in some cases the ripening developed more than had been planned.

The entire lot of cream was mixed; one half the quantity was pasteurized in a Farrington pasteurizer at 180° F.; the other half was not pasteurized. After the pasteurization of the first half the two lots of cream were treated in the same way. One-fourth of each lot was cooled and then churned as soon as possible. To the remaining cream was added 14 per cent of the starter in use at the creamery. One-third of this lot was cooled and churned as soon as possible. The remaining cream was allowed to ripen to about 0.45 per cent,[d]

[a] G. E. Patrick, F. A. Leighton, and D. B. Bisbee. Sweet versus Sour Cream Butter. Iowa Agricultural Experiment Station, Bulletin 18, pp. 478–487. 1892.

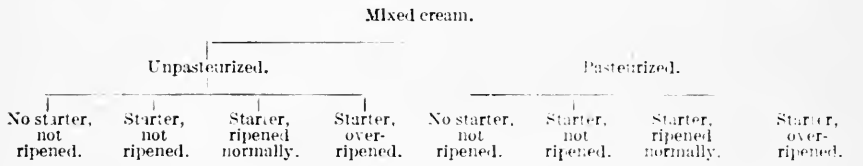
[b] G. E. Patrick, F. A. Leighton, and W. H. Heileman. Sweet versus Ripened Cream Butter. Iowa Agricultural Experiment Station, Bulletin 21, pp. 788–791. 1893.

[c] H. H. Dean. Experiments in Creaming and Butter Making. Ontario Agricultural College and Experimental Farms, Twenty-first Annual Report (for 1895), pp. 60–66. Toronto, 1896.

[d] In this paper acidity is expressed as per cent of lactic acid.

when it was divided, one half cooled and churned, and the other half allowed to stand forty-eight hours after separation.

The mode of procedure may be illustrated by the following diagram:



The acidity of the overripened cream developed very little above that of the normally ripened cream. The acidity of the overripened pasteurized cream at time of churning was 0.52 per cent. The acidity of the corresponding unpasteurized cream was 0.47 per cent. The salt and moisture contents were controlled as closely as possible and showed no variations which could be expected to influence the results, except in the case of the unpasteurized cream churned without starter. In this case the salt was 1.81 per cent. The butter, which will be designated as Lot I, was packed in 20-pound tubs and held seven days in the creamery refrigerator, when it was scored by Mr. J. G. Moore and then shipped by refrigerator freight to the cold-storage rooms in Chicago. Two tubs of each lot were stored at temperatures of 32°, 10°, and −10° F. The storage rooms were held at these temperatures with very little variation.

In the following summer a quantity of butter (Lot II) was made at Albert Lea, Minn., by the same method. This butter was made from milk received in the creamery in one day. Half of this cream was pasteurized in a regenerative Jensen pasteurizer at 170° F. The various lots were churned at the following acidities:

	Per cent.
Unpasteurized:	
No starter	0.13
Starter added	.37
Ripened	.51
Overripened	.86
Pasteurized:	
No starter	.13
Starter added	.16
Normally ripened	.51
Overripened	.68

The starter used in this cream was not very active and the acidity developed slowly in the pasteurized cream; otherwise this butter could be taken as representative of butter made under normal commercial conditions. The butter was packed in sealed 10-pound tin cans and stored, as was the Madison butter, at 32°, 10°, and −10° F.

The butter of Lot I was scored after six months in storage by Messrs. Credicott, Smarzo, Kieffer, and White, and after nine months by the

three first named. Each man scored independently and without knowledge of the history of the butter. The average scores of the Madison butter were as follows:

TABLE 1.—*Average scores of butter of Lot I.*

Method.	Storage temperature.	Score when fresh.	Score after six months' storage.	Score after nine months' storage.
Unpasteurized:	° F.			
No starter, no ripening	−10	92	90.6	91.3
	10		91	91.6
	32		87	86.6
Starter, no ripening	−10	93.5	89.5	90
	10		90	92
	32		86.5	86
Starter, normal ripening	−10	96	91	91.3
	10		90	91
	32		86.5	85.3
Starter, overripening	−10	92	90.05	92.6
	10		90.2	No tub.
	32		87.2	87.5
Pasteurized:				
No starter, no ripening	−10	97	91.3	92.3
	10		91.3	92
	32		90.6	89.3
Starter, no ripening	−10	96.5	91.18	92
	10		91.37	92
	32		88.3	89
Starter, normal ripening	−10	95	89	91.8
	10		87.5	90.3
	32		85.6	84
Starter, overripening	−10	92.5	85.5	90.3
	10		85.1	84.3
	32		81.75	82

The butter of Lot II stored at 10° F. was scored after four months by Mr. Credicott, and all the butter was scored after eight months by Messrs. Kieffer and Smarzo. In the latter scoring a number of grades with a definite score were arranged and the packages grouped accordingly. In all cases a separate package was used for each scoring.

TABLE 2.—*Average scores of butter of Lot II.*

Method.	Storage temperature.	Score after four months.	Score after six months.
Unpasteurized:	° F.		
No starter, churned sweet	−10		90.
	10	90. Rancid.	90.
	32		87. Cheesy.
Starter, not ripened	−10		90.
	10	90. Rancid.	90.
	32		90.
Starter	−10		90.
	10	90. Cold storage.	82. Fishy.
	32		82. Fishy.
Starter, overripened	−10		84. Curdy, cheesy.
	10	89. Bad.	82. Curdy, very poor.
	32		82. Curdy, very poor.
Pasteurized:			
No starter, churned sweet	−10		92.
	10	92.5.	90.
	32		91.
Starter, not ripened	−10		91.
	10	92.	91.
	32		91.
Starter, normal ripening	−10		91.
	10	91. Cold storage.	91.
	32		90.
Starter, overripened	−10		84. Curdy, cheesy.
	10	88. Bad.	82. Curdy, very poor.
	32		82. Curdy, very poor.

A third lot of butter (Lot III) was made, as before, from one lot of cream, one-half of which was pasteurized at 180° F. After taking out one-fourth of each half to be churned sweet, 15 per cent of starter was added. The different portions of this lot of cream were churned at the following acidities:

	Per cent.
Unpasteurized cream:	
No starter	0.18
Starter added	.32
Ripened	.54
Overripened	.64
Pasteurized cream:	
No starter	.16
Starter added	.32
Ripened	.59
Overripened	.70

This butter was packed in sealed tin cans. One can from each lot was sent to New York, where it was scored when twenty days old by Mr. Kieffer. The remainder was stored at 10° F. and was again scored by Mr. Kieffer at the end of five months. The scores are shown in the following table:

TABLE 3.—*Scores of butter in Lot III.*

Method.	Twenty days old.		After five months' storage at 10° F.	
Unpasteurized:				
No starter	85.	Strong	90.	
Starter added	90.		90.	
Ripened	88.	Oily	80.	Very fishy.
Overripened	85.		88.	
Pasteurized:				
No starter	93.		91.	
Starter added	95.		90.	
Ripened	90.	Slight metallic	87.	
Overripened	87.	Metallic	87.	

DISCUSSION OF RESULTS.

The score of the fresh butter of Lot I immediately before it went into storage indicates that while there were some differences all of the butter was at least fairly good, while the average of the scores made after the butter had been in storage shows marked differences in a few cases. The comments of the scorers show that the butter made from unripened unpasteurized cream always developed a cheesy or rancid flavor. The butter made from ripened cream, both pasteurized and unpasteurized, developed cold-storage, fishy, and other flavors typical of storage butter. In all cases the overripe butter showed marked deterioration. The butter made from pasteurized cream without starter usually retained its flavor with little or no change. Even at 32° F., where all the ripened butter showed decided changes, the sweet-cream butter deteriorated very little. The score of the sweet-cream butter in the Madison lot was decreased by a "woody"

or "fruity" flavor which was noticeable at the top and sides of the package. In the opinion of the judges, this flavor was due to some extraneous cause.

The difference between butter made from pasteurized sweet cream and that from ripened cream, both pasteurized and unpasteurized, became very marked after holding in a warm room for a short time. Butter made from pasteurized cream with starter added, after the so-called Le Clair or Credicott method, retained its fresh flavor better than the ripened-cream butter, but was not quite equal in keeping quality to that made from sweet pasteurized cream.

In making deductions from results obtained by the usual method of scoring butter, allowance must be made for certain variations due to the sense of taste, which is not adapted to expression in mathematical terms. However, after making allowance for the personal tastes and variations that can not be avoided in butter scoring, it is evident from the results shown in the tables that some factor having a deleterious influence on the butter was developed with the ripening of the cream. The action of this factor is especially evident in the cream allowed to stand beyond the usual ripening period, although it is not necessarily accompanied by a marked increase in acidity, as is shown by the overripened butter of Lot I. In determining what this deleterious factor is, it should be remembered that these changes took place at temperatures of 20 and even 40 degrees below the freezing point. We know that a comparatively high acidity was developed in the cream from which this butter was made, but there is also the possibility that other influences having little connection with the acid may have developed to affect the flavor of the butter.

The direct action of bacteria in causing changes at these temperatures is obviously excluded, but an indirect action may be found in the possibility that enzymes are secreted in the cream by bacteria and that these enzymes are able to act even at the low temperatures at which this butter was stored.

DETERMINATIONS OF BACTERIA IN THE BUTTER.

Qualitative and quantitative determinations of the bacteria in the cream and butter were made according to the following methods: Gelatin, and in some cases both gelatin and agar, plates were made of the cream at the various stages of the ripening. All media used contained 2 per cent lactose and were corrected to a reaction of +0.2 Fuller's scale, with the exception of plates made from Lot III, in which the reaction was +1.0. Anaerobic plates showed no bacteria not present on the ordinary aerobic plates. In making plates from the butter, samples of 5 to 10 grams each were taken, with proper precautions to prevent contamination, from five or six different places in each tub. The samples were melted at 40° C., and after thorough

mixing, 5 grams of each were weighed into flasks containing 500 c. c. of sterile water. These flasks were held in a water bath until the temperature reached 40° C. and were shaken vigorously to insure a thorough distribution of the bacteria. Plates with varying dilutions were made in the usual way.

The results of the bacterial determinations are given in Table 4 for the Lot I butter, in Table 5 for the Lot II butter, and in Table 6 for the Lot III butter.

TABLE 4.—*Bacteria in butter of Lot I.*

Method.	Initial number.	Storage temperature.	After six months' storage.	After nine months' storage.
		° F.		
Unpasteurized cream:				
Churned sweet	8,983,000	−10	2,300,000	3,000,000
		10	2,360,000	1,131,000
		32	1,195,000	816,000
Starter added	2,893,000	−10	872,500	906,000
		10	730,000	351,000
		32	531,000	202,000
Normal ripening	3,924,000	−10	1,257,750	949,000
		10	1,107,500	1,026,000
		32	349,825	271,000
Overripened	9,825,000	−10	24,727,500	1,187,000
		10	1,470,166	No butter.
		32	554,000	124,000
Pasteurized cream:				
Churned sweet	386,166	−10	146,625	49,000
		10	134,166	106,211
		32	6,870,000	174,000
Starter added	2,800,000	−10	855,750	720,000
		10	245,250	102,000
		32	305,000	253,000
Normal ripening	945,000	−10	110,000	10,500
		10	275,000	6,600
		32	265,000	32,875
Overripened	1,956,000	−10	67,500	11,800
		10	300,166	16,100
		32	24,500	8,100

TABLE 5.—*Bacteria in cream and butter of Lot II.*

Method.	Bacteria per cubic centimeter in cream before churning.	Bacteria per gram in butter before storage.	Storage temperature.	Bacteria per gram in butter after storage.
			° F.	
Not pasteurized:				
No starter	66,100,000	11,900,000	−10	490,000
			10	365,000
			32	153,000
Starter added	553,500,000	12,800,000	−10	726,000
			10	133,000
			32	64,000
Normal ripening	779,000,000	4,260,000	−10	376,000
			10	297,000
			32	106,000
Overripened	620,000,000	613,000	−10	.....
			10	13,000
			32	5,000
Pasteurized:				
No starter	27,000	491,500	−10	28,000
			10	.....
			32	.....
Starter added	85,750,000	826,000	−10	90,000
			10	.....
			32	211,000
Normal ripening	781,000,000	13,650,000	−10	381,000
			10	450,000
			32	35,000
Overripened	880,000,000	38,400,000	−10	172,000
			10	1,100,000
			32	23,000

TABLE 6.—*Bacteria in cream and butter of Lot III.*

Method.	Bacteria per cubic centimeter in cream at time of churning.		Bacteria per gram in fresh butter.		Bacteria per gram in butter after storage at 10° F.	
	Total.	Liquefiers.	Total.	Liquefiers.	Total.	Liquefiers.
Unpasteurized:						
No starter	43,800,000	1,750,000	3,755,000	161,000	610,000	85,000
Starter added	226,000,000	540,000	7,233,000	94,000	563,000	1,000
Ripened	258,500,000	75,000	12,766,000	None.	469,500	None.
Overripened	362,500,000	40,000	3,136,000	None.	87,000	2,000
Pasteurized:						
No starter	195,500	13,300	88,500	20,000	[a]1,344,000	56,000
Starter added	162,500,000	None.	10,300,000	3,000	2,275,000	1,500
Ripened	1,000,000,000	None.	11,520,000	None.	278,500	400
Overripened	526,000,000	None.	24,666,000	None.	420,000	None.

[a] Development of *Oïdium lactis* and *Bacterium lactis aerogenes*.

There is, of course, always the possibility that bacteriological methods do not show true bacteriological conditions. Assuming that the gelatin plates gave a correct indication of the nature and number of the bacteria present, there is little in the results in the Lot I butter to connect the bacteria in any direct way with the changes in the butter. The unpasteurized cream contained a total of 9,000,000 bacteria per cubic centimeter, of which 300,000 were of the liquefying type. There was an increase for a short time of the liquefying bacteria, but these were soon suppressed by the lactic-acid bacteria. When the maximum development was reached the lactic bacteria decreased slowly. There was, however, no apparent growth of any other kind of bacteria. The freshly pasteurized cream contained 1,192 bacteria. There was a small increase of nonlactic bacteria, but this was soon checked by the lactic bacteria, and the subsequent development agreed with that observed in the unpasteurized cream.

The cream from which Lot II was made contained 66,100,000 bacteria per cubic centimeter, which were reduced by pasteurization to 27,000. In the unpasteurized cream the lactic-acid bacteria soon gained the ascendency and suppressed all other kinds. There was a considerable development of bacteria of the aerogenes type in the normally ripened pasteurized cream, but these were suppressed in the overripe cream by the lactic-acid bacteria. Otherwise the plates showed no bacteria which could be expected to influence the flavor.

The bacteria in the cream of Lot III followed the same general course. There was no appreciable growth of gas-forming bacteria in this cream, but in the overripened unpasteurized cream there was a small development of *Oïdium lactis*. Ten days elapsed after this butter was taken from storage before it was received at the laboratory. During this time it was doubtless held at temperatures within the thermal growth limits of ordinary bacteria. There was a distinct increase of bacteria in the pasteurized sweet-cream butter in which

the two inhibiting factors, acid and salt, were low. This bacterial growth may have been responsible for the deterioration of this butter.

In all the butter stored at 10° and −10° F. there was a gradual decrease in the total bacteria. This was usually slightly more rapid at the higher temperature, but this difference in the rate of decrease was sometimes obscured by errors, due largely to the difficulty of securing a representative sample. At 32° F. this decrease was usually much more pronounced than at the lower temperatures. In several cases, however, there was an actual increase confined chiefly, if not entirely, to the torula group of yeasts. In one package the development was sufficient to make an actual increase in the total number of bacteria, which in the ordinary technique includes yeasts as well as bacteria. Usually the growth of yeasts was so much less than the decrease in bacteria that the total number showed a decrease. It has been demonstrated that some members of this group of yeasts may cause a decomposition of butterfat.[a]

In some cases the change in the flavor of the butter stored at 32° F. might be accounted for by this development of yeasts, but in others in which there was an equal deterioration there was no appreciable increase of yeasts or bacteria.

The inference should not be drawn that the writers exclude the action of bacteria as a factor in causing changes taking place in butter. It is undoubtedly true that not only the flavor of the fresh butter but the change in flavor after the butter is made may be influenced by the bacterial growth in the cream, and under certain conditions bacteria and yeasts may grow in the butter itself. The uniform deterioration of the high-acid butter at the lower temperatures, however, could not be accounted for in this way.

POSSIBLE ACTION OF ENZYMES IN DETERIORATING HIGH-ACID BUTTER.

A plausible explanation of the changes may be found in the possible production of enzymes by the lactic-acid bacteria, which if carried into the butter would continue to act, as has been previously suggested, even at the lower temperatures at which it was stored. It is doubtful if enzymes are excreted by the lactic-acid bacteria, but it is well established that all cells contain enzymes which rapidly bring about the destruction of the cell after its death. Even the minute amounts of the decomposition products of the bacterial cells might affect the flavor of butter. Moreover, it is possible that enzymes not normally excreted are liberated by the natural death and disintegration of the cell. This is at least a possibility that can not be disregarded.

[a] L. A. Rogers. Studies upon the Keeping Qualities of Butter.—I. Canned Butter. United States Department of Agriculture, Bureau of Animal Industry, Bulletin 57.

The situation in the unpasteurized cream is complicated by the possible action of the enzymes of the milk, which include proteolytic, lipolytic, and oxidizing enzymes, but these enzymes would be destroyed by the pasteurization of the cream, which, as we have seen, did not prevent the deterioration.

If, as suggested, enzymes are liberated in any way by the lactic-acid bacteria, butter made from cream heated sufficiently after ripening to destroy the enzymes should not change at temperatures low enough to prevent the growth of bacteria and other organisms. In Table 7 are given the results of an experiment in which 10 per cent of starter was added to sour hand-separated cream, the mixture pasteurized at once at 180° F., cooled properly, and churned. One-half of this cream was pasteurized, starter added, and allowed to ripen over night.

TABLE 7.—*Showing changes in butter made from cream pasteurized after ripening.*

Method.	Score after one week (before storage).	Storage temperature.	Score after two months.	Score after five months.
		° F.		
a. Sour hand-separator cream, 10 per cent starter added, pasteurized at 180° F., cooled, and churned.	93	−10	83.7	84.2
		10	84.7	84.0
		32	82.7	85.0
b. Half of *a*. Pasteurized at 180° F., 10 per cent starter added, ripened over night, cooled, and churned.	92	−10	83.2	83.5
		10	83.7	83.5
		32	83.7	84.0

When these lots of butter went into storage one week after making, they scored 93 and 92, respectively. In two months both lots had developed, regardless of storage temperature, a rank, fishy flavor. All enzymes would be nearly if not quite destroyed by the temperature to which this cream was exposed. To assume that this marked change in flavor was caused by the development of bacteria would be contrary to our experience with other butter. These results have been duplicated many times in the course of other investigations.

One lot of butter was made in our experimental creamery in Albert Lea in the following way: The fresh cream was pasteurized at 170° F. To this was added 20 per cent of starter, and one-fourth was cooled and churned at once (designated as *a*). Another fourth was ripened overnight to an acidity of 0.41 per cent (*b*). The remainder was allowed to stand forty-eight hours. At this time the acidity was 0.59 per cent. Half of this remainder was properly cooled and churned (*c*), and the remaining fourth heated in a vat at 158° F. for ten minutes, after which it was cooled and churned (*d*). These butters were examined by numbers only when they went into storage one week after making, and again after four and one-half months of

storage at a temperature of 10° F. The results of the examination are given below:

TABLE 8.—*Changes in butter made from cream pasteurized after ripening.*

Portion and method.	Acidity.	Result after one week.	Score after four and one-half months storage at 10° F.
	Per cent.		
a. Starter added		Perfectly good	92. Tallowy.
b. Ripened	0.41	Very nice butter; good aroma	92. Tallowy. Slight storage.
c. Overripened	.59	Unclean	91. Stale-water flavor.
d. Overripened and heated.	.59	Extremely unclean	87. Old, tallow, rancid, grease.

It is apparent that the deleterious effect of high acidity was not due to any organism, enzyme, or other substance which can be destroyed by heat. It is evident, then, that some by-product of bacterial growth, unaffected by heat, had a marked influence on the flavor of the butter. It is probable that this was a by-product of the lactic-acid bacteria and that the by-product was lactic acid itself.

INFLUENCE OF LACTIC ACID ON FLAVOR OF BUTTER.

A number of experiments have been made to determine the influence of acidity developed in the cream by the addition of lactic acid. These have invariably given results similar to those shown in Table 9. In securing the results shown in this table one-third of a lot of pasteurized cream was cooled and churned at once (*a*). To the remainder were added small portions of chemically pure lactic acid until it showed an acidity of 0.36 per cent. Half of this was cooled and churned on the following morning (*b*). The acidity of the remaining third was increased to 0.41 per cent, cooled, held overnight, and churned the next day (*c*). The butter remained in the creamery refrigerator two weeks, when it was examined by numbers only, and shipped to storage at 10° F. It was examined again after three and a half months in storage with the following results:

TABLE 9.—*Influence of lactic acid on the flavor of butter.*

Portion and method.	Acidity.	Condition after two weeks.	Score after three and one-half months in storage at 10° F.
	Per cent.		
a. Churned sweet	0.099	Good	93.5. Sweet.
b. Lactic acid added	.360	Oily, unclean	89. Sweet, fruity.
c. Lactic acid added	.444	Oily, decomposed fat	87. Sweet, oily.

RESULT OF PRODUCING ACIDITY WITH OTHER ACIDS THAN LACTIC ACID.

Similar results have been obtained with butter made from cream acidified with acid other than lactic acid. These butters were made in the following manner: Sweet cream sufficient to make three churn-

ings was pasteurized in a continuous pasteurizer at 170° F. One-third was cooled and churned at once (*a*). To the remaining two-thirds acid was added slowly until the acidity expressed as lactic acid equaled about 0.22 per cent. This portion was divided and one-half cooled (*b*). The remaining portion was acidified to about 0.4 per cent and cooled (*c*). Portions *b* and *c* were churned on the following day. Lot 1 was acidified with lactic acid, lot 2 with acetic acid, and lot 3 with hydrochloric acid.

There was a slight development of bacteria in these creams, which was evidently checked by the higher acidity. The greater part of the bacteria present were of the lactic-acid type, or had no appreciable effect on milk. This butter was packed in sealed cans and a few days after making was shipped to storage and was examined by Mr. Credicott when about 15 days old. The results are given in Table 10.

TABLE 10.—*Showing the influence of different acids on the flavor of butter.*

Lot.	Acid added.	Acidity of cream.	Score after fifteen days.
		Per cent.	
1 *a*	None	0.144	88. Trifle unclean and very greasy.
1 *b*	Lactic	.216	88. Do.
1 *c*	do	.432	86. Fishy and greasy.
2 *a*	None	.126	90. Trifle oily, body weak and greasy.
2 *b*	Acetic	.216	87. Very greasy, and rancid on fishy order.
2 *c*	do	.350	84. Very fishy and greasy.
3 *a*	None	.126	90. Clean but greasy.
3 *b*	Hydrochloric	.225	90. Trifle unclean and oily.
3 *c*	do	.450	84. Very fishy, greasy.

This table shows that this action is not peculiar to lactic acid or even to organic acids.

It would appear, therefore, that the acidity of the cream has a direct influence on the changes in the butter. This is, of course, usually complicated by the influence of other factors, many of which are still undetermined. Just what action the acid has and what parts of the butter are changed to bring about the undesired flavors we are not prepared to say at this time, but investigations are in progress which it is hoped will throw some light on the complex chemical changes controlling the flavor of butter.

THE MANUFACTURE OF COMMERCIAL BUTTER FROM SWEET CREAM.

To the person interested in the application of these results to practice it is obvious that butter which market conditions require to be held for any length of time should be made with as little acid as possible. This is especially true of butter held for several months in cold storage and butter canned for use on shipboard or for export to tropical countries. While the object of this investigation was to determine the causes of change in butter, the results allow some com-

parisons to be made of the commercial value of the different methods of butter making. The deterioration in storage of butter made from overripened cream is well known, and this investigation has shown clearly that butter made from cream ripened according to the usual creamery practice changes much more than butter made with a low acidity. A number of trials were made to determine if adding sufficient starter to cream to improve the flavor of the butter would seriously impair the keeping quality.

The keeping quality of butter made from sweet pasteurized cream is compared in the next table with that of butter made with starter. The scores given in this table are the average scores of six lots of butter made in the creamery at Bloomer, Wis. The cream from which this butter was made was pasteurized in a Farrington pasteurizer at temperatures varying from 155° to 175° F. The lot was divided, a large starter added to one-half, and each portion cooled and churned at once. In a few cases one-half was ripened, but this butter was so much poorer than the sweet-cream butter that it was not stored. The scorers were Messrs. Kieffer, Smarzo, Credicott, and White:

TABLE 11.—*Showing relative keeping quality of butter made from pasteurized sweet cream, sweet cream with starter added, and normally ripened cream.*

Lot and method.	Storage temperature.	Average score after four months.	Average score after eight months.
	°F.		
1 *a*. Sweet cream	−10	92.6	93.0
	10	91.3	93.1
	32	89.3	91.0
1 *b*. Starter added	−10	91.0	92.5
	10	91.3	92.3
	32	89.3	89.0
2 *a*. Sweet cream	−10	90.3	92.6
	10	90.8	92.6
	32	90.6	88.6
2 *b*. Starter added	−10	92.2	94.3
	10	92.1	93.5
	32	90.0	92.0
3 *a*. Sweet cream	−10	90.6	92.1
	10	90.6	91.8
	32	89.2	88.3
3 *c*. Ripened normally	−10	90.4	88.6
	10	88.5	88.6
	32	85.7	83.3
4 *a*. Sweet cream	−10	91.8	92.7
	10	91.4	92.7
	32	92.0	93.0
4 *b*. Starter added	−10	91.9	93.0
	10	91.2	92.8
	32	87.3	87.3
5 *a*. Sweet cream	−10	91.1	93.0
	10	91.5	93.0
	32	92.2	91.5
5 *b*. Starter added	−10	92.1	93.0
	10	90.9	92.1
	32	88.0	86.0
6 *a*. Sweet cream	−10	91.3	93.5
	10	90.6	91.5
	32	89.6	92.2
6 *b*. Starter added	−10	91.0	93.0
	10	90.8	92.7
	32	87.3	89.3

The foregoing table is summarized in Table 12, which gives the average of the scores of the six lots of sweet-cream butter and of the five lots of butter made from sweet cream with starter:

TABLE 12.—*Showing average scores of butter made from pasteurized sweet cream and sweet cream with starter added.*

Method.	Storage temperature.	Average score after four months.	Average score after eight months.
	° *F.*		
Sweet cream (six lots)	−10	91.28	92.81
	10	91.03	92.45
	32	90.32	90.73
Starter added (five lots)	−10	91.64	93.16
	10	91.26	92.68
	32	88.38	88.72

The foregoing table shows that at the two lower temperatures there was little or no advantage in the sweet-cream butter over that with the starter, but at 32° F. there was a decided difference in favor of the sweet-cream butter. Butter has been made under commercial conditions by this method in large quantities, and when sold after several months in storage was considered highly satisfactory.

In the work described in the foregoing pages we have given little attention to sweet-cream butter for immediate consumption. We have, however, a number of scores of fresh butter, most of which are comparisons of butter made from pasteurized sweet cream with and without starter added.

In three lots sent to the New York market the butter made from cream with starter added was scored from 1 to 2½ points higher than the sweet-cream butter. On the other hand, in eight lots of butter sent to the Fox River Butter Company the average score of the sweet-cream butter was 93.7, against 93.3 for the butter with starter. The difference in favor of the sweet-cream butter was greater in the butter eight or ten days old at the time of scoring, while in the butter scored immediately after making the highest score was given to the butter with starter. In four lots in which sweet-cream butter was compared with butter made from cream ripened in the normal manner, the former received an average score of 94 against 91.2 for the ripened-cream butter.

The difference between the scores given the butter sent to New York and that sent to the Fox River Butter Company may be explained by the demand of the market and the personal tastes of the scorers. The New York market calls for a butter with a decided flavor, and the mild sweet-cream butter consequently received a low score. The scorer at the Fox River Butter Company, on the other hand, gives a good score to a butter free from any objectionable flavors. The scores of these lots are given in Table 13:

TABLE 13.—*Scores of fresh butter made from pasteurized sweet cream, sweet cream with starter added, and cream ripened normally.*

	Lot and method.	New York (Kieffer) score.	Fox River Butter Company score.
1	*a.* Sweet cream		94
	b. Starter added		94
2	*a.* Sweet cream	92.5	94
	b. Starter added	93.5	92
3	*a.* Sweet cream	92	94
	b. Starter added	94	92.5
	c. Ripened		90
4	*a.* Sweet cream		94
	b. Starter added		93.5
5	*a.* Sweet cream		93
	b. Starter added		94.5
6	*a.* Sweet cream		93
	b. Starter added		94
7	*a.* Sweet cream		94.5
	b. Starter added		94
8	*a.* Sweet cream	90.5	93.5
	b. Starter added	93	92.5
9	*a.* Sweet cream		94.5
	b. Ripened		92
10	*a.* Sweet cream		94
	b. Ripened		92
11	*a.* Sweet cream		93.5
	b. Ripened		91

These results show at least that butter may be made from sweet cream which will after long storage at comparatively high temperatures be classed as good butter by competent judges. The method for making this butter is so simple that a uniform output with little danger from undesirable fermentations can be insured. The trouble and expense of starters are eliminated. In churning sweet cream it is essential that careful attention be given to the churning temperature and to the speed of the churn, otherwise there is likely to be an unnecessary loss of fat in the buttermilk. Care should be taken in storing butter made from sweet cream to guard against woody or other extraneous flavors, which are likely to be more noticeable in this mild-flavored butter than in butter with a high flavor.

The Dairy Division is not advising the adoption of this method for general use, but its trial for butter intended for storage is recommended.

CONCLUSIONS.

Butter frequently undergoes marked changes, even when stored at very low temperatures.

These changes are more marked as the acidity of the cream from which the butter is made is increased.

No bacteria were found in the cream or the butter which could reasonably be expected to be the cause of the more rapid deterioration of the high-acid butter.

The changes in the high-acid butter were not checked by heating the ripened cream, which shows that they were not brought about by enzymes secreted with or in the cream and carried into the butter.

Marked changes of an undesirable nature were produced in butter by acidifying pasteurized cream with various acids. These changes did not take place all at once, but were of a progressive nature.

The results indicate that the acid developed normally in the cream by the action of the lactic-acid bacteria, or added directly to the cream in the form of pure acid, brings about or assists in bringing about a slow decomposition of one or more of the labile compounds of which butter is largely composed.

Butter can be made commercially from sweet pasteurized cream without the addition of a starter. Fresh butter made in this way has a flavor too mild to suit the average dealer, but it changes less in storage than butter made by the ordinary method, and can be sold after storage as high-grade butter.

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