Approved
C. H. Eckles
Lonnie Stanley

CREAM RIPENING AND ITS RELATION TO BUTTER FLAVORS.

by

Asa Claude Stanton, B. S. in Agr.

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Table of Contents.

INTRODUCTION.

The rapid development of the butter industry and the constant demand of the markets for a high quality of butter is forcing the butter-makers to give the greatest possible attention to the quality of their product. The time has passed, and competition is too keen, for the butter-maker to put a poor grade of butter on the market and receive sufficient remuneration to enable him to continue in business.

The increasing demand for "Better Butter" is causing buttermakers to give careful consideration to all factors relating to the quality of their product, and among these factors cream ripening is usually given first place. The term "Cream Ripening", while probably familiar to most of those who manufacture butter on a large scale, is not in common usage by all interested in this subject. The term is synonymous with the term "Cream Souring", and may be described as the development of certain bacteria which bring about both a chemical and physical change in the cream. The principal chemical change involved is the conversion of the milk sugar into lactic acid, which, in turn, causes the cream to thicken by coagulating the casein. The presence of lactic acid is unfavorable to the growth of other bacteria, and when sufficiently present will inhibit their growth.

The lactic acid organism was discovered by Lister in the year 1877[1], but not until thirteen years later (1890) was the attention of bacteriologists called to the method of using artificial cultures of bacteria in ripening cream. Professor Storch of Copenhagen was the first to show that while some species of bacteria produce an excellent aroma in butter, others produce a very inferior quality.[2] Subsequent investigators have followed this lead and have shown quite definitely that the flavors of the butter are due to the character of the ripening, and that the most desirable species of bacteria are those producing lactic acid. However, while it is very generally conceded by bacteriologists that the essential process in proper cream ripening is lactic acid fermentation, it has not been proved that the lactic acid fermentation alone is responsible for all the changes which take place in cream during the process of ripening.

1. Storrs Annual Report, 1900.
2. Storrs Annual Report, 1893. (Trans. from original)

REVIEW OF LITERATURE.

In reviewing the literature which has been published to date on the subject of cream ripening and its relation to butter flavors, we find that most of the work reported has been done in the way of testing the influence of different organisms present in cream during the process of ripening. A great deal of work has been done on testing the influence of pasteurization on the keeping qualities of butter. The work with the most direct bearing on the work in this Thesis is given in detail in the following discussion.

The Use of Various Acids.

Some of the earliest experimental work reported on cream ripening was the method of souring the cream by means of mineral and organic acids to test the effect upon the general quality of the butter. Hittcher[1] about 1894, at the suggestion of Dr. Fleischman, attempted to determine the value of a method granted a patent by the German Government. The method consisted of souring cream by the addition of hydrochloric acid instead of by ordinary

1. Exp. Sta. Rec., Vol. 6, p. 248.
(Milch Zitg.,23 (1894) No. 27, pp. 425-427.

acid fermentation. Twenty-six trials were made, and in twenty cases out of the twenty-six trials the butter was in normal condition when it was taken from the churn, and in the remaining cases it was oily or finely granulated. In taste the butter could hardly be told from ordinary butter, except that some of the experts remarked that there was a lack of the sour cream butter aroma. Hoft[1] and Tamm[2] did some work along the same line, and found that the general quality of the butter was not affected.

Among the American investigators to work on this subject were Rogers and Gray.[3] They state that marked changes of an undesirable nature were produced in butter by acidifying pasteurized cream with various acids. The changes did not take place at once but were of a progressive nature. By acidifying sweet cream with lactic acid to the extent of 0.36 per cent, only a fair quality of butter was produced. When the butter was examined at the end of two weeks the condition was described by market experts as "unclean", "oily". At the end of three and one-half months in storage at 10° F. it scored 89, and was described as "sweet," "fruity". When the acidity was increased to .44 per cent, at the end of two weeks,

1. Exp. Sta. Rec., Vol.,6, p. 249.(Milch Zitg., 23, No. 27)
2. " " " " " p. 672 (" " " " 29)
3. U. S. Dept. Agr., Bur. An. Ind., Bul. 114.

it was said to be "oily", "decomposed fat." At the end of three and one-half months it was given a score of 87, and described as "sweet," "oily."

In testing the influence of acetic acid they found that when cream was acidified to .35 per cent, at the end of 15 days the butter was very fishy and greasy, and was given a score of 84 points. Trials were also made in which hydrochloric acid was used. They found that when this acid was added to the extent of .45 per cent, the butter became very fishy and greasy when examined after 15 days in storage.

Influence of Lactic Acid Fermentation.

It was formerly supposed that the formation of lactic acid in milk was entirely due to the action of a single organism, described by Hueppe, and called Bacillus acidi lactici.[1] Later investigators have found that this was not the typical lactic acid organism, but that there are a number of organisms that may produce lactic acid, the most typical of which is Bacterium lactic acidi. The lactic acid organisms are the most common and the most numerous organisms found in milk, and ordinarily the lactic acid fermentations are the first to take place.

The pioneer investigator on this subject is Dr. Conn of Wesleyan University, Connecticut. Dr. Conn in

1. Wing, Milk and Its Products, p. 115.

some of his earliest investigations was lead to believe that the species of bacteria producing flavor and aroma in butter were independent of the acid producing bacteria. Those producing aroma usually occurring oftener than those producing flavor.[1] After carrying on a vast amount of experimental work in studying this subject it was found that in well ripened cream there must be an abundance of lactis acid bacteria. He further states that the question is a very complex one, but the probability is that flavors and aromas are not due, in ordinary butter, to any one kind of bacterium or to any one kind of decomposition, but that quite a variety of processes may contribute thereto.[2] He brings forth evidence to emphasize the fact that the Bacterium lacti acidi represents a group of varieties, and not a single organism. He further states that it is certain that the production of both flavor and aroma is more or less independent of the production of acid, but that this does not mean that the bacteria producing acid may not also produce flavors and aromas, but that the two phenomena of acid production and flavor production are not identical.

1. Storrs Agr. Exp. Sta., Bul, 16.
2. Conn. Dairy Bacteriology, p. 200.

Professor Eckles[1] in discussing the results of his work on the relation of acid fermentation to butter flavor and aroma, states that when good flavored cream is ready for churning, the number of bacteria per cubic centimeter varies from 280 million to 3 billion, 91 to 98 per cent of which are of the acid producing type. He further found in confirmation of Conn's[2] statement that the general superiority of butter flavor in the summer season is mainly due to the difference in the fermentation which takes place in the milk. This, no doubt, remains an undisputed fact, but Conn[3] says that whether this June flavor is due to a large growth of miscellaneous bacteria during the first few hours of ripening, or whether it is due to a difference in the chemical nature of the fat remains to be determined.

McKay[4] in experimenting with the factors affecting butter flavors found that the best results were obtained by quick ripening of the cream with frequent stirring. The highest flavored butter was produced when the cream had an acidity of about .66 per cent (Calculated as lactic acid.) and ripened at a temperature above 70°F.

1. Iowa Agr. Exp., Bul. 40.
2. Storrs Annual Rept., 1896.
3. " " " 1900
4. Iowa Agr. Exp., Bul. 32.

It was found that when cream was ripened to an acidity above .7 per cent it took on a bitter flavor. The same results were noticeable when the cream was ripened for a long time at a low temperature.

Michels[1] states that it has been found that butter with the best keeping quality is made from well ripened cream, but when butter is made from cream that has ripened a little too far it will possess a very poor keeping quality. An acidity of .5 per cent should be placed as the limit when good butter is desired.

McKay and Larsen[2] state that it is recognized that if the fermentation is carried too far the keeping quality of the butter is injured. They also state that in overripened cream undesirable bacteria may gain ascendency and cause deterioration of the butter.

Wing[3] in discussing the bad effects of overripening has this to say, "When too much lactic acid is developed in the cream the casein is firmly coagulated, and in the process of churning is broken up into minute granules, which become incorporated into the butter in the form of white specks or flakes of casein. Such white specks, besides injuring the appearance of the butter, greatly detract

1. Michels. Creamery Butter Making.
2. McKay and Larsen. Principles and Practice of Butter Making.
3. Wing. Milk and Its Products.

from its keeping qualities, as the putrefactive fermentations soon set up in them and give rise to disagreebale flavors. Danger from this source is liable to be present if the coagulation of the cream has gone so far that any whey has separated. ....The chief evil effect in over-ripening is in the production of strong and undesirable flavors accompanying the undue production of lactic acid."

In 1906 Rogers and Gray[1] began a 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. The investigation was planned to include butter made from both pasteurized and unpasteurized cream with varying degrees of acidity.

In discussing their results they state that the comments of the experts who scored the butter 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 cold storage butter. In all cases the butter from overripe cream showed marked deterioration. The butter made from pasteurized cream without

1. U. S. Dept. Agr. Bureau of An. Ind., Bul. 114.

starter usually retained its flavor with little or no change. Even at 32° F., when all the ripened cream butter showed decided changes, the sweet cream butter deteriorated very little. 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 retained its fresh flavor better than ripened cream butter, but was not quite equal in keeping quality to that made from sweet pasteurized cream. The investigators state that it is evident from the results 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 if the cream is allowed to stand beyond the usual ripening period, although it is not necessarily accompanied by a marked increase in acidity. These changes took place 20 and even 40 degrees below the freezing point. 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 temperature at which the butter was stored. Quoting direct from the authors they have this to say, "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 the butter. Moreover, it is possible that enzymes not normally excreted are liberated by the natural death and disintegration of the cell.

"If 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." To determine this several trials were made. They found that the changes in the high acid butter were not checked by heating the ripened cream to a temperature of 158° F. for ten minutes. It appears from this 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 suggested that probably this marked influence was due to a by-product of the lactic acid bacteria, and that the by-product was lactic acid itself.

Effect of Temperature.

The temperatures recommended for cream ripening show a wide range of variation. The general tendency has been in latter years to increase the temperature to a higher degree. This has been due mainly to the fact that in well ripened cream there must be an abundance of lactic acid bacteria, and these do not grow well below 60° F. At this low temperature certain other bacteria, which produce a bitter taste, are likely to develop. On the other hand, too high a temperature is favorable for the growth of undesirable bacteria as well as a temperature too low. Therefore, a temperature from 65° to 70° appears most likely to avoid both of the difficulties, and under ordinary circumstances the best results can be obtained with a temperature of 70°.[1]

Rosengen[2] found that cream may be ripened to advantage 12° C. (53.5° F.) in 20 to 22 hours by the addition of 8 per cent of pure culture starter, He states that the best arrangement in regard to temperature of cream during ripening is to start the process at such a temperature so that when the ripening is completed it will be of the right temperature for churning. A low ripening temperature was not found less favorable than a high temperature

1. Conn. Dairy Bacteriology. p. 201
2. Exp. Sta. Rec., Vol. 13, p. 1086.
(Landtmannen, 12 (1901) No. 1, pp. 2-11.)

during ripening. He further found when cream was pasteurized then cooled and allowed to ripen, that the temperature increased from 1 to 2 degrees irrespective of room temperature. It is suggested that this increase may be due to a gradual change taking place in the physical condition of the butter fat which is accompanied by the liberation of heat.

Dean[1] reported some work on the relation of temperature to cream ripening in which one lot was ripened at 73° and another at 60° F. On scoring the butter there were no conclusive indications which was the better. In some later work he reported a slight increase in favor of the lower temperature.

McKay[2] found that the highest flavored butter was produced when the cream had an acidity of about .66 per cent and ripened at a temperature above 70°. He also states that it was found that cream took on a bitter flavor when ripened for a long time at a low temperature.

Oidium Lactis and Molds.

According to Jensen[3] the organisms which produce rancidity in butter are Oidium lactis, Cladoporium butyri (a mold which looks

1. Ontario Agr. Coll. & Exp. Sta., Rept., 1897, pp. 66-67
2. Iowa Agr. Exp., Bul. 32.
3. " " " " 71 (Trans. from original)

considerably like the first one mentioned but at times it assumes a brownish green color), Bacillus fluorescens liquefaceous (a bacterium which liquefies gelatine, and during its growth a greenish fluorscent colored material is formed). At times Bacillus prodigiosus (a bacterium which liquefies gelatine and at the same time forms a red colored substance). If the butter is especially exposed during the time of keeping and process of making, to a damp and unclean atmosphere, many other germs may enter in, such as the ordinary molds, especially Penicillium glaucum (ordinary green mold.)

O'Callaghan[1] claims that fishy flavor in butter is caused by the organism Oidium lactis. He found that a fishy flavored butter was produced by inoculating a portion of milk with this organism, but by pasteurizing an inoculated portion a good flavored butter was produced. Contrary to this Rogers[2] claims that he could not produce a fishy flavor in butter by inoculating the cream with Oidium lactis.

Sayer, Rahn and Farrand[3] in studying the bacterial flora of butter found that the most frequent molds present were Oidium lactis, Pencillium glaucum and

1. Exp. Sta. Rec., Vol. 13, p. 129.
   (Agr. Gaz. New South Wales, 1901.)
2. U. S. Dept. Agr., Bureau of An. Ind., Cir. 146.
3. Mich. Tech. Bul. No. 1.

Aspergillus glaucus.

Rahn, Brown and Smith[1] found Oidium to increase with age in unsalted butter, but not in salted butter.

Bouska[2] in studying overripened cream found that the lactic acid bacteria increased in numbers until .4 to .5 per cent of acid was reached and then they decreased. The putrefactic bacteria either decreased from the start or increased till .6 per cent of acidity was present, then they decreased. When an acidity of .4 to .7 per cent was reached Oidium lactis became apparent. Then it grew to several million per cubic centimeter when a white film developed on the surface. As the Oidium increased to great numbers the acidity diminished. Bad flavors and odors appeared at the time when Oidium reached great numbers. He found that there was a more direct relation between the bad flavors and the increase in Oidium lactis than between the bad flavors and the number of putrefactive bacteria.

Thom and Shaw[3] in studying the relation of humidity to mold growth in butter found that mold will not grow upon the surface of a piece of butter exposed to humidities of 70 per cent or lower. The water in the butter is not sufficiently available to the mold to support the development of a colony. In studying the influence

1. Mich. Tech. Bul. No. 2.
2. Iowa Bul. 103.
3. Journal of Agr. Research, Vol. 3, No. 4.

of salt they found that when salt is present in butter to the extent of 2.5 to 3 per cent it is sufficient to eliminate mold or reduce to negligible amount. Species of Oidium lactis, Alternaria, and Cladosporium cannot develop in butter containing 2.5 per cent of salt.

Summary of Previous Investigations.

From literature reported it seems to be the concensus of opinion among investigators that the use of organic as well as inorganic acids do not give satisfactory results when used to sour cream. It does not appear to be simply a matter of souring the cream, but that there is some other factor which gives the butter the desirable flavor and aroma.

The fact has been proven by investigators and recognized by practical buttermakers that certain fermentations which take place in cream will produce a good quality butter, while there are other fermentations which will produce butter of very poor quality.

The most desirable fermentation which takes place in cream while ripening is the lactic acid fermentation. This fermentation is brought about principally by the organism Bacterium lactis acidi. No definite conclusion has been reached in regard to whether or not an over amount of lactic acid developed in cream is responsible for

rapid deterioration in butter, but it seems to be the opinion of practical buttermakers that the lactic acid fermentation can be carried too far.

In consideration of the work reported there is no doubt but what a high per cent of salt in butter will prevent to some extent the development of molds while the butter is in storage, but nothing is known in regard to the influence of molds, in the cream, on the keeping qualities of the butter.

EXPERIMENTAL WORK.

General Outline.

The work herein reported is a study of a few of the problems of cream ripening and the resulting effects on the flavor of the butter, which have not heretofore been studied to any extent.

Since the introduction of the hand separator practically all the cream produced is separated on the farms and delivered to the creameries in the form of cream. Some times the small producer allows his cream to stand a long time before shipping in order to reduce the expense of transportation. This has caused an inferior grade of cream to be delivered which in turn produces an inferior grade of butter which deteriorates very rapidly.

Knowing that this cream does produce a poor grade of butter the question arises as to what is the nature of the fermentation which develops to cause this poor grade of cream. If it is due to standing a long time before it is churned, what is it that takes place in the cream which causes it to be of an inferior quality.

One possibility is that the acid fermentation itself is allowed to develop too far. It has been assumed by some, but has not been demonstrated experimentally, that the over development of lactic acid is responsible for this inferior quality of cream and rapidly

deteriorating butter. The theory has been advanced that by allowing the acid fermentation to develop too far, the large amount of acid produced coagulates the casein which forms hard pieces of curd which are not gotten out of the butter during the process of churning. These particles of casein are then incorporated in the butter and when this butter is put in storage the decomposition of this protein material takes place in a short time and results in a rapid deterioration.[1]

One object of the experiments which were conducted was to determine whether or not an over development of lactic acid fermentation is responsible for this condition.

Since the results of the investigation as reported later showed that an over amount of lactic acid fermentation is not an important factor in poor quality cream and butter, attention was next given to other possible causes. The first to receive attention was those organisms grouped under the names of molds and Oidium lactis.

It is a well known fact that Oidium lactis and molds develop rapidly on a high acid cream after it stands 2 or 3 days or longer.

1. Wing. Milk and Its Products. P. 208.

In addition to their rapid development they are able to secrete chemical ferments known as enzymes, and reduce the acidity of the cream on which it is grown to a neutral, or slightly alkaline, condition. After the acid has disappeared another type of bacteria develop which digest the casein and produces a general putrifaction and decomposition.[1]

Oidium lactis and molds usually find conditions favorable on the average farm, as the cream is often kept in a dark, damp room or cellar, and held for sometime before being churned or delivered to the creamery.

If these organisms do cause a poor grade of butter to be produced, then it should be possible to determine the fact experimentally by inoculating the cream directly with these organisms.

After conducting a few experiments along this line, it was found that these organisms did have some effect on the quality of the cream and the keeping qualities of the butter.

Then the next thing to suggest itself was the possibility that by preventing the development of these organisms, the quality of the cream and butter could be improved. The fact that Oidium lactis and molds are strictly aerobic, suggested the possibility of eliminating

1. Conn. Practical Dairy Bacteriology. P. 82.

their growth by excluding the air from the cream. To study this question experiments were carried out in which cream was ripened in an open and in a closed container.

It was observed in the previous investigation that at times the cream developed a disagreeable flavor even when Oidium lactis and molds were prevented from developing. This condition was attributed to some type of fermentation which probably took place in connection with the lactic acid fermentation, or before the acid fermentation had a chance to overcome its development.

If the acid produced by the lactic acid bacteria is capable of inhibiting the growth of undesirable bacteria, then why would not the addition of a small amount of C. P. lactic acid have the same effect?

For this reason experiments were conducted in which C. P. lactic acid was added to cream, to determine the effect on the keeping qualities of cream and butter.

It is well known that the quality of the butter when first made can be judged by the quality of the cream before it is churned. For this reason in a portion of the experiments made the cream was not churned into butter. In this way we were able to do a larger number of experiments than otherwise would have been possible.

Description of Containers.

In the course of some trials made previous to the time the writer began the work it was found that when cream was held for sometime in a metal container it took on a metallic taste. This condition, however, has been the observation of investigators and practical butter makers for sometime, and it is due to the action of the acid on the metal of the container.

In order to eliminate flavors arising from this source it was decided to ripen the cream in glass jars. All the containers used were either fitted with glass stoppers or they were sealed air tight by means of running a layer of paraffin in on top of a paper cap which was forced down into the neck of the bottle until it came in contact with the cream. Caution was taken to make sure that the cream and stopper came in contact with each other.

For the cream experiments small half pint glass jars were used which could easily be sealed air tight the same as described above.

The butter samples at first were kept in small card board packages, but it was observed that mold developed around the edge of the butter while in storage, To eliminate this trouble the butter was kept in small

glass jars which could be closed air tight.

Kind of Starter Used.

In the beginning a starter was used which was made by inoculating a flask of sterile milk from a pure culture of Bacterium lactis acidi. This was found not to be satisfactory as the starter made in this way always gave the cream the cooked taste which is characteristic of over heated milk. In order to over come this the skim milk which was intended for the final starter was pasteurized at a temperature of 175° F, for 30 minutes. This was done in an open pail and the milk was constantly stirred while heating and while it was being held. It was then cooled to 70° and inoculated to the amount of 10% of its volume with a skim milk culture of Bacterium lactis acidi. The starter was then held at a temperature of 70° F. If the starter was not used within 48 hours from the time it was prepared it was discarded.

The Relation of Over Development of Lactic Acid Fermentation to Butter Flavors.

The common use of the expression, "Made from old, overripened cream," which is frequently used by butter judges in describing a peculiar flavor very often found in butter, was largely responsible for the beginning of this

particular investigation. While the term is frequently used, it is not a question as to whether or not this particular flavor is present and indicates a flavor characteristic of old sour cream, but the question is whether or not this particular flavor is due, as is generally said, to the over-ripening of the cream. If this is the case the question arises as to whether it is due to the over development of the lactic acid fermentation or some other factor or some other type of fermentation which takes place in the cream in connection with the lactic acid fermentation. In other words is the acid fermentation alone, under any condition, responsible for bad flavors in cream.

To test the effect of lactic acid fermentation it is necessary to hold the cream for some time to allow the acid fermentation to develop and the cream remain in contact with the acid. But in order to prevent the development of fermentations other than that of lactic acid, it is first necessary to eliminate all factors and other types of fermentation which are liable to occur in the cream.

In planning this investigation the first thing that was done was to use cream which was as fresh as could be obtained and the germ content as low as possible. Therefore, cream from the University herd was used as it could be gotten fresh and was exceptionally free from

contamination.

It was then pasteurized at a temperature known to be sufficient to destroy practically all the bacteria that were present. Then it was inoculated with a pure culture of the organism Bacterium lactis acidi, and held in an air tight container to prevent contamination from other organisms, especially, Oidium lactis and molds.

It had been previously found when a sample of butter was open and examined and then replaced for a later examination that the butter invariably became contaminated with molds while being examined, and by the time the second examination was made these molds had developed. For this reason two or more small samples of butter from each experiment were kept for examination. After a sample was once examined it was discarded, and for the next examination another sample of the same butter which had been kept under the same conditions was used and compared with the condition of the first sample.

The samples which were kept in the cooler were held at a temperature of from 50 to 60° F.

The butter in the last 6 experiments was salted very lightly so as not to hide any flavor which might develop. Records were kept in regard to the pasteurizing temperature, the amount of starter used, temperature ripened, length of time ripened, acidity of cream

after ripening, and the condition of the cream with relation to taste and smell, and the quality of the butter at different ages.

Discussion of Experiments.

Experiments Nos. 9 to 15 inclusive were carried out by the writer, and the remaining ones were taken from records of work which was done by advanced students in the Dairy Department.

As stated before, some of the butter samples at first were not properly protected, and consequently the samples were spoiled by the development of molds.

Experiment 1. The cream in this experiment was placed in a metal container and was pasteurized at a temperature of 149° F. for 20 minutes. The can was fitted with a stirrer and a special constructed cover so as to eliminate mold contamination. A pure culture of lactis acid starter was added and the cream was left at room temperature to ripen. The cream was stirred daily for twelve days and then it was churned. When the cream was examined in regard to taste it was found to be slightly metallic, which was attributed to the fact that it had stood in a metal container. The butter when examined immediately after churning was of fair quality, except a slight taste of the metallic flavor could be detected, but the taste of old cream could not be noticed. The butter samples were

placed in the cooler.

When the butter was examined 17 days later there was no preceptible change. When examined at the end of 60 days a slight rancid taste had begun to develop.

Experiment 2. This sample of cream was pasteurized at 140° for 20 minutes, cooled and a starter added and then placed in a glass jar which was covered with cotton so as to eliminate molds and at the same time admit air. However, some mold grew on the surface of the cream. The sample was held at room temperature for 14 days and then churned. No bad flavor was noticed in the cream due to standing so long.

The butter was examined after standing in the cooler for 41 days, and it was found that a slight rancid taste was being developed. The sample examined 90 days after churning was found to be in fair condition, but was beginning to get rancid. It was found that the worst was near the edge of the butter, nearer the center the taste was not so distinct. Molds had grown around the edge of the butter which probably accounts for the rancidity.

Experiment 3. In this experiment the cream was treated as in the previous experiment except that the container was closed air tight. The sample was allowed to

ripen at room temperature for 13 days. When open the cream was still in good condition and the butter made was of good quality.

When examined 22 days later it scored 37 on flavor. When 56 days old it was remarkably good for its age. It was neither rancid nor fishy.

Experiment 4. This sample was treated as in the previous experiment, and was allowed to ripen for 18 days. The condition of the cream when churned was not bad, but the butter was not quite as good as the butter in the previous experiment. The butter received a score of 35 on flavor after being in the cooler for 12 days.

When the sample was 46 days old no change was noticed and the butter was still in good condition.

Experiment 5. This sample of cream was pasteurized at 140° for 20 minutes, then cooled and a starter added. It was then held at room temperature for 15 days. The taste of the cream when churned was a little flat, and the same taste was noticed in the butter when it was churned, and when examined 34 days later.

When examined 63 days old it was a little off in flavor, especially around the edge where it was pronounced a trifle rancid. The center of the sample was not rancid.

Experiment 6. The treatment of this sample was the same as in the previous experiment, but was held for only 8 days. When churned the cream was in good condition, and the butter was better than in any previous experiment.

When the butter was examined 5 days later it had a peculiar flavor which was noticed slightly when first churned, but was given a score of 35 points. When examined 32 days after churning the peculiar flavor was still present. When examined 61 days old the butter was still in good condition.

Experiment 7. The cream was treated as in experiment 6 and was churned when 11 days old. The quality of the cream was good and the butter had a high acid flavor but was not objectionable. When 63 days old the butter was still good, and after standing 94 days the center of the package, away from the molds, was good.

Experiment 8. This sample of cream which was treated the same as the previous one, stood for 14 days before churning. At that time the cream was still in good condition.

The butter when 66 days old was very good and received a score of 39 on flavor. It was considered as being good enough to pass as first class butter.

Experiment 9. The cream used in this experiment was pasteurized at 150° for 20 minutes, cooled and 10% of pure culture starter added. It was placed in a closed container and held at a temperature of 60° for 9 days. The condition of the cream when churned was very good and the acidity was .69 per cent.

The butter immediately after churning was of fair quality, and when examined after being in the cooler 156 days the butter had an old taste, otherwise there was nothing objectionable about its flavor.

Experiment 10. The cream used in this experiment was treated the same as in the previous experiment, and was allowed to ripen for 7 days at a temperature of 60°. When the cream was churned it had a slightly cooked taste, which was also noticed in the butter when churned.

The butter was examined when 144 days old and there was no flavor present except that it was a little old tasting. When 154 days old it was the same as when first examined.

Experiment 11. The cream used in this experiment was part of the lot of cream used in Experiment 10, and was treated identically the same except that it was allowed to ripen 14 days instead of 7. The condition

of the cream at the end of 14 days was very good, except the slight cooked taste referred to in Experiment 10. The acidity was .72 per cent.

The butter when churned was of good quality except the cooked taste. When examined 137 days old the flavor was not quite as good as in Experiment 10. When 147 days old there was no change in the flavor.

Experiment 12. This cream was from the same lot as Experiments Nos. 10 and 11, but was ripened for 21 days. At the end of that time the cream had a good flavor, and an acidity of .73 per cent.

The condition of the butter was about the same as in the other two samples. When examined 130 days old it was the poorest of the three samples. But there was very little difference in the three samples.

Experiment 13. The cream used in Experiments 13, 14 and 15 was pasteurized at 145° for 20 minutes, cooled to 70 and a starter added. At this point the cream was divided into three lots and used in Experiments 13, 14 and 15 respectively. The cream in this experiment was ripened for 17 days at a temperature of 53° F. The condition of the cream at the end of that time was very good. It had an acidity of .69 per cent and a clean sharp acid taste.

The butter when churned was of a fair flavor except a little flat. When 82 days old it was slightly old tasting but no other flavor could be detected. There was no change in the butter when 92 days old.

Experiment 14. This cream when churned was equally as good as the cream in Experiment 13 when churned, and the per cent of acidity was the same.

The condition of the butter when churned was good. When examined after standing 63 days it was slightly better than the butter in Experiment 13 which had been churned 82 days. When 73 days old there was no change.

Experiment 15. This sample of cream was churned after it had stood 70 days at an average temperature of 56^{0}. The quality of the cream at the end of this period was equal to the average as recorded at the creameries in this state. It was somewhat bitter, but the bitterness was not similar to the bitterness which is ordinarily found in cream which has stood for a long time at a low temperature. The cream would have passed without trouble as second grade cream. The acidity had developed to .8 per cent and the taste of acid was sharp.

The butter when churned was of fair quality, and when examined 27 days after churning the taste was very similar to that of the butter in Experiment 14 when it was

63 days old. The sample examined when 37 days old was not quite as good as when first examined, neither was it as good as the samples in Experiments 13 and 14.

Table I.

Showing treatment and condition of the cream.

No. of Exp.	Age of Cream Churned	Treatment of cream	Container	Temp. Ripened	Taste of Cream Churned
1	12 days	Past. 149° 20 min., starter	Tin pail, Covered	Room	Slightly metallic
2	14 "	Past. 140° 20 min., starter	Glass jar, cotton cover	Do	No bad flavors
3	13 "	Do	Glass jar, tightly stoppered	Do	Good
4	18 "	Do	Do	Do	Not bad
5	15 "	Same as Exp. No. 2	Do	Do	Fair, rather flat
6	8 "	Do	Do	Do	Good
7	11 "	Do	Do	Do	Good
8	14 "	Do	Do	Do	Good
9	9 "	Past. 150° 20 min., Starter	Do	60°F	Good. Acidity .69%

Table I. (Continued)

No. of Exp.	Age of Cream Churned	Treatment of cream	Container	Temp. Ripened	Taste of Cream Churned
10	7 days	Past. 150°	Glass jar, tightly stoppered	60°F	Good. Acidity .66% slightly cooked taste
11	14 "	Do	Do	Do	Good. Acidity .72% Slightly cooked taste
12	21 "	Do	Do	Do	Good. No cooked taste. Acidity .73%
13	17 "	Past. 140° 20 min., starter	Do	53°F	Good, clean acid taste. Acidity .69%
14	35 "	Do	Do	55°F	Good, clean acid taste. Acidity .69%
15	70 "	Do	Do	56°F	Slightly bitter. Sharp acid taste Otherwise fair. Acidity .8%

Table II.

Condition of Butter when Examined.

No. of Exp.	Cond. of Butter when churned	Age when first examined	Cond. when first examined	Age when examined 2nd time	Cond. when examined 2nd time
1	Fair quality	17 days	No change in flavor	60 days	slightly rancid
2		41 "	Very slight rancid taste	90 "	Fair, a little rancid. Worst near edge of butter. Mold on edge.
3	Good	22 "	Scored 37	56 "	Remarkably good
4	Not as good as in Exp.3	12 "	Scored 35	46 "	Good cond. No change in flavor
5		34 "	A little flat	63 "	A little off in flavor near edge. Trifle rancid but not in center pkg.
6	Good	32 " 2nd Exam.	Score 35 peculiar flavor but good	61 "	Little if any change
7	High acid taste. Good	63 "	still good.	94 "	Good cond. in center package, away from molds.

Table II. (Continued)

No. of Exp.	Cond. of Butter when churned	Age when first examined	Cond. when first examined	Age when examined 2nd time	Cond. when examined 2nd time
8		66 days	Very good Scored 39		
9	Fair	156 "	Old tasting not rancid nor any noticeable flavor.		
10	Slightly cooked	144 "	Old tasting No flavor other than old	154 days	No change in flavor
11	Do	137 "	Similar but not quite as good as No.10	147 "	No change in flavor
12	Cooked taste not noticed	130 "	Similar to, but not quite as good as No. 11.		
13	Good flavor except a little flat	82 "	No flavor other than an old taste could be detected	92 "	No change in flavor
14	Good	63 "	Similar to No. 13, except slightly better	73 "	No change in flavor
15	Fair, could not notice bitter taste as in the cream	27 "	Best of last three samples but all three were very similar.	37 "	Not as good as when first examined. Inferior to 13 and 14.

Dicussion of Results.

In summing up the results of these experiments it is found that in the trials reported there was nothing to indicate that any kind of fermentation other than that of lactic acid had taken place in the cream while ripening, except in Experiment 15 where the cream stood an unusual length of time. However, the bitterness which was detected in the cream was not very noticeable, and the presence of a large amount of acid might have been responsible for this taste to a certain degree.

Even after allowing for individual variation in taste we find in the description of the condition of the cream that the results are very consistent, and that these results show that the cream was uniformly good.

In the condition of the butter, however, the results were less consistent, but it must be remembered that some of the butter samples stood a long time at a comparatively high temperature.

In only three experiments out of the 15 were there any samples described as being rancid. In two of the cases molds had developed around the edge of the butter. Near the center of the package, away from the molds, the rancidity was only slightly found, if at all.

It appears from this that the molds which developed on the butter were responsible for the development of the rancid flavor, and that by preventing their development rancidity did not appear in the butter. This agrees with the conclusions of Jensen[1] that mold is one of the chief causes of rancidity in butter.

In Experiments 13, 14, and 15, where all the samples were set at the same time and from the same lot of cream; the condition of the butter, when all the samples were examined and compared 97 days from the time the cream was set, was very similar in every respect, regardless of whether it stood in the form of cream or butter.

The same was true in Experiments 10, 11, and 12 which were also set at the same time and from the same lot of cream.

This certainly does not bear out the theory that overripe cream produces a rapidly deteriorating butter. On the other hand it seems that a rapidly deteriorating butter is not necessarily produced from cream in which lactic acid has been allowed to develop to the maximum, even when held at what would be considered an extremely abnormal length of time before churning.

1. Iowa Bul.,,71. (Trans. from original)

When a poor keeping butter is produced from old overripe cream it is due to some other factor or some other type of fermentation, and not to the action of the lactic acid organism.

In no case out of the 15 experiments was there any flavor noticed in the butter samples as indicating that it was made from old overripened cream, and it appears that the development of a high per cent of acid does not have a tendency to produce a butter which, on standing will produce a variety of disagreeable flavors.

Fishiness was not developed in any sample at any time.

The Effect of Oidium Lactis and Molds on Flavors in Butter.

Since it is shown that the lactic acid fermentation in cream is not responsible for a rapidly deteriorating butter, and that molds seem to be related to the rancidity in butter, the next question to suggest itself is that possibly this deterioration is due to the influence of molds and Oidium lactis which so frequently develop on cream that has been standing for a long time.

To determine the influence of these organisms a plan similar to that used in the previous investigation was followed out, except that air was not excluded from the cream while ripening. The containers were filled so that the depth of the cream about equalled the diameter of the container.

The cream was pasteurized at 145° for 20 minutes, cooled to 70 and a starter was added. It was then divided into three samples and treated as follows:-

Sample No. 1. Check.

" " 2. Inoculated with Oidium lactis.

" " 3. " " a common blue mold.

The samples were allowed to ripen for 9 days at a temperature of 54° F., before churning.

Table 3 shows the condition of the cream when churned and the condition of the butter at churning time and after standing a while.

Table III.

Sample No.	Condition of cream.	Taste of butter when churned.	Taste of butter when 78 days old.
1	Good	Good	Moldy tasting
2	Strong growth of Oidium	Similar to No. 1.	Poor taste. Cheesy smell.
3	Strong growth of mold.	A slight moldy taste	Old moldy taste. Cheesy smell.

In sample No. 1 a slight growth of Oidium was found on the cream when it was churned, and the butter sample got contaminated with mold while in storage which was probably the cause of the moldy flavor which developed.

In sample No. 2 a strong growth of Oidium lactis developed on the surface of the cream, which was stirred into the mass of cream before it was churned, but on examining the cream no unusual flavor could be noticed.

The butter when examined 78 days after churning had a peculiar and unpleasant flavor, and a cheesy smell.

The strong growth of mold which grew on the surface of sample No. 3, was also mixed into the cream before it was churned, and caused the cream to have a slight moldy taste.

The butter when first churned had a slight moldy taste, and when examined 78 days later the taste was disagreeably moldy.

Another experiment was conducted in which the treatment of the cream was the same as in the first experiment, and was allowed to ripen for 10 days at 57° F.

Table 4 gives the results of the second experiment.

Table IV.

Sample No.	Condition of cream	Taste of butter when churned.	Taste of butter when 13 days old.	Taste of butte when 23 days old.
1	Good Quality	Good	Good butter scored 36 on flavor	No change
2	Unpleasant taste.	Disagreeable taste.	Poor flavor, might be described as burnt taste	More disagreeable than when examined any time before.
3	Fair Quality	Similar to No. 1, but not as good.	Slightly inferior to No. 1.	Very little if any change

The butter from sample No. 2 in this experiment had a very peculiar and unpleasant taste. The same flavor could be noticed to a slight extent in sample No. 2 of the first experiment. This disagreeable flavor, however, did not develop while the butter was in storage, but during the time the cream was ripening. While the same flavor was present in the cream and butter when it was first churned, it gradually grew worse as the age of the butter advanced. The last examination of the butter showed the most disagreeable flavor.

The mold growth on sample No. 3 was considered too heavy to be mixed with the cream, consequently it was removed before the cream was churned.

The flavor of the cream after removing the mold was good, but slightly inferior to No. 1 which was the check. The butter when churned was also slightly inferior, and the same relation existed as the age of the butter advanced. Sample No. 1 was good butter and was given a score of 36 on flavor.

Discussion of Results.

The results of these experiments show that molds which develop on the surface of cream, when stirred into the mass before it is churned, will cause a very disagreeable moldy flavor to develop in the butter while in storage.

When this mold growth is removed before the cream is churned, it does not produce a butter in which a moldy flavor becomes so distinct.

If the enzymes secreted by these organisms penetrate into the cream sufficiently/ so as not to be removed with the "skin like" layer of mold growth, they do not produce a very rapidly deteriorating butter, and do not affect the quality of the cream to any appreciable extent.

When the organism Oidium lactis is allowed to develop on cream and is stirred into the mass before churning, it produces a poor flavored cream and butter. This condition was not brought out in the first experiment as noticeably as in the second. This might have been due to the fact that the area of the container used in the first experiment was about 1/4 the area of the surface exposed in the second container, and that a stronger growth had developed on the second sample. This was probably due to being ripened at a higher temperature.

The Effect of an Open and a Closed Container on the Keeping Qualities of Cream and Butter.

Having found that the organisms Oidium lactis and molds do cause peculiar and undesirable flavors in cream and butter; the next thing to which we turned our attention was to determine if the development of these organisms can be prevented, and by preventing their development, can the quality of cream and the keeping qualities of butter be improved.

If some practical and inexpensive way could be devised whereby the farmer could keep his cream for a period of from three to seven days and still be practically as good for butter making as when fresh, a problem of great importance to the creameryman as well as the producer would be worked out.

The fact that Oidium lactis and molds are strictly aerobic organisms makes it quite possible to eliminate their development by allowing the cream to ripen in the absence of air.

Experiments were carried out in which cream was ripened in containers closed so that there was no air present except that which was incorporated in the cream. These closed samples of cream were compared with samples

to which air was admitted.

The cream used in these experiments was fresh unpasteurized cream.

Discussion of Experiments.

Experiments 1 and 2 were conducted by the writer, and the remaining ones were done by other advanced students in this department.

Experiment 1. The containers which are designated as "open" had a piece of card board over the top of the jar in order to keep out dust.

Sample No.	Treatment of cream	Temp. held.	Condition of cream when examined 6 days old.
1	No starter closed	72°F.	No mold, disagreeable taste.
2	No starter open	72°F.	Mold on surface, taste worse than No. 1.
3	Starter closed	72°F.	No mold, taste considerably better than No. 1, a fair grade of cream.
4	Starter open	72°F.	Strong growth of mold, taste not as good as No. 3, moldy and disagreeable.
5	.45% C.P.L.A. *Closed	72°F.	No mold, good cream, taste a little peculiar, sweetish

*Chemical Pure Lactic Acid.

Sample No.	Treatment of cream	Temp. held.	Condition of cream when examined 6 days old.
6	.45% C.P.L.A. open	72°F.	Strong growth of mold, not as good taste as No. 5, better than samples 1-2-3-4.
7	No starter closed	54°F.	No mold, not to say good cream but better than 1 and 2.
8	No starter open	54°F.	Slight growth of mold, not as good as No. 7
9	Starter closed	54°F.	No mold, first class cream, best of all 12 samples.
10	Starter open	54°F.	Slight mold, good cream.
11	.45% C.P.L.A. closed	54°F.	No mold, good cream.
12	.45% C.P.L.A. open	54°F.	No mold, not so good as No. 11 but better than any sample from 1 to 8 inclusive.

Samples 5 and 11 were very similar in taste and both were considered a good grade of cream.

The best two samples of the 6 held at a temperature of 72° were Nos. 5 and 6 which had .45% of acid added. Contrary to this in the 6 samples held at 54° the best two were Nos. 9 and 10 which had 10 per cent of pure culture starter added.

Experiment 2. This experiment is a duplication of Experiment No. 1.

Sample No.	Treatment of cream	Temp. held.	Condition of cream when examined 6 days old
1.	No starter Closed	76°	Poor quality
2.	No starter open	76°	Very poor
3.	Starter closed	76°	Better than Nos. 1 and 2, but not as good as Nos. 5 and 6
4.	Starter open	76°	Similar to No. 3 but not quite as good
5.	.2% C.P.L.A. Closed	76°	Good, best of first 6 samples.
6.	.2% C.P.L.A. open.	76°	Similar to No. 5, but not quite as good
7.	No starter closed	56°	Exceptionally good cream.
8.	No starter open	56°	Very similar to No. 7.
9.	Starter closed	56°	Very good grade of cream, best of 12 samples.
10.	Starter open	56°	Good cream, next to best.

Sample No.	Treatment of cream	Temp. held.	Condition of cream when examined 6 days old.
11.	.2% C.P.L.A. Closed	56°	Ranked as a good grade of cream, but inferior to all four previous samples held at 56°.
12.	.2% C.P.L.A. open.	56°	Good cream but not as good as No. 11.

Of the 6 samples ripened at a high temperature the best two were Nos. 5 and 6, while Nos. 9 and 10 were the best of the 6 samples ripened at a low temperature. This is the same condition which was found in Experiment 1. In this experiment samples Nos. 11 and 12 were inferior to Nos. 7 and 8, which is contrary to the results in Experiment 1. However, 5 and 6 were better than 1 and 2, which agrees with the results in the previous experiment.

In summing up the results we find that the closed samples were uniformly better than the open samples, and the best grade of cream was that ripened at the lower temperature. The influence of the lactic acid was the same as previously found with the high temperature, but in case of the low temperature it was not the same. This probably was due to the small amount which was added.

Experiment 3. In this experiment those samples which are designated as "open" were covered with cheese cloth so as to exclude dust.

All the samples were held at room temperature.

Sample No.	Treatment of cream.	Acidity when first examined	Condition of cream when 4 days old.
1.	No acid, open.	.62%	No mold, similar to No. 2. Fair.
2.	No acid closed.	.6 %	Not as good as Nos. 3 and 4
3.	.37% C.P.L.A. closed.	.45%	Best of the four samples. A keen acid taste.
4.	.37% C.P.L.A. open	.5 %	Similar to No. 3, but not quite as good.

From general appearance samples 1 and 2 showed a greater gasy fermentation than did samples 3 and 4. Samples 1 and 4 which were not covered showed more gasy fermentation than did samples 2 and 3.

In judging the cream by taste samples 3 and 4 were considerably better than 1 and 2, and had a keener acid taste. But in each of the two different sets the closed sample was the better of the two.

Experiment 4.

Sample No.	Treatment of cream	Acidity when first examined	Condition of cream when 4 days old.
1.	No acid open	.9	A great deal of gas, mold, and an old bitter taste.

Sample No.	Treatment of cream.	Acidity when first examined.	Condition of cream when 4 days old.
2.	No acid closed.	.97	Similar to No. 1, but no mold.
3.	.33% C.P.L.A. open.	.87	Very little gas, some mold, and slightly bitter.
4.	.33% C.P.L.A. closed	.9	Similar to No. 3, but no mold.
5.	.58% C.P.L.A. open.	.62	No gas, but some mold wheyed off.
6.	.58% C.P.L.A. closed.	.56	Similar to No. 5, but no mold.

In the last two samples the large amount of acid which was added coagulated the casein and the samples wheyed off about 1/3 of their volume. The low per cent of acidity in these two samples was probably due to some extent to the acid being incorporated in the casein. However, there appears to be less acid produced by bacterial action when the larger amounts of acid was added so the total acidity of the cream acidified with lactic acid was less than that of those where the acidity developed by the bacterial action.

In each case it was found that the closed samples were better than the open samples.

Experiment 5. In this experiment all the containers were closed so as not to admit air, but two of the jars were only partly filled.

Sample No.	Treatment of cream.	Acidity when first examined, %	Condition of cream when 7 days old
1.	.33% C.P.L.A. Full.	.85	Good sharp acid taste, best of the 4 samples.
2.	.33% C.P.L.A. 2/3 full	.81	Good cream, next to No. 1 in quality.
3.	No acid Full	.78	Only fair cream.
4.	No acid 2/3 full	.79	Poor cream, poorest of the 4 samples. A mold had developed.

The two samples which were acidified with acid were very similar in condition, and considerably better than the other two. There was a marked difference between samples 3 and 4.

The full sample in each case where the samples were treated the same was much better than the sample which was only partly full. Still the non acidified sample which was full was not as good as the acidified sample which was only partly filled.

The samples which were full in the first place were refilled and all four samples were left for

7 days, and then the following results were obtained:-

Sample No.	Acidity %	Condition when 14 days old.
1.	.89	Best of the 4 samples. Similar to the condition when first examined.
2.	.74	Quite a change from previous week, molds developed, poorest of four samples.
3.	.87	Second best of the 4 samples and similar in quality to condition when first examined.
4.	.8	A slight mold growth.

It will be seen that sample No. 2 had a lower per cent of acid the second week than it did the previous week, which was probably due to the mold which had grown on the surface.

It is shown again that the best samples were those in the full containers.

Experiment 6.

Sample No.	Treatment of cream	% acidity	Condition of cream when 7 days old.
1.	.31% C.P.L.A. Full	.71	Best of the 4 samples.
2.	.31% C.P.L.A. 3/4 full.	.69	Second best sample, a little Oidium had grown on the surface. A little bitter taste.

Sample No.	Treatment of cream	% Acidity	Condition of cream when 7 days old.
3.	No acid full	.72	
4.	No acid 3/4 full	.74	Poorest of the 4 samples, a little Oidium grew on the surface. A little bitter taste.

There was not a great deal of difference in any of these samples. Those that were full were a little better than those that were not full, and the samples that had acid added to them were better than those to which it was not added.

These samples were refilled to the same fullness that they were started with and left for 7 days more.

When the samples were examined the second time they were in very poor condition. A great deal of mold and Oidium lactis had grown on the surface of those samples which were not full. The best two samples were the two that were full.

Experiment 7.

Sample No.	Treatment of cream	% Acidity	Condition of cream 7 days old.
1.	.37% C.P.L.A. Full	.8	Fair condition, best of the 4 samples.

Sample No.	Treatment of cream.	% Acidity	Condition of cream 7 days old.
2.	.37% C.P.L.A. Partly full.	.72	Moldy, Poor.
3.	No acid full.	.76	Medium fair.
4.	No acid partly full.	.77	Moldy, poorest of the 4 samples.

Churning Experiments.

The last three samples of this series of experiments were churned into butter, and the condition of the butter in relation to taste, was examined after standing in storage for some time.

Experiment 8. The cream used in this experiment was divided into 3 lots and treated as follows:-

1. Not pasteurized, but closed air tight.
2. " " , " exposed to the air.
3. Pasteurized, but closed air tight.

The same amount and kind of starter was used in each case. At churning time the quality of the different samples of cream was quite different, and the same relation existed in the butter samples when the cream was churned.

Table 5 shows the condition of the cream after it had ripened 14 days, and the condition of the butter

when it was first made and after being in the cooler for 65 days.

Sample No.	Condition of cream.	Taste of butter when made.	Taste of butter when 65 days old.
1.	Fair quality.	Fair	Somewhat old flavor, not fishy nor oily, but a little rancid. Scored 32 on flavor.
2.	Poor quality	Poor	Very strong, mold, rancid smell and taste. Unsaleable.
3.	Good quality	Good	Good clean butter flavor, Scored 39 on flavor. Could have been sold as first class butter.

Of the two unpasteurized samples in this experiment the one which was kept away from the air was considerably better than the one which was exposed to the air. The sample to which air was admitted was too poor for consumption. While sample No. 1 was better than sample No. 2, it was decidedly inferior to sample No. 3 which was pasteurized.

Experiment 9. The cream in this experiment was divided into two lots, and neither lot was pasteurized, but each had a starter added.

1. Closed air tight.
2. Open to the air.

These samples were churned when 7 days old.

Table 6 shows the condition of the cream and butter.

Sample No.	Condition of cream.	Taste of butter when made.	Taste of butter when 38 days old.
1.	No mold, sour, somewhat bitter acidity.63%	Fair	Some mold on top of butter. In lower part of package, flavor good.
2.	Heavy growth of mold and Oidium. Inferior to No.1	Inferior to No. 1.	Very strong, moldy and rancid taste, and smelled like soft cheese. Unfit for use.

In neither sample of this experiment was the cream or butter of a very good quality, but the better sample of the two was the one kept away from the air, especially, in the butter samples.

Experiment 10. The cream in this experiment was treated the same as in experiment 9, and was churned when 4 days old.

1. Closed air tight.
2. Open to the air.

Table 7 shows the condition of the cream and butter.

Sample No.	Condition of cream.	Taste of butter when 14 days old.	Taste of butter when 48 days old.
1.	Sour odor and taste.	Good butter. About the same as when churned.	Mold on top, some rancid.
2.	Similar to No.1	About the same as No. 1.	Some mold on top. Very rancid and strong.

The results in this experiment do not show a very good butter in either case, but sample No. 2 showed a greater deterioration when 48 days old.

Discussion of Results.

These experiments show that cream can be ripened with better results when the cream is kept free from mold contamination. In most cases where two samples were treated identically the same, except that the one was closed and the other was open, the sample in the closed container was the better of the two. In several trials, however, the two samples were very similar. In some cases both samples were of good quality, while in others, neither sample was of very good quality.

The fact that molds almost always developed on the surface of cream kept in the open containers and not in case of the closed ones, and that it was found that the

cream invariably kept better when excluded from mold contamination, seems to indicate that the poor quality of cream produced in these experiments was largely due to the development of these organisms.

Table 8 shows the relation between the mold growth in the open and closed containers.

Table 8.

Sample No.	Treatment of cream.	Open Container.	Closed Container.
1.	No acid	No mold	No mold
2.	.37% acid	No mold	No mold
3.	No acid	Mold	No mold
4.	.33% acid	Mold	No mold
5.	.58% acid	Mold	No mold
6.	.33% acid, partly filled	No mold	No mold
7.	No acid, " "	Mold	No mold
8.	.33% acid, " "	Mold	No mold
9.	No acid, " "	Mold	No mold
10.	.31% acid, " "	Oidium	No mold
11.	No acid, " "	Oidium	No mold
12.	.37% acid " "	Mold	No mold
13.	No acid " "	Mold	No mold

It appears quite evident from results as shown in this table and from the experiments reported, that molds have a deleterious effect on the quality of the cream.

In consideration of the results obtained from the samples churned into butter, we find that in each experiment the exposed sample of cream resulted in an inferior flavored butter when first churned.

A similar relation existed in the butter at an older age, but owing to the difficulty of keeping the butter samples free from mold contamination, the flavor of the butter in the last two experiments was, no doubt, affected by the molds which developed on the samples.

In Experiment 8 where sample No. 3 served as a check on the other two samples, it shows that not only are the molds and oidium lactis responsible for the production of rancid butter, but that some other factor appears to play an active part in the production of a rancid flavor.

The fact that sample No 3 did produce a very superior grade of butter as is indicated by the score, confirms the work reported in an earlier part of this Thesis.

The Effect of Chemical Pure Lactic Acid on the Keeping Qualities of Cream and Butter.

When fresh unpasteurized cream was used in studying the influence of ripening cream in a closed container, it was found at times that a disagreeable flavor developed in the cream, even when it was kept free from Oidium lactis and mold contamination.

Knowing that bacteria are one of the chief causes of deterioration in cream and butter, a possible explanation of this condition is the development of some type of fermentation which takes place in the cream before the lactic acid fermentation has a chance to develop and over come the development of the undesirable fermentation.

It has been stated before that it is very generally conceded by bacteriologist and practical butter makers that lactic acid fermentation is the desirable fermentation of those taking place in milk, and by the development of the lactic acid bacteria and the production of lactic acid, this fermentation is capable of inhibiting the development of undesirable bacteria.

The question then arises; is the development of the undesirable bacteria inhibited by the presence of the acid which is produced by the action of the lactic acid

bacteria, or is it due to the direct action of the bacteria themselves?

If the presence of the acid is the only factor which inhibits the growth of undesirable bacteria, then could this undesirable fermentation be prevented by the addition of a small amount of lactic acid to the cream while fresh?

To study this problem cream was acidified with Chemical Pure lactic acid, and compared with samples to which no acid was added.

The first 9 samples were held in closed containers and the remainder were held in open containers.

Trial I.

Sample No.	Treatment of cream.	Temp. Ripened.	Age of cream, days.	Condition of cream in relation to taste.
1.	No acid	77°	6	Old cheesy taste.
2.	.4% acid	77°	6	A little old tasting.

Trial II.

1.	No acid	76°	6	Poor quality.
2.	.2% acid	76°	6	Good quality.

Trial III.

1.	No acid	72°	6	Disagreeable taste.
2.	.45% acid	72°	6	Good cream, sweetish.

Trial IV.

Sample No.	Treatment of cream.	Temp. Ripened.	Age of cream, days.	Condition of cream in relation to taste.
1.	No acid	56°	6	Fair quality.
2.	.4% acid	56°	6	Sweetish, otherwise good.

Trial V.

1.	No acid	56°	6	Very good cream.
2.	.2% acid	56°	6	Good cream.

Trial VI.

1.	No acid	54°	6	Fair tasting cream.
2.	.45% acid	54°	6	Good cream.

Trial VII.

1.	No acid	Room	4	Fair tasting.
2.	.37% acid	Room	4	A keen acid taste.

Trial VIII.

1.	No acid	Room	4	Bitter taste. A great deal of gas.
2.	.33% acid	Room	4	Slightly bitter, Very little gas.
3.	.58% acid	Room	4	No gas. Wheyed off.

Trial IX.

1.	No acid	Room	7	Only fair cream.
2.	.33% acid	Room	7	Good sharp acid taste.

Trial X.

Sample No.	Treatment of cream.	Temp. Ripened.	Age of cream, days.	Condition of cream in relation to taste.
1.	No acid	72°	6	Mold on surface. Disagreeable taste.
2.	.45% acid	72°	6	Mold on surface. Good cream, sweetish taste.

Trial XI.

1.	No acid	54°	6	Slight growth of mold. Only fair cream.
2.	.45% acid	54°	6	Good cream.

Trial XII.

1.	No acid.	76°	6	Very poor.
2.	.2% acid	76°	6	Good cream.

Trial XIII.

1.	No acid	56°	6	Very good.
2.	.2% acid	56°	6	Good.

Trial XIV.

In this trial the cream was divided into three lots, and held at a temperature of 60° for 4 days, and then churned.

The samples were treated as follows:-

Sample 1. Check.
" 2. .21% of lactic acid added.
" 3. .33% of lactic acid added.

The condition of the cream in relation to flavor when churned was very similar in the three samples, and very little difference, if any, could be noticed in the butter when churned.

Table 9 shows the acidity of the samples when churned and the condition of the butter at different ages.

Table 9.

Sample No.	Acidity	Taste of butter when churned.	Taste when 8 days old.	Taste when 18 days old.
1.	.65%	Good	Good	A slight change. Little deteriorated.
2.	.66%	Good	Good	No change
3.	.61%	Good	Good. Scored 36.	No change

When the butter was examined 8 days after churning sample No. 3 was given a score of 36 on flavor and was the best of the three samples. Sample No. 1 was the poorest of the three, and it was considered good butter.

An examination of the samples when 18 days old showed a noticeable difference between samples 1 and 3. Sample 3 was equally as good as when first examined, but sample 1 showed a slight change in flavor and a slight deterioration in taste.

Discussion of Results.

The results of these trials indicate that the addition of a small amount of lactic acid to cream held at a temperature of from 70° to 80° F. does exert an influence by inhibiting the development of disagreeable flavors, but in the samples held at a temperature of from 50° to 60° the acid did not seem to have any material influence, as the non-acidified cream at this low temperature resulted in a cream of good quality itself.

The addition of a small amount of lactic acid to cream while fresh, and then allowed to ripen, produces a butter which retains its flavor longer than butter from cream to which no acid has been added.

Summary and Conclusions.

The object of the investigations reported in this Thesis was to study a few of the factors affecting the quality of cream before it is churned, and the quality of the butter within a short duration of time after it is churned.

Under ordinary farm conditions cream stands an unusually long time before it is churned and fresh cream is often added to that from the previous milkings without first being cooled. This brings about a condition which is very favorable for the development of the bacteria which are present in the cream.

Among the bacteria which find this condition favorable is the group which causes the lactic acid fermentation.

Practical butter makers and market experts have attributed some of the undesirable flavors found in butter to the over development of the lactic acid fermentation and the common practice of holding cream for some time after it has soured.

This, however, has been only an observation, and in order to secure more information on the question it was planned to study the problem experimentally. In the experiments planned for studying the relation of the over

development of the lactic acid fermentation to butter flavors, the character of the fermentation was controlled in all cases. Where the lactic acid fermentation was the only one taking place in the cream the results show, that no disagreeable flavor was developed which could be attributed to the action of the lactic acid. When cream fermented with a pure culture of B. lactis acidi was held for a period several times longer before churning than is ordinarily done the resulting butter was in all cases of good quality. The experiments indicate that the acid fermentation alone does not produce bad flavors in butter.

In studying the effect of Oidium lactis and molds on the keeping qualities of butter, it was found that these organisms produced flavors of a disagreeable nature.

The flavor arising from the action of the mold was a typical moldy flavor which is frequently found in old moldy butter. The flavor arising from the action of the Oidium lactis was very disagreeable.

Experiments were made to eliminate the development of the organisms Oidium lactis and molds by the exclusion of air. These results show that the quality of the cream was considerably increased and the keeping qualities of the butter was improved by preventing the

growth of these organisms in this manner.

Another factor which affects the quality of the cream and butter seems to be a type of bacterial fermentation which takes an active part in the production of undesirable flavors in cream and butter.

The results of the experiments show that the addition of a small amount of lactic acid to the cream when fresh will inhibit, to a large extent, the development of these undesirable fermentations.

While the addition of this acid improves the quality of the cream, it is doubtful if it would be practical in a commercial way at the present cost of C. P. lactic acid.

Conclusions may be drawn from the data as follows:-

1. The over-development of the lactic acid fermentation alone does not produce a poor grade of cream, and a butter which deteriorates rapidly.

2. Oidium lactis and molds are capable of causing undesirable flavors in cream and butter, and the quality of cream can be improved by preventing their growth.

3. It is entirely feasible to prevent the growth of Oidium lactis and molds by excluding the air from the cream.

4. Lactic acid, when added to fresh cream in small amounts, improves the quality of the cream by inhibiting certain types of fermentation and prevents the rapid development of "off flavors" in butter.

Acknowledgement.

The writer wishes to express his appreciation to Professor C. H. Eckles for his helpful suggestions given in the preparation of this Thesis. Part of the data used was taken from records of work done by advanced students in the Dairy Department under the direction of Professor Eckles. The experimental work which has been done by the writer is, in part, a continuation of the work started by previous students.

UNIVERSITY OF MISSOURI
COLUMBIA

DEPARTMENT OF HOME ECONOMICS

May 20, 1915.

Dean Walter Miller,
Graduate School,
Academic Hall.

Dear Mr. Miller:

I am returning under separate cover the thesis which you asked me to examine. I have approved same. I should like to call attention however to a conclusion drawn on page 61 which is unwarranted from the table above. This same conclusion might be drawn from some previous work in the thesis. There are several other slight discrepancies and some instances the conclusions seem to be drawn from too meagre data. I have not undertaken to correct the grammatical errors.

Very truly yours,

Louise Stanley

LS/R

Chairman Department Home Economics.

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