A STUDY OF THE EFFECTS OF SEVERAL FACTORS ON THE SEPARATION OF SKIM MILK FROM BOTTLED CREAM

THESIS FOR THE DEGREE OF M. S.

John Curtis McCan

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Thesis

Respectfully submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science.

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INTRODUCTION

It is generally conceded that, as a result of the intense advertising and sales promotion activities of the past several years, the attention of the consumer is being drawn more and more to the quality of the products which he buys. As a result, he is becoming more critical of the quality, or more discriminating in the lack of quality, of the goods which he is offered on the market. Producers and distributers are realizing that it is on the quality of their products that good will and permanent trade relations are attained with the public. Manufacturers are, therefore, attempting to reduce to a minimum the defects of the goods which they sell.

The separation of a layer of skim milk or serum at the bottom of the bottle of cream is a defect in the quality of cream of economic importance to every milk distributer. The consumer attributes the presence of this skim milk, even when an appreciable layer appears in whipping cream containing as high as 40 per cent butterfat, to a very low fat content.

Since the greater proportion of cream is sold as table, or coffee cream, and since practically all of this grade of cream is standardized by the distributer to approximately 20 per cent butterfat, correlation by the consumer of the amount of the skim milk layer with the fat content is especially undesirable, because it is believed that many factors other than fat content of the cream affect the volume of this skim milk layer.

Distributers in appealing to "Cream line" in selling milk have tended to attract the attention of a greater number of cream buyers to this defect in cream.

Insofar as could be determined, no experimental work has ever been reported on this problem. However, there are many current theories concerning the best methods of processing cream in the plant to reduce the prominence of this layer. Milk plant practices in processing cream are based largely upon results obtained from "Cream line" studies with milk and general observations in commercial plants. These methods, therefore, lack experimental foundation. Believing that experimental work attempting to verify or disprove the prevailing theories associated with this problem would be a contribution to the market milk industry, this study of the effects of several factors affecting the separation of the skim milk layer from bottled cream was undertaken.

REVIEW OF LITERATURE

Although no record of experimental work directly bearing upon a study of the separation of skim milk from cream was found in the literature, a considerable amount of study has been done, both in this country and abroad, relative to the separation of cream from bottled milk. Since there is little difference in the content of cream and that of milk other than fat to solids-not-fat ratio, the same factors responsible for fat separation should be involved. A review of the investigational work dealing with the factors being observed in this study of cream should, therefore, be of value.

Effect of Separation, Clarification and Agitation Several investigators have demonstrated that agitation by various means has an effect upon the physical condition of the milk.

Dahlberg and Hening (9) found that the viscosity of cream could be greatly altered by the condition of the milk fat at the time of separation. If the fat was in a semi-solid condition, the viscosity of the cream from both raw and pasteurized milk was increased. If the milk was separated without cooling, immediately following milking or pasteurization, the resulting cream was low in viscosity. These workers believe that the separator exerted its influence by its effect on the size and grouping of the fat globules.

Sharp (57) stated that there is a growing tendency to separate milk at lower temperatures in order to increase the body of the cream.

Numerous investigators have observed that violent agitation of milk reduces the volume of the cream layer to a slight extent. This is shown by the clarification studies of Hammer (22), Martin and Combs (37), Whitaker, Archibald, Shere and Clement (69), Dean (16), Dahlberg and Marquardt (11), McInerney (39), Judkins and Downs (31), Kilbourne (33), and by Lucas and co-workers (34) at this station.

McInerney (39) and Kilbourne (33) agreed that clarification reduced the cream volume from two to three per cent. Judkins and Downs (31) reported a slight decrease in cream line on both raw and pasteurized milk by clarification.

The work of Dahlberg and Marquardt (11) showed that the most favorable clarification temperature in regard to cream volume was 40° F. or below, whereas an increase in temperature above 40° F. resulted in a decreased cream layer. Dean (16) also observed that clarification of cold raw milk reduced creaming ability slightly, and that clarification at 145° F. made for further reduction. Clarification of milk held cold for several hours and then warmed to 85° F. generally showed an increase in creaming ability which entirely disappeared when the milk was pasteurized. Whitaker, Archibald, Shere and Clement (69) concluded that clarifying between 60° and 65° F. had only a slight effect, while temperatures above 80° F. gave a considerable decrease in cream volume. On the other hand Lucas and co-workers (34) showed that cold clarification between 55° and 70° F. reduced the cream volume about two per cent while clarification at 85 to 90° F. gave a reduction of one and one-half per cent. Martin and Combs (37) obtained a slight decrease in cream volume by clarifying

at 55° F. and no decrease at 90° F. They further stated that there was no decrease in cream volume when the milk was heated to 90° F. after clarification. They believed their results indicated that milk heated to pasteurization temperature after clarification would not have its creaming ability reduced due to the effect of the clarifier.

Trout (64) reached the conclusion that clarification of preheated raw milk had little effect on the creaming ability of the milk.

According to Hammer (22) separator clarification reduced the cream volume to a greater extent than did clarification with the ordinary machine.

The effect on creaming by pumping and agitating milk in vats has also received considerable attention. Whitaker and co-workers (69) have shown that pumping milk at temperatures between 60° and 120° F. reduced the volume of cream layer to a slight extent in some cases, while pumping raw milk below 60° F. and pumping pasteurized milk between 120° and 145° F. had no appreciable effect on the cream line. Martin and Combs (37) agreed that pumping milk cold had no effect while pumping hot milk showed but a small loss in creaming ability. Trout (64) stated that pumping pasteurized milk at 145° F. or between 80° and 90° F. gave a reduction of from two to five per cent in creaming ability, while between 115° and 135° the creaming ability was slightly increased, thereby recovering part of the loss due to pasteurization. Pumping raw milk at 60° F. and preheating to 85-90° decreased the creaming ability about 9 per cent. Rodhouse and Marquardt (55) agitated cold milk with a stirring device revolving at 170 R. P. M. without affecting the creaming ability.

In regard to agitation, Whitaker, Archibald, Shere and Clement (69) found moderate agitation during the 30 minute holding period at 145° F. apparently had no appreciable effect on the cream volume. At temperatures between 60° and 110° F. there was a decrease in volume. Martin and Combs (37) subjected hot milk to agitation for a long period of time. The milk showed a gradual loss in creaming ability, being relatively small for the first two hours but after that the loss amounted to 20 to 75 per cent. Trout (64) found that excessive agitation at temperatures between 105 and 135° F. did not materially reduce the creaming ability.

The influence of agitating cold milk has given contradictory evidence, and as Dahlberg and Marquardt (10) pointed out, this is probably due to the failure to separate the effects of aging milk from the effects of agitation.

Harding (24) discovered that milk received at the plant below 50° F., when heated momentarily to from 80 to 142° F. gave an increase in cream volume. When the receiving temperature was 50 to 60° F. similar heating usually produced no change. When the temperature of the milk was above 65° F. such heating resulted in a distinct decrease in creaming ability. Harding believed this indicated that agitation while cold affected the creaming ability of raw milk, but as Dahlberg and Marquardt (10) have pointed out it is probably due to re-creaming after storage at a cold temperature.

Whitaker and co-workers (69) reached the conclusion that the re-creaming of raw milk decreased the cream volume, but after one re-creaming the age of the milk was more important than the number of times it was re-creamed. The re-creaming of pasteurized milk also had a detri-

mental effect on the cream volume which these workers believe is of commercial importance at plants which bottle pasteurized milk after it has been allowed to cream.

Dahlberg and Marquardt (10) stated that cream layer volumes forming on raw milk set for creaming at 40° F. were usually reduced, if the original fresh milk had been previously cooled by a tubular cooler to 40° F. and held for 18 hours before remixing and re-setting. Very slow cooling of the fresh milk to 40° and 60° F., or rapid tubular cooling to 60° F., followed by aging at these temperatures generally increased the cream volumes. Violent agitation produced very slight increases in cream volumes of milk stored and agitated at 60° F. and very slight decreases at 40° F. Results with pasteurized milk showed that storage, prior to setting at any temperature, gave reduced cream volumes. These workers added, however, that there was considerable variation in the results of aging and agitating pasteurized milk. According to Hammer (22), when samples are re-creamed, there is usually a slight decrease in creaming ability with a less distinct cream line.

Effect of Pasteurization Since the pasteurization process has become almost universally adopted as a means of protecting the consuming public from the contraction of milk-borne diseases as well as an economic necessity, and since investigators are united in the opinion that pasteurization, as carried out at the ordinary exposures required by health departments, reduces the creaming ability of milk, this phase of the problem has received a great deal of experimental observation.

Whitaker and co-workers (69) found that heating milk to 145° F. for 30 minutes showed practically no decrease in the cream volume while in some cases an increase resulted. Pasteurization at 145° to 146° F. for 30 minutes reduced the cream layer an average of approximately 8 per cent, although the results showed considerable variation. Pasteurization at approximately 148° F. for the same time gave a decreased cream volume varying from 18.5 to 41.7 per cent with an average of 31 per cent. These investigators also stated that the reduction in cream volume due to pasteurization at 145° to 146° F. was not so great in the case of 24 to 36 hours old milk as in fresh milk due to the fact that old milk does not give as deep a cream line before pasteurization as does fresh milk. They further stated that pasteurization of old market milk tended to restore its creaming ability.

Trout's (64) results showed that pasteurizing at 145° F. for 30 minutes decreased the creaming ability of milk held at ice water temperature approximately 9 per cent.

Harding (24) found that the volume of cream begins to decrease measurably when the pasteurization temperature rises from 142° to 144° F. and as the temperature goes higher the decrease becomes rapidly greater, giving over 10 per cent reduction at 145°, 16.6 per cent at 146°, and approximately 40 per cent at 148° F. He stated that although pasteurization at 151° F. had reduced the cream volume more than 80 per cent, a distinct cream line was still formed. Harding also studied the effect of heating milk which was received at the plant at various temperatures. He observed that milk received at 50° F. or below, when heated momentarily

to from 80° to 142° F., gave an increased cream volume. Similar treatment of milk received between 50° to 60° F. usually gave no change while milk received above 65° F. gave a distinct decrease in creaming ability. Harding interpreted these results as indicating that the amount of cream which will develop on raw milk depends to a large extent upon the agitation it is subjected to while cold.

Hammer (22) found that pasteurization reduced the cream volume, but this reduction could be held quite small by careful temperature control, Kilbourne's (33) results under commercial conditions showed considerable variation but the cream volume was generally reduced by pasteurization.

Reid's (52) results show that pasteurization at 140° - 142° F. decreased the cream line to a negligible extent, 145° F. gave a 10 per cent reduction, 150° F. gave about 32 per cent, and 155° gave approximately 61 per cent reduction in cream volume. Judkins and Downs (31) observed that the higher the temperature to which the milk is heated the greater the reduction in cream line. They found a 2.8 per cent average reduction at 145.5° and 8.1 per cent at 147.5° F.

Martin and Combs (37) pasteurized milk at 144° to 145° F. for 30 minutes and rapidly cooled it over a surface cooler. This treatment gave a decrease in cream volume varying from 7 to 15 per cent.

Karstin (32) stated that heating milk at 140° F. (60° C.) caused the cream to rise more rapidly than in the case of raw milk. When the milk was held some time at that temperature or when heated to 149° F. (65° C.) or over, the cream rose more slowly than on pasteurized milk, while pasteurization at 145.4° F. (65° C.) for a few minutes gave about the same results as unheated milk.

According to Farrington and Russell (21), pasteurization at 140° F. for an hour gave normal creaming. Pasteurization at 155° F. for 15 minutes followed by cooling to 50° F. gave a reduced cream line which was less distinct and which could not be readily seen until creaming had continued some 48 hours.

Hammer and Hauser (23), who pasteurized milk in the bottle, stated that a high temperature of pasteurization decreased the creaming ability while an increase in creaming ability was induced by a slight exposure to heat. They used milk received at the college creamery in this experiment.

Burri (8) pasteurized milk for 30 minutes at every whole degree between 55° and 70° C. (131 to 158° F.). He found that creaming ability increased from 55° to 61° C. (131 to 141.8° F.) after which there was a decrease.

Dahlberg and Marquardt (10) have recently made an extensive study of the creaming of raw and pasteurized milk. The volume of the cream layers showed very slight decreases with increased pasteurization temperatures above 140° when held for 30 minutes, but these decreases, they state, were not of importance at 144° F. Pasteurization at 146° F. gave a decrease of 10 per cent, however, and higher temperatures brought about more rapid decreases in the depth of the cream layers. These workers used the milk temporarily heated to 135° to 140° F. as their check samples representing normal creaming. Dahlberg and Marquardt further demonstrated that the reduction of cream layer by pasteurization is a time-temperature relationship. Momentary heating to 150° F. for less than one minute did not affect creaming. Milk held at 140° F. for three

hours gave no noticeable decrease in cream layer volume and at 150° F. the influence of heat on creaming was very rapid during the first 30 minutes and was almost over in 90 minutes. It was further shown by Dahlberg and Marquardt that the creaming properties of the milk as altered by the temperature of storage, could be restored to normal by heating the aged milk from 135° to 140° F. and that pasteurization increased, decreased, or did not change the creaming ability of the milk, depending upon the history of the raw milk. They further state that re-pasteurization did not appreciably affect the creaming of milk.

<u>Effect</u> <u>of</u> <u>Standardization</u> Dean (16) found that when fresh raw cream and skim milk were mixed to give the original percentage of fat, the layer was sometimes deeper and sometimes shallower than the original. Mixing pasteurized skim milk with raw cream gave a greater loss in creaming ability than did mixing raw skim and pasteurized cream. Dean (17), in his study of viscolized milk, later standardized fresh 20 per cent raw cream to 4 per cent milk using fresh raw skim milk. This standardized milk gave 12.0 per cent cream volume as compared with 12.8 for the normal whole milk testing 4 per cent. Only one trial was run, however, as he was not studying the effect of standardization. Hammer (22) found a slight decrease in creaming ability as a result of remixing skim milk from separator clarified milk and cream by allowing the two liquids to run direct from the separator into the same container.

Dahlberg and Marquardt (10) studied the creaming ability of milk remade from skim milk and cream. They state the cream volume of the remade milk was equal to that of the original fresh milk providing the milk

was fresh and warm at the time of separation, that the skim milk and cream were re-mixed immediately, and that the re-made milk was set at once for cream rising. When the skim milk was cooled and stored before standardizing the cream volume was reduced. The detrimental influence of aged skim milk was overcome by heating the skim milk or the remade milk to 90° F. or above for a half hour or more prior to setting for cream rising. The aging of cream at cold temperatures did not give uniform results, but in general, it did not alter the volume of the cream layers. The reduced cream layers were, therefore, associated with the cold aging of the skim milk. These investigators concluded as a result of their work that all standardization of milk should be done before pasteurization to secure uniform cream volumes.

Palmer and Anderson (44) state that when skim milk is heated to 145° F. for 30 minutes and mixed with raw cream, no cream will rise, whereas, whole milk must be pasteurized at 155° F. or above to destroy completely the creaming ability. They add that raw cream mixed with raw skim milk will produce a normal cream layer.

<u>Effect of Method of Cooling</u> In 1890 Hills (29) found that cooling quickly resulted in a less loss of fat in the skim milk. Whitaker, Archibald, Shere, and Clement (69) stated that milk cooled in a tank or in vat pasteurizers from 145° to 50° F. showed a poor cream volume while cooling milk in a tank or vat pasteurizer to 110° or 120°, followed by rapid cooling below 50° F. over a surface cooler resulted in a good cream volume. Their tests also showed that cooling milk to a low temperature after pasteurization gave a deeper cream line since cooling below 45° F. showed a much better cream volume than cooling to

50° F. or above. Judkins and Downs (51) cooled milk in the vat and over a surface cooler. The reduction in cream line was 2.9 per cent and 1.5 per cent respectively.

Martin and Combs (37) also found less loss due to pasteurization when the milk was cooled over a surface cooler than when cooled in the vat.

Dahlberg and Marquardt (10) found that the cream layers on raw, fresh milk were not affected by tubular cooling while the cream layers on pasteurized milk were deeper when the pasteurized milk was tubular cooled. These layers were especially deeper a few hours after cooling. This indicated to the investigators that raw and pasteurized milk responds differently to tubular cooling.

Effect of Temperature of Creaming Investigators are all in general agreement that low temperatures of creaming or storage give deeper cream layers than do higher temperatures. Among the early investigators, Wing and Smith (72), Hills (29), Wing (71), Babcock (2) (3), Plumb (47), and Dean (14) all agreed that the lower the temperature the more efficient is the creaming as measured by the amount of fat left in the skim milk. Temperatures of approximately 40° F. and lower always gave more efficient creaming than higher temperatures and the creaming efficiency decreased with increase in temperature. Later, after the efficiency of gravity creaming had become less important because of the widespread use of the centrifugal separator and the depth of the cream line became the all important factor in cream rising, Hammer (22) noted that ice water temperatures gave big increases in cream volume over that at room temperature. Van Dam and Sirks (66) also stated that gravity separation is better the

lower the temperature. Martin concluded (36) that the storage temperature for bottled milk should be as close to freezing as possible. Trout (64) observed that the cream volume was slightly greater on raw milk creamed at 40° F. in air than at 32° F. in ice-water while 70° F. gave a much less cream volume. With pasteurized milk, 32° F. gave a greater volume of cream than 40° F. and 40° F. gave a much greater amount than 70° F.

Whitaker and co-workers (69) stored milk at 38° to 48° F. and at temperatures above 50° F. they found that the difference in favor of the colder temperatures was more marked in the case of the raw milk than in that of the pasteurized milk.

Dahlberg and Marquardt (10) calculated the cream volume for each per cent fat at 38° and 58° F. The lower temperature gave 4.2 per cent while the higher temperature gave only 2.8 per cent.

<u>Effect of Viscolization on the Creaming of Milk</u>   Hammer (22) in 1916 called attention to the fact that when milk is homogenized no definite cream layer is thrown up. Martin and Combs (37) were probably the first to give definite data showing the effect on the cream layer of milk made by mixing homogenized cream and skim milk. Milk testing 4 per cent was separated and the cream viscolized at 2500 pounds pressure before reconstructing. This reconstructed sample gave a much greater cream volume than the original raw milk. Previous to this, these workers viscolized a sample of milk at 2000 pounds and obtained a cream volume of 2 per cent as compared with the 10 per cent cream volume on the unprocessed check sample.

Dean (16) reported that the homogenization of a portion of the milk decreased the cream volume at all pressures but homogenization of the

cream alone gave an enormous increase in cream volume. Troy and Sharp (65) obtained similar results by homogenizing the cream and mixing with skim milk. Later Dean (17) upon further study with viscolized milk homogenized 20 per cent cream and constructed 4 per cent milk by mixing with skim milk. He also remade 4 per cent milk with 20 per cent unhomogenized cream. The former gave 71.2 per cent cream volume while the latter gave 12.0 per cent. He also demonstrated that in obtaining an abnormally deep cream layer, the greater the amount of cream taken off, the larger will be the volume of cream, and also the richer the cream viscolized the larger the volume of cream, although the cream volume does not correlate directly with the amount of fat viscolized. Dean concluded that the factor exerting the greatest influence on the volume of cream is not the amount of fat exposed to homogenization, but the amount of cream in which a given amount of fat is contained. He stated also that homogenization of whole milk destroys the cream layer entirely. Later Dean (18) stated that neither milk nor cream which had been homogenized will separate a cream layer on standing.

Holm (30) made the statement that practical experience has shown that in order to produce homogenized milk of sufficient stability to prevent fat separation, pressures of 2500 to 3000 pounds per square inch are required.

Effect of Addition of Salts Several attempts have been made to increase the depth of the cream layer in milk through the addition of various chemical compounds. Salts have generally been used. Babcock (3) found that by adding 0.1 per cent caustic soda, milk creamed rapidly and efficiently leaving only about one-third the normal amount of fat in the skim milk.

Wool, Babcock, and Russell (74) added lime to milk in an attempt to restore the viscosity to pasteurized milk. This was not successful for the casein flocculated in tiny masses. However, by adding cane sugar to this, thereby developing viscogen, they restored the viscosity of the pasteurized milk.

Hammer (22) found that large amounts of viscogen increased the cream layer until the whole material had the appearance of cream. His results were not uniform, however, for in certain trials, small amounts of viscogen gave better results than large amounts. Van Dam and Sirks (66) stated that both alkali and acid decrease the velocity of separation with fresh milk but in old milk alkali had very little influence. Dean (19) recently showed that the addition of soluble calcium salts to milk which had lost some or all of its creaming ability gave no restoration of creaming and that when calcium was added in quantity there was further loss. Sodium citrate produced similar effects though not as detrimental. Rahn (49) (50) and Dahlberg and Marquardt (10) found salts added in sufficient quantities hindered cream rising. Troy and Sharp (65) found milk made tenth-normal with sodium hydroxide and creamed at 0°C. gave a 95 per cent cream volume.

Effect of Addition of Gelatin Rahn's (50) results showed that the addition of gelatin leads to a quicker creaming and a deeper layer of cream and a very complete separation of the fat in the cream. Other colloidal substances hastened the separation of cream from raw milk and restored the creaming power of cooked milk. Van Dam and Sirks (66) also observed that salep and gum tragacanth considerably increased the separation of cream from milk, and that gum arabic, starch, and gelatin had a similar though not so pronounced effect.

Effect of Addition of Milk Solids Dean's (16) results showed that the addition of serum solids in the form of plain condensed skim milk and skim milk powder gave no increase in creaming ability either to raw or pasteurized milk. Dahlberg and Marquardt (10) by diluting normal milk with distilled water or the addition of skim milk, and condensed skim milk agreed that changes in serum solid content does not affect cream rising.

THEORETICAL ASPECTS OF CREAM RISING

Along with the results obtained from the experimental work that has been done on cream rising have come many attempts to explain these results on a scientific basis. While many of the conclusions explaining cream rising from a physico-chemical standpoint have been drawn with a consideration of a single factor involved rather than explaining the phenomena on a broader basis, a study of these theoretical aspects should be valuable to any student of this problem. It has always been agreed that the fundamental cause of the rise of fat on normal milk to form a cream layer is, of course, the difference between the specific gravity of the fat and the plasma.

Fibrin Theory Probably the first theory of cream rising was the fibrin theory presented by Babcock (3) in 1889. He noted the clumped fat globules and believed that milk contained a substance identified with blood fibrin, capable of spontaneous coagulation, the clots of which entangled the fat globules and, being heavy, prevented an efficient creaming. Babcock explained the efficiency of low temperature creaming and the addition of caustic soda on the grounds that the coagulation of the fibrin, which would cluster the fat globules, was prevented.

<u>Fat Clumping</u> A few years later Babcock and Russell (4) observed that fat clumping was absent in milk which did not cream well due to high temperature pasteurization, whereas, clumping was present in milk which had creamed normally. They, therefore, reversed the former theory relative to clustering, stating that clumping of the fat globules was necessary in cream rising. Moreover, Hekma (25) has also shown that normal milk does not contain fibrin. Henseval (26), in studying the differences in rapid and slow creaming milks, also noted that the former had large fat globules often in clumps, while in the latter, grouping of the fat globules was rare. Since that time Dahlberg and Marquardt (10) (11), Van Dam and Sirks (66), Wool, Babcock and Russell (74), Rahn (49) (50), and Troy and Sharp (65) after making specific study of the relation of clustering to cream rising reached the conclusion that clustering of the fat globules is essential to cream rising. Hammer (22), Lucas and co-workers (34) and Reid (52) have associated clumping with cream rising in explaining their results in processing milk and ice cream mixes. Troy and Sharp (65), applying Stokes law to the velocity of rising of the individual fat globules, reached the conclusion that the globules rise so slowly as individuals that it would require many times the ordinary creaming period for them to form the cream layer. With the aid of a microscopic creaming cell these investigators observed clusters large enough to account for normal cream rising. Dahlberg and Marquardt (10) found that the fat clusters of normal creaming milk were large enough to be seen easily with the unaided eye when observed in a creaming cell. These workers stated that the larger clusters were seen to rise as fast as one inch per minute.

Rahn (50), observing the creaming process through a horizontal microscope, found raw milk contained fat globules grouped in large and small masses while in heated milk the individual globules were quite distinct. The larger masses rose much faster than the individual globules. Rahn, therefore, accounted for the differences in cream rising of raw and heated milk in this way.

Rahn (49) (50), Van Dam and Sirks (66), and Sirks (59) stated that substances accelerating and increasing cream formation such as gelatin, tragacanth, saleb, and soforth, increased the aggregation of the fat globules. Troy and Sharp (65) found that treatments favoring creaming also increased the clumping tendency, and observed that viscogen and sodium hydroxide which gave very deep cream lines threw the globules into extremely large clusters.

Bancroft (5) suggested the importance of clumping in cream rising in explaining that the more rapid creaming in deep than in shallow pans is due to the finer globules of butterfat being caught by the coarser ones and swept upwards, the concentration of the coarser globules becoming great enough to have a filtering action.

On the other hand, Palmer, Hening, and Anderson (46), with the aid of the microscope, found no relation between creaming and fat clustering, and therefore, reached the conclusion that fat clumping was not an important factor in cream rising. As Troy and Sharp (65) have pointed out, their conclusion was probably due to the difficulty of finding clumps in their method of study.

According to Palmer and Anderson (45), the size of fat globules due to breed differences has no effect on cream formation.

Babcock and Russell (4), Rahn (49) (50), Reid (52), and Troy and Sharp (65) all explained the effect of pasteurization on creaming as due to the breaking up of the fat clusters. Troy and Sharp (65) stated that in pasteurized milk which creams normally the fat globules which are broken up by pasteurization re-clump, but the detrimental effect on creaming is caused by heating the milk to the extent that the globules do not clump again on cooling.

Troy and Sharp (65) believed that too much agitation while the milk is being cooled breaks up the clumps and results in poor creaming. McInerney (39), Lucas and co-workers (34) and Hammer (22) accounted for the reduction in cream line on clarified milk as due to the breaking up of the clusters. Dahlberg and Marquardt (11) believed that this effect of clarification at a high temperature is due to both a breaking up of the clusters and a reduction in size of the original globules. Hammer (22) believed separator clarification breaks up clusters to a greater extent than ordinary clarification and that the slight decrease in cream line due to agitation is a result of a slight modification in the groupings of the globules. Dahlberg and Hening (9) stated that the separator exerted its influence on viscosity by its effect on the size and grouping of the globules. Rahn (51) believed that plant operations which agitate the milk tend to split the globules, but only to a slight extent, and also, stated that when the temperature is not over 63° C. (145.4° F.) in certain cases of agitation, there is a tendency to clump the fat globules.

Hammer (22) held that the breaking up of clusters through agitation was responsible for the slight decrease in creaming ability which he observed when re-creaming milk.

Troy and Sharp (65) attempted to explain the increase in creaming ability of milk pasteurized at a low temperature observed by Hammer (22), Hammer and Hauser (23), and Whitaker, Archibald, Shere and Clement (69). They observed that if milk is agitated, especially at near room temperature, the clumps of fat globules are broken down and these do not readily form again even if the milk is cooled to a low temperature. By carefully pasteurizing this milk and cooling rapidly to a low temperature the large clumps were again formed and the milk gave an improved cream layer as a result of pasteurizing. They, therefore, believed an increase in cream volume as a result of pasteurization indicates that the raw milk has been treated in such a way during or after cooling so as to break up the clumps of fat globules or to prevent their formation.

Troy and Sharp (65) found that the rate of clustering of the fat globules in fresh raw milk depended upon the rate of cooling which probably explains why rapid cooling increases the creaming ability of milk.

The same investigators (65) concluded that for a given percentage of fat the depth of the cream layer depends primarily on the clustering and condition of the fat globules, large, irregular, stable clusters forming deep layers while compact, spherical, weak clusters forming shallow layers. Deeper cream layers at lower temperatures are, therefore, explained on the basis that the rigidity of the clusters lessen with increase in temperature, permitting closer packing of the fat at the warmer temperatures.

Adsorption   It is well known in colloidal chemistry that emulsions are stabilized by the adsorption of material at the interface. Since milk is an emulsion of fat in water containing various substances which are

capable of being adsorbed, it is believed by many investigators, that the fat globules are surrounded by an adsorbed membrane which probably plays an important role in the stability of the fat or, to be more specific, in cream rising. Holm (50) after reviewing the results of various investigations, has concluded that specific adsorption and hydration changes at the globule-serum interface exert a marked effect upon the rates of rise of globules and perhaps explains the marked variations in some milks with respect to cream rising.

Palmer (45) stated that the more or less permanent dispersion of the fat globules in milk are due apparently to a concentration of the plasma colloids at the globule-plasma interface and that the relative proportion of the colloids adsorbed - calcium caseinate, lactalbumin, lacto-globulin, and calcium phosphate - should be in proportion to their ability to lower surface tension rather than in the proportion in which they occur in milk. Palmer added that this property of the milk colloids has never been measured.

According to Dean (18), the clumping tendency of the fat globules shows there is an attraction between them, which he believed, is probably best explained as an interfacial tension effect on which he enlarges somewhat as follows: Fat and water interfaces give rise to relatively high interfacial tension. Since this free energy can be reduced by a decrease in surface area made possible by coalescence of the fat globules, the globules would ultimately separate into a layer of fat and a layer of water, but in milk there are opposing forces which counteract this inter-globule attraction. The interfacial energy is also reduced by the adsorption of surface tension active substances present in the

milk plasma. Adsorption occurs reducing the free energy, although this energy is not entirely done away with since the fat globules in normal milk tend to agglutinate into clumps due to the slight attraction remaining. No coalescence takes place, however, Doan stated, either because the tendency is so greatly overcome that it is insufficient to do more than attract the globules together, or more logical, he believed, because the adsorbed layer prevents an intimate contact of the globules.

Prieger (48) reached the conclusion that the fat particles are surrounded by protein-like films. Titus, Sommer and Hart (62) concluded after making a study in an attempt to determine the nature of the adsorbed layer, that the adsorbed layer was related with, if not identical to, casein, although slight variations in chemical properties indicated a possible contamination with some unknown substance. Zoller (75) also believed the fat globules are protected from coalescing by a protecting coat of milk proteins. Rahn (49) stated that it would appear as though milk contains a colloidal membrane, which accounts for the aggregation of fat globules and that this membrane is destroyed by heat. Rahn (49) and Sirks (59) both believed that the beneficial action of gelatin, tragacanth and similar substances in promoting cream rising is due to their adsorption which promotes the sticking together of the globules. Van Dam and Sirks (66) believed that in the case of old milk the adsorbed protein hinders creaming, although there was no effect on fresh milk.

The fat globules of milk ordinarily carry a slight negative electrical charge due to the adsorption of salts and dissolved proteins (59). Several investigators have added electrolytes to milk in an attempt to

promote greater clumping and, therefore, better creaming through a change in the electrical charge on the globules.

Zeller (75) stated that a protecting coat of protein gives the globules an electrical charge which can be destroyed by the addition of an agent of unlike charge or by the denaturization of this membrane material through some physical agency such as heat or freezing.

Sirks (59) concluded that while the magnitude of the charge on the globules of various samples of milk varied irregularly, he found no relation between this charge and velocity of clumping.

In a very recent study of the effect of the electrical charge on cream rising Sommer and North (61) found an increased cream layer volume under conditions causing a decrease in the negative charge on the fat. Aging, or heating to 142° F., decreased, while heating to 142° F. increased the charge. Calcium salts or iron chloride decreased, while sodium citrate and di-sodium-phosphate increased, the charge. These investigators explained the increase in viscosity resulting from aging as due to a decrease in the electrical charge on the fat globules, thus permitting them to cluster.

Babcock (3), Hammer (22) and Troy and Sharp (65) found greater creaming only when relatively large amounts of a strong electrolyte such as sodium hydroxide was used while Dahlberg and Marquardt (10) pointed out that failure to obtain success with small amounts is probably due to the affinities of several milk constituents for the ions added which may interfere with their adsorption on the fat.

Dahlberg and Marquardt (10) presented a theory of cream rising in which they explain the clustering of the globules as due to a decrease

in the electric charge due to a change in the calcium ion concentration. According to these investigators "The most plausible theory of the cause of the fat globules forming into clusters was that this aggregation was caused by the presence of a maximum quantity of calcium ions, which, by imparting some positive charges to the weak, negatively charged fat globules, created an electrical affinity between the globules. At warm temperatures the Brownian movement caused by kinetic energy was considered to be sufficient to hold the globules apart which would account for the better creaming near 40° F. or below. Both prolonged holding at the cold temperature of 40° or pasteurization at 145° F. or above precipitated calcium as colloidal salts and hence diminished the creaming powers of the milk. In the former case the calcium could be redissolved by increased temperature, while in the latter case the reaction was not reversible which agreed with the observed change in creaming."

There is a difference of opinion, however, as to whether soluble calcium is precipitated at pasteurization temperatures especially in quantities large enough to account for the effects of pasteurization on creaming.

Palmer (42) and Van Slyke and Bosworth (67) believed that the calcium phosphate of milk is present as neutral di-calcium phosphate. Palmer (42) concluded that the partial fixation of this di-calcium phosphate during heating is due to its precipitation as colloidal mono-calcium phosphate.

Magee and Harvey (35) found about 26 per cent of the total calcium oxide was in the diffusible form in fresh milk, about 20 per cent in milk pasteurized at 158° F. for 30 minutes, and about 15 per cent in boiled

milk. The losses in soluble calcium after heating were believed to be due to the formation of colloidal tri-calcium phosphate from the soluble di-calcium phosphate.

The work of Rupp (56), Mattick and Hallett (38), and Bell (7) indicated only a very slight precipitation of calcium at pasteurization temperatures up to 155° to 160° F.

Dean (19) believed his results lend evidence against the calcium ion precipitation theory for he found that the addition of soluble calcium salts to milk which had lost some or all of its creaming ability gave no restoration. Calcium added in quantity gave further loss. Study with the aid of a creaming cell showed that calcium acetate and sodium citrate both interfered with fat clumping, the calcium salt being most active.

Sommer and Herth (61) believed that the increased viscosity following the addition of viscogen is due to the decrease in the electrical charge brought about by the calcium salts in the viscogen.

The results obtained by Hening and Dahlberg (27), working with salts in ice cream mixes, also gave support to the calcium ion theory. These workers found that by adding the salts before homogenizing, sodium salts (sodium citrate and di-sodium phosphate) decreased clumping while calcium lactate increased clumping as a result of the homogenization process. Potassium oxalate, which removed the soluble calcium, gave mixes free from clumps, therefore, indicating to these investigators that the presence of calcium salts is essential in securing clusters in homogenized mixes. Salts added after homogenization, however, produced no effect. These investigators believed that the sodium and potassium

salt content in the mix made from normal dairy products varies sufficiently to affect the whipping properties of the mix, due to their effect on clumping. Tracy and Ruehe (63) also believed that there is sufficient variation in the calcium content of cream sometimes sufficiently great to cause a calcium excess, which brings about feathering in homogenized cream of low acidity. They suggest that this variation in the calcium content is probably due to feed and period of lactation. Sommer and Hart (60) have also shown that the salt balance in milk varies enough to have an influence upon the heat coagulation of evaporated milk.

The Relation of Various Components to Cream Rising There has been considerable evidence presented to prove that the properties chiefly influencing cream rising are inherent in the plasma rather than in the fat as shown by the work of Babcock (3), Wool (73), Van Dam and Sirks (66), Palmer, Hening and Anderson (46), and Martin and Combs (37). Babcock (3) in 1889 suggested, and Wool (73) in 1895 concluded, that the physical changes in milk and cream brought about by heat are due to the unstable character of the nitrogenous or mineral constituents. Palmer, Hening and Anderson (46) also found that the plasma phase was affected chiefly by pasteurization and Palmer (43) stated that the presence of fat globules in whole milk actually seems to protect the milk against the detrimental effects of pasteurization. Rahn (49), however, stated that the effect of pasteurization on creaming appears to be due to alteration in the fat globule groupings and not to changes in other constituents for he found, just opposite to Palmer, Hening and Anderson's (46) results, that if the skim milk was separated, heated at 147° F. (65° C.) and then remixed, that normal creaming occurred.

Dahlberg and Marquardt (10) pointed out that since the action of pasteurization in reducing the cream layer was, according to some results, due to the effect of heat on the serum, and since others have demonstrated the destruction of fat clumps by heat, it is evident that the serum in turn affects fat clumping.

It has been assumed by many that the effect of pasteurization is due to the precipitation of albumin. Rahn (49), however, stated that heat does not weigh the fat globules down with coagulated albumin. This theory is supported by Troy and Sharp (65) who pointed out that there is not enough albumin present to exert this influence. Whitaker, Sherman and Sharp (70) take a similar point of view, explaining that if the albumin was coagulated by pasteurization there would be an increase rather than a decrease in viscosity and, further, that the maximum decrease in viscosity due to heat occurs below the coagulating point of albumin. It has been shown by Rupp (56) that no coagulation of albumin takes place at 145° F., but at 150°, 5.75 per cent is rendered insoluble. The amount precipitated increases with increase in temperature as 12.75 per cent is coagulated at 155°, and approximately 31 per cent at 160° F.

In an attempt to determine which constituents of the serum were influential in cream rising phenomena, Palmer, Hening, and Anderson (46) working with synthetic milks, concluded that calcium caseinate, although the most prominent colloid in milk, hinders cream rising, that the whey colloids, lactalbumin and lacto-globulin, promote cream rising, and that these effects are enhanced by pasteurization. Removal of mineral salts and lactose, in a large measure, by dialysis was found to have no detrimental effect on creaming. These conclusions also led them to suspect that the detrimental effect of pasteurization was due chiefly to the ef-

fect of heat on calcium caseinate. These workers pointed out that in their belief, questions involved in cream rising do not include that of emulsion stability for, while there may be differences between calcium caseinate and whey proteins concerning emulsion stability, both kinds of proteins are to be considered excellent emulsifiers.

The Relation of Viscosity to Creaming Many investigators have noted the effect of pasteurization on viscosity and some workers have attempted to explain changes in cream rising as due to changes in viscosity. Dahlberg and Hening (9) in their viscosity studies of milk and cream observed that the viscosity increased with fat content, especially 20 per cent and above, that pasteurization decreased the viscosity of milk slightly and cream greatly, and that the effect of aging on viscosity was inhibited in a large measure by pasteurization. Babcock and Russell (4) and Reid (52) maintained that the reduction in viscosity in pasteurization is due to a breaking up of the fat clumps. Sherwood and Smallfield (58) who studied the clumping in cream and ice cream on aging, concluded that the increase in viscosity is attributable to a greater grouping of the fat globules with its resulting fixation of a part of the free serum. Wool (73) and Everson and Ferris (20) have shown that the viscosity is decreased at ordinary pasteurization temperatures, but at considerably higher temperatures (75-90° C.) the viscosity is increased. Rahn (49) stated that there is no simple relation between viscosity and rate of creaming. Troy and Sharp (65), by diluting milk containing normally clumped fat with water and securing the same volume of cream as in the undiluted check sample, demonstrated the apparent lack of correlation between viscosity and cream formation.

Nevertheless, Palmer and Anderson (45) stated that the viscosity of raw milk is a good index of its creaming ability and that viscosity can be used as an explanation of changes in cream layers caused by the temperature of creaming and the concentration of plasma solids in the milk. They added, however, that viscosity is only a minor factor in determining the cream layers on pasteurized milk and that the fundamental factors exerting their influence remain to be determined.

Whitaker, Sherman and Sharp (70) observed that the viscosity of skim milk was reduced on pasteurization and, therefore, maintained that the breaking up of fat clumps is not the only cause of the decrease in viscosity of whole milk.

Holm (30) interpreted the literature as indicating that although viscosity is usually greater in cases showing increased cream volumes, there seems to be little doubt that in most cases the viscosity is a result of the physical state rather than a reason for and an explanation of its cause. The increased viscosity, often noticed, he believed, is due to larger aggregates brought about by favorable conditions at the interfaces.

The Theory of Viscolization Homogenized milk or cream, Dean (18) stated, will not separate out a layer of cream whether the fat globules are clumped or unclumped. Homogenized milk or cream, diluted with skim milk or whole milk yields a cream layer, the volume of which becomes greater as the degree of fat clumping increases. Samples containing unclumped fat diluted with skim milk, however, gave no cream layer.

Hammer (22) believed that the loss of creaming ability of homogenized milk is due to the breaking up of the fat globules into very small masses which, having less tendency to rise than the original globules, remain evenly distributed as does the extremely small or residual fat globules of ordinary milk. Bateman and Sharp (6) and Troy and Sharp (65) have observed that in homogenized milk the globules are not clumped and explain the stability of the fat emulsion in milk on this lack of clumping. Dean (17) stated that at ordinary pressures milk does not give rise to "Visco-clumps" of fat until the concentration of fat is in excess of eight per cent which agrees very closely with Hening's conclusions (26).

Mortensen (40), Troy and Sharp (65), and Dean (17) (18) have all found that viscolization or homogenization of cream greatly reduced the size of the globules and resulted in the formation of large clumps, while Dahle and Martin (13), DePew (15), and Reid and Moseley (53) agreed on the same results in ice cream mixes.

The greatly increased volume of cream secured by diluting homogenized cream with milk is due, according to Dean (17), to the looseness of packing of the very large clusters of fat globules. A possible reason that the amount of cream in which the fat is contained is more important than the amount of fat, itself, in increasing the cream volume of mixed homogenized milk is that homogenization sets up a structure among the "Visco-clumps" of fat in the cream and the volume of this structure depends on the available space at the time of homogenization and further, that this structure maintains, to a certain extent, its volume upon di-

lution of the cream with normal whole or skim milk.

Doan (18) has found that the clumping of homogenized milk and cream is greatly augmented by increases in the fat content, which disagrees with the results of Mortensen (41) who concluded there was apparently no definite relationship between fat content and size of clumps. Mortensen observed a great difference in clumping of different lots of cream containing the same per cent of butterfat and handled in as nearly the same way as possible.

According to Doan (18) and De Pew (15), increased pressures result in a greater dispersion and increased clustering of the fat globules, which is to be expected, although these findings are in disagreement with those of Reid and Skinner (54) and Mortensen (41).

Doan (18) heated the milk plasma at 180° F. for 10 minutes, after which the plasma and cream were remixed and homogenized. He found reduced clumping which he associated with the results of other workers who have shown that heating the plasma reduced the fat clumping and creaming power of normal milk.

Webb and Holm (68) in their study of the feathering of homogenized cream, have suggested that the clumping of fat globules is a result of variation in electrical potential on the fat globules. Doan (18) believed that if this were true, variation in hydrogen ion concentration would cause differences in clumping but found that increased acidity apparently had little effect and concluded, therefore, that the electrical potential on the globules had little effect. Tracy and Ruehe (65), however, observed that any treatment causing the fat to clump increased feathering,

and finding that preheating cream and homogenizing at a high temperature (175° F.) removed all tendencies to feather, explained this as due, partly at least, to the precipitation of soluble calcium salts. It was found by Dahle and Barnhart (12) that pasteurization and homogenization of ice cream mixes at 170 and 180° F. resulted in lower viscosity and greatly reduced fat clumping as compared with 150° F. It was also shown that the temperature of homogenization was more important than the temperature of pasteurization. Holm (30), however, explains that the magnitude of forces of viscosity and interfacial tension is usually less at the higher temperatures, and, since these are forces that must be overcome by homogenization, the degree of dispersion increases, within certain limits, with increases in temperature. Tracy and Ruehe (63) also obtained greater clustering by homogenizing at 125° F. than at 145°.

Doan (18) found that the ratio of the amount of serum solids to fat in the processed mixtures is a limiting factor in fat clumping and stated that there is a critical ratio above which no clumping is obtained but that owing to uncontrollable and undetermined factors this critical ratio cannot be established at a definite value. By diluting with water, thus reducing the proportion of serum to fat, Doan, was able to secure clumping in normal low fat milk.

Doan (18) suggested the following as a partial explanation of the phenomena of fat clumping of homogenized mixtures: "When milk or cream is homogenized, the normal fat globules are divided into from 10 to 100 individuals. This action creates an enormous new surface area which, of course, represents a considerable increase of interfacial tension and which in turn creates an increased attraction between globules and a

great activity in the adsorption of the surface active plasma colloids. If the fat content of the product homogenized is low, the divided globules will be relatively far apart and before any noticeable amount of clumping can occur, the interfacial tension of the globules has been practically neutralized by diffusion of the plasma colloids to the surface and adsorption. If, however, the fat content of the product is high, the globules are relatively close together and clumping occurs before the adsorption has progressed far enough to reduce greatly the interglobule attraction. In this case further diffusion of the colloids to the interface and adsorption will be much greater on the outer surface of the clump than on the inner surfaces. This will tend to leave more or less undisturbed the attraction between the globules forming the cluster or clump and may explain the comparative stability of the clumps. (Dean (17) has demonstrated that pasteurization does not destroy the clumps to any great extent.) It must be assumed that even in the richest creams enough adsorption takes place instantly, from the immediately surrounding plasma to prevent a coalescence of the globules.

"It might be inferred that in the case of homogenized milk (low fat content), where no clumping is produced, the individual small globules present would clump on aging just as the individual large globules do in normal milk. This is not the case, however, and the only apparent explanation seems to be the much greater Brownian movement in the case of the smaller globules which more than overcomes the inter-globule attraction."

In explaining the plasma solids-fat ratio effect Dean (61) continues: "Increases in the amount of plasma colloids would mean more available sur-

face active material in the immediate vicinity of the newly formed surfaces after homogenization which would, of course, tend to overcome more quickly the free surface energy created and prevent the attraction between globules from being so great. In such cases grouping would be greatly reduced in amount, if not entirely prevented, depending on the colloid concentration.

"The increase of homogenizer pressure was found to favor clumping and since such increases in pressure create smaller globules, more fat surface and a greater total increase in the amount of interfacial tension, the immediately available plasma colloids, would be more quickly exhausted without reducing the inter-globule attraction to so low a degree as would occur with lesser pressures."

De Pew (15) explained the increase in viscosity of homogenized ice cream mixes as due to the greater dispersion of the fat and the increase in fat surface exposed. Mortensen (40) stated that the increased viscosity is due to the increased surface with the resulting fixation of a part of the serum and also to the inclosure of serum within the clusters. Bateman and Sharp (6) found homogenization increased the viscosity of milk when the clumps were practically absent.

<u>Miscellaneous Considerations</u> There are a number of miscellaneous considerations that may possibly be of value in a study of cream rising.

Holm (30), after reviewing the literature, stated that the physical state of the fat when creaming takes place influences the rate, that if milk is held cold until the fat becomes solid before creaming is permitted, the rate is decreased and best results are obtained with a medium or low temperature with the fat in a semi-solid condition.

According to Van Dam and Sirks (66) the surface tension between the milk fat and the milk plasma had no effect on separation.

Dahlberg and Hening (9) have shown that milk and cream decreases in surface tension with an increase in fat and usually decreases in surface tension with aging.

It has been reported by Dahlberg and Marquardt (10) that the specific gravity of milk is not associated with creaming.

Hammer (22) believed that the greater difference in specific gravity of the fat and serum at higher temperatures than at ice-water temperatures is responsible, in part at least, for the closer packing of the fat clusters and, therefore, a shallower cream line.

The first theory attempting to explain why creaming was increased by rapid cooling was advanced by Arnold (1) who stated that water is a better conductor of heat than fat, and therefore, when the temperature of the milk varies either up or down the water in the milk changes in specific gravity more rapidly than the fat and this tends to increase the difference in specific gravity between the two when the temperature is falling.

Holm (50) has noted that most investigators have found that exhaustiveness of creaming is associated with cream volume, and stated that though the apparent cream volume is not necessarily an index of the amount of fat that has risen in the cream, in general the most complete creaming is associated with the deepest cream layers.

PURPOSE OF THE EXPERIMENT

The purpose of this experiment was to determine the effect of the following factors on the separation of skim milk from bottled cream:

1. Effect of temperature of separation of milk
   (1) Fresh milk
   (2) Old milk stored at low temperature
2. Effect of heat treatment of milk prior to separation
3. Effect of pasteurization of cream
   (1) Raw standardized cream
   (2) Cream secured from pasteurized milk
4. Effect of high temperature of pasteurization on the milk as compared with the cream used in standardization
5. Effect of standardizing pasteurized cream with milk processed as follows:
   (1) Raw whole milk
   (2) Pasteurized whole milk
   (3) Skim milk secured from pasteurized milk
6. Effect of the following factors involved in standardization:
   (1) Separating high test cream and standardizing back as compared with separating low test cream
   (2) Standardizing cream with whole milk as compared with standardizing with skim milk
   (3) Standardizing before as compared with after pasteurization
   (4) Temperature of standardization
   (5) Standardizing cream while fresh as compared with standardizing after storing 24 hours at low temperature

7. Effect of agitation of cream after storing

8. Effect of rapid as compared with slow cooling of cream

9. Effect of temperature of creaming

10. Effect of time of creaming

11. Effect of viscolization of raw cream

    (1) Temperature of viscolization

    (2) Pressure of viscolization

    (3) Viscolizing high test cream and standardizing with unviscolized whole milk

    (4) Viscolizing only a portion of the cream

12. Effect of addition of salts

    (1) Sodium carbonate

    (2) Calcium chloride

    (3) Di-calcium phosphate

    (4) Sodium citrate

    (5) Mono-calcium phosphate

13. Effect of addition of gelatin to the milk before separation

14. Effect of addition of evaporated milk, skim milk powder, and casein

PLAN OF EXPERIMENTAL WORK

Source of Milk Supply

In order to eliminate large variations in the composition and previous treatment of the milk from day to day, and, in order that the results of this work should apply to commercial conditions insofar as possible, it was thought desirable that mixed milk should be used. The milk for these experiments was, therefore, obtained each day from the same 300 gallon Pfaudler pasteurizer in the college creamery after it had been filled with milk delivered by the same group of milk patrons. This mixed milk varied in temperature from 55° to 65° F. when received and the fat content varied from 3.4 to 3.8 per cent.

Processing

The greater part of the processing was carried on in the experimental laboratory. However, when milk and cream was needed in amounts too large to handle conveniently in the laboratory, this part of the processing was done in the creamery.

Separation For the major part of the experimental work, where only small lots of cream were required, the milk was separated in the experimental laboratory using a De Laval, No. 12, electrically driven separator. Preliminary runs were made to determine the proper cream screw setting to make in order to obtain approximately the percentage of cream desired at the various temperatures. The separator supply tank was filled with milk which had been heated to the proper temperature in the pasteurizer. Approximately one gallon of milk was allowed to run through the machine in order to temper the separator before saving the samples of cream and skim milk. The cream sample was obtained from the remaining 25 pounds of milk in the supply tank.

When large quantities of cream were needed it was separated in the college creamery with a No. 40, electrically driven, De Laval separator.

Pasteurization A Cherry-Burrell 50 gallon, coil type, vat pasteurizer was used in pasteurizing milk and cream in the laboratory. The coil was kept running during both the heating and the holding period. The milk pasteurized in the creamery was processed in a glass lined, 300 gallon, water-jacketed Pfaudler pasteurizer with a propeller agitator which was shut off during the holding period. Pasteurization of cream in the creamery was accomplished with a 60 gallon water-jacketed Cherry-Burrell pasteurizer with a propeller agitator. The pasteurization of cream for viscolization was done in a water-jacketed 100 gallon Ladd Blue Line pasteurizer that was connected up directly to the viscolizer with a pipe line. Very small amounts of milk and cream were pasteurized in one gallon cans by setting them in a tank of hot water and gently stirring the contents at frequent intervals.

Cooling The cooling was done by three different methods. Some of the cooling was done in the pasteurizing vats; some of it was accomplished by placing the cream or milk in one gallon cans in water and gently stirring at intervals, and the remainder of the cooling was done over a surface cooler. In each method cold water was the cooling medium and the product was cooled to approximately 60° F. for standardization or for the taking of samples.

Standardization Large quantities of cream were standardized by weighing on the springless scales in the creamery. Small quantities were standardized using dairy scales reading in tenths of pounds. With the exception of stored milk and cream which were standardized at the storage temperature, all the standardization was done at near 60° F. unless otherwise stated. The cream was always standardized with skim milk from the same milk from which the cream was secured unless it is otherwise specifically stated in the results.

Agitation All stirring and agitating was done in one gallon ice cream cans with a stirring rod.

Viscolization The cream, after being heated to the proper temperature in the pasteurizer, was run through the viscolizer at the various pressures desired. Care was taken to assure accurate pressures and about two gallons of cream was allowed to run through the viscolizer after the desired pressure was obtained, to assure that the entire sample was processed at that pressure. A new Union Steam Pump Company viscolizer of 200 gallons per hour capacity, containing a "Duo-Visco" valve, was used. The samples were taken in one gallon cans directly from the viscolizer, cooled, and set for creaming.

Addition of Gelatin The gelatin was added to the milk before separation instead of adding it to the cream. A high grade of commercial gelatin was used. It was carefully weighed on scales sensitive to 0.1 of a gram, mixed with one pint of cold water and heated in a tank of hot water until completely dissolved. The dissolved gelatin was then added to a 60 pound lot of milk, in the pasteurizer, at 120° F. as the milk was being heated to 145° F. for separation.

Addition of Salts The sodium carbonate, calcium chloride, mono-calcium phosphate and sodium citrate solutions were made up in distilled water so that five cc. of the solution would give 0.1 per cent of the salt when added to a 500 cc. sample of cream. Five cc., 15 cc., and 25 cc. of each of these solutions were added to the cream, by means of a pipette, at 100° to 110° F., the cream being stirred well during the addition of the solutions. A saturated solution of di-calcium phosphate, which was not so soluble in water, was added in the same quantities.

Addition of Condensed Milk, Milk Powder and Casein These products were weighed on the same scales used in weighing the salts and gelatin and were added at approximately 110° F., the cream being stirred gently until the condensed milk, milk powder, and casein were thoroughly dissolved. The condensed milk used was a well known commercial brand of sterilized un-sweetened evaporated milk which had been condensed 100 per cent. Milk powder, testing 95 per cent solids, made by the spray process, was obtained from a local manufacturer. The casein used was a commercial brand of soluble food casein.

Methods of Taking Samples for Creaming Samples were taken in order to determine the amount of the skim milk layer appearing in the cream and, also, to observe the distinctness or attention-attracting power of this layer as evidenced first by the sharpness of the line of demarcation between the layers, and, second by the difference in the appearance of the cream and skim milk layers as a result of the completeness of separation of the fat. It was believed at first that both observations could be made by setting the cream in standard 100 cc. graduated cylinders which were used to determine the amount of the layer of

skim milk. Preliminary runs, however, showed the distinctness of the layer was always much greater in bottles than in the cylinders. Samples were, therefore, taken in both cylinders and one-half pint cream bottles - in cylinders to determine the amount of the skim milk layer and in the bottles to observe the distinctness of this layer. The samples were taken after the cream had been cooled to about 60° F. The cylinders and bottles were then cooled in ice water to 40° F. and set away for creaming.

Temperature of Storage and Creaming The milk and cream was stored in the cold storage room of the creamery which ranged in temperature from 35 to 40° F. All samples set for creaming were placed in this room with the exception of a few samples in that part of the experiment treating with the effect of temperature of creaming. In this study samples were set in ice water in the cold room at 32° F., in an electric refrigerator held constant between 39 and 41° F., in cold running water maintained at 56° F. and in a culture control oven kept at 68 to 70° F. Two drops of 40 per cent formaldehyde were added to each pint of cream as a preservative after preliminary study showed the addition of this reagent in considerably larger quantities had no noticeable effect on cream rising.

Description of Tests Made and Observed

Butterfat Tests The milk and cream were tested for butterfat by the Babcock method.

Temperature The temperature of heating and cooling the milk and cream in the various treatments was observed with dairy thermometers graduated to read to two degrees Fahrenheit. Each thermometer was checked for accuracy against one known to be accurate. Regular observations of the thermometers made accurate temperature control possible.

Observation of "Creaming off" The observations of creaming were made after 48 hours except when it was necessary to study the results after 72 hours creaming. Considerable difficulty was encountered in this part of the work especially in observing the creaming in the cylinders where the separation of the layers was far less distinct than in the bottles. The fat soluble dye, Sudan III, was used in an attempt to make more accurate and more reliable readings possible but without success. A microscopic light was tried in order to standardize the source of light for the observations. Preliminary work, however, showed that the best source of light was indirect sunlight which was used in making all observations.

The following alphabetical and numerical system was adopted as a means of recording the distinctness, and as a means of arriving at the average distinctness of the skim milk layers.

A	Skim milk layer very distinct	+1 2 - 3
B	Skim milk layer quite distinct	+4 5 - 6
C	Skim milk layer fairly distinct	+7 8 - 9
D	Skim milk layer not very distinct	+10 11 -12

		+ 13
E	Skim milk layer barely noticeable	14
		-15
F	No distinct skim milk layer but showing a difference in appearance between the bottom and upper contents due to some separation of skim milk	+ 16 17 - 18
		+19
G	No evident separation of skim milk	20
		-21

Plus and minus signs were used to show fine gradations in distinctness. While layers of the same distinctness were probably not always placed in the same class due to differences in the intensity of the light from day to day due to cloudiness, and the impossibility of having a permanent standard of comparison, the data, however, should be reliable in giving comparative results.

The observations were checked by some member of the staff who was not informed as to the previous treatment of the samples. When the cream line was so indistinct that accurate reading was impossible, this is shown in the tables by an asterisk (*).

Feathering Test In testing the viscolized cream for feathering the coffee was made with water from the college supply which contained 200 parts per million of calcium. The coffee was maintained at 190-200° F. and the cream was added a drop at a time from a stirring rod.

RESULTS

Effect of Temperature of Separation

Fresh Milk The temperature of fresh milk at the time of separation was found to have an influence on both the amount and the distinctness of the skim milk layer as shown in Tables 1, 2, and 3. Separation of the milk at the receiving temperature, 55° to 65° F., gave a deeper skim milk later than did separation at any of the higher temperatures. This difference was very evident in the bottled cream as well as in the cylinders. Temperatures of separation ranging from 90° to 180° F. were found to have little influence on the amount of the skim milk layer that appeared in bottled cream. Separation at the receiving temperature, 55° to 65° F., or at 90° F., gave a considerably more distinct skim milk layer than did separation at 120° F. or above. At 145° F. the layer was more distinct than at 120° F. This difference, however, was only slight and might have been due to the effect of heat on the milk during the time required for the separation process, since pasteurization at 145° F. for 30 minutes, as will be shown in the consideration of the effect of pasteurization, was found to increase the distinctness of the layer.

The influence of the temperature of separation at 90° and 120° F. varied depending upon whether the milk was being heated up to those temperatures or was being cooled from a higher temperature. Pasteurizing milk at 145° F. for 30 minutes followed by subsequent cooling to 120° and 90° F. for separation gave no appreciable difference in the distinctness or volume of the skim milk layer at the two temperatures. However, when the temperature of the milk was raised from the temperature at

Table I. Effect of Heat Treatment of Milk Prior to Separation on the Appearance of the Skim Milk Layer when Low Test Cream Was Secured

Trial No.	Fat Test of Milk %	Fat Test of Cream Per cent Temperature of Separation degrees F.					Skim Milk Layer 48 hours at 35–40° F. Heat Treatment Prior to Separation					Distinctness of Skim Milk Layer Heat Treatment Prior to Separation**				
		90	120	145	120 after Past.	90 after Past.	Heated to 90° F.	Heated to 120°F.	Heated to 145°F.	Heated to 145°F. for 30 min. & to 120°F.	Heated to 145°F. for 30 min. & to 90° F.	Heated to 90° F.	Heated to 120°F.	Heated to 145°F.	Heated to 145°F. for 30 min. & to 120° F.	Heated to 145°F. for 30 min. & to 90° F.
1	3.5	20.5	20.0	21.0			2.0	2.5	2.0			B–	D	C		
2	3.5	21.0	19.5	20.5			2.0	1.7	1.5			C	C	C		
3	3.3	19.5	18.0	18.5			1.5	*	2.0			C+	D	C		
4	3.6	22.0	20.5	21.5	21.5	22.0	1.5	2.0	2.0	2.3	2.0	A–	E+	D	C	C
5	3.5	21.0	19.0	21.5	21.0	22.0	2.0	2.0	2.0	2.0	2.0	B	D–	C–	B–	C+
6	3.5	21.0	20.0	20.5	21.0	22.0	2.0	2.0	2.5	2.0	2.0	C	D	C	B–	B–
Ave.	3.48	20.8	19.5	20.6	21.2	22.0	1.83	2.04	2.0	2.1	2.0	B–	D	C–	C+	C+

*Accurate reading impossible due to indistinctness of cream line.

**A Layer very distinct
B Layer quite distinct
C Layer fairly distinct
D Layer not very distinct
E Layer barely noticeable
F No distinct layer
G No evident separation of skim milk

Table II. Effect of Heat Treatment of Milk Prior to Separation when High Test Cream Was Secured and Standardized Back to Approximately 20 per cent Butterfat

Trial No.	Fat Test of Milk %	Fat Test of Cream Per cent Temperature of Separation					Fat Test of Std. Cream per cent Heat Treatment Prior to Separation					Skim Milk Layer 48 hours at 35–40° F. Per cent Heat Treatment Prior to Separation					Distinctness of Skim Milk Layer Heat Treatment Prior to Separation				
		a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
1	3.5	51.0	40.0	43.0	43.0	44.5	21.0	20.5	21.0	20.5	21.0	2.5	3.0	2.0	2.0	2.0	B–	B	D	D	C
2	3.5	52.0	40.0	43.0	42.0	45.5	21.0	20.0	20.0	20.0	20.0	2.7	2.0	*	1.5	2.0	B+	B	D	C	C
3	3.3	49.5	36.0	37.5	39.0	39.0	20.0	20.5	20.0	20.0	20.0	3.0	2.0	2.0	1.5	2.0	B	A	D	D	C
4	3.6	49.5	35.0	44.5	45.0	46.0	20.0	18.0	19.5	19.0	20.0	2.3	1.2	2.5	2.5	2.0	B	A	E	E+	D
5	3.5	50.0	40.0	43.5	38.5	46.0	19.5	20.5	20.0	23.0	19.5	3.0	3.0	3.0	*	2.0	B–	B	E+	C–	D+
6	3.5	50.5	40.0	42.5	45.0	45.5	21.0	20.0	19.5	20.5	20.0	3.5	2.0	*	2.5	2.0	B	B	E	E	C
Ave.	3.48	50.4	38.5	42.3	41.8	44.4	20.4	19.9	20.1	20.6	20.2	2.83	2.2	2.38	2.0	2.0	B	B+	D–	D	C–

a Unheated, 55–65° F.

b Heated to 90° F.

c Heated to 120° F.

d Heated to 145° F.

e Heated at 145° F. for 30 min.

Table III. Effect of High Temperature of Heat Treatment of Milk Prior to Separation

Trial No.	Fat Test of Milk %	Fat Test of Cream Per cent Temperature of Separation degrees F.			Skim Milk Layer 48 hours at 35–40^{0} F. Heat Treatment Prior to Separation			Distinctness of Skim Milk Layer Heat Treatment Prior to Separation		
		145	160	180	Heated to 145^{0} F. (check)	Heated at 160^{0} F. for 15 min.	Heated at 160^{0} F. for 15 min. & raised to 180^{0}F. for separation	Heated to 145^{0} F. (check)	Heated at 160^{0} F. for 15 min.	Heated at 160^{0}F. for 15 min. & raised to 180^{0}F. for separation
1	3.5	19.5	20.0	21.0	2.5	2.2	2.2	D	C+	C–
2	3.5		20.5	21.0		2.0	2.2		C+	C–
3	3.5	20.0	20.5	21.0	1.9	1.8	2.2	D	C+	C–
4	3.5		20.0	20.0		1.8	2.3		C+	C–
5	3.5	20.0	20.5	21.0	2.0	1.5	2.0	D+	E	D+
6	3.5		20.0	20.0		1.5	1.9		D+	D+
7	3.5		21.0	21.0		1.5	2.0		C	D+
Ave.	3.5	19.8	20.4	20.7	2.13	1.76	2.11	D	C–	C–

which it was received at the plant, to 90° and to 120° F., separation at 90° F. gave by far the more distinct cream line.

Milk Stored at Low Temperature Results reported in the literature suggested that it might be possible to alter the "creaming off" phenomena by storing milk at a low temperature for a sufficient time to harden the fat and then controlling the temperature of separation. The results of storing for 24 and 48 hours at 35° to 40° F. and separating after slowly and carefully warming the milk to the various temperatures are given in Table 4. The temperature of separation was found to have little effect on the amount of the skim milk layer as little difference was shown at any of the temperatures from 60° to 145° F. The results indicate that the time of storing the milk at low temperature had little influence upon the volume of the skim milk layer as compared to that obtained from fresh milk, except at 60° F. As compared with fresh milk separated at 55° to 65° F., separation of old stored milk at 60° F. reduced the skim milk layer from 2.83 per cent in case of the fresh milk to 2.07 per cent in case of the old milk. The volume of the skim milk layer was, therefore, reduced approximately 27 per cent due to storing the milk at low temperature.

For unaccountable reasons there was considerable variation in the distinctness of the skim milk layer when old milk was separated at 60° F. It was found that raising the temperature of the milk from 60° F. to 80° or 90° F. and separating, a much more distinct skim milk layer was formed than when the old milk was separated at 60° F. Results of separation of old milk at 80°, 90°, 120°, and 145° F. revealed that

Table IV. Effect of Heat Treatment of Stored Milk Prior to Separation

Trial No.	Fat Test of Milk %	Time Stored at 35-40° F. hours	Temp. of Milk at End of Storage Period degrees F.	Fat Test of Cream Per cent Temperature of Separation 60	80	90	120	145	Fat Test of Std. Cream Per cent Temperature of Separation 60	80	90	120	145	Skim Milk Layer 48 hours at 35-40° F. Per cent Temperature of Separation 60	80	90	120	145	Distinctness of Skim Milk Layer Temperature of Separation 60	80	90	120	145
1	3.5	48	38	27.0		23.5		20.5	19.5		19.5		20.5	*		4.0		*	F		B		E-
2	3.6	48	40	23.0		21.0	18.5	20.0	23.0		21.0	18.5	20.0	1.6		2.0	2.0	2.0	A		B	D	E-
3	3.4	48	39	23.5	20.0	19.0	19.5	20.0	20.0	20.0	19.0	19.5	20.0	2.0	1.3	1.5	1.5	1.8	B	A	A	D	C
4	3.7	48	40	27.0	21.0		19.5	21.0	20.5	21.0		19.5	21.0	2.0	1.2		1.5	2.0	C	A		E	C
5	3.65	48	38		20.0	20.0	21.0	20.5		20.0	20.0	21.0	20.5		3.5	2.5	*	*		A	A	F	C-
6	3.65	24	41	22.5	20.0	20.0	18.5	20.0	20.5	20.0	20.0	18.5	20.0	1.3	1.7	1.7	2.2	2.2	C	A	A	E	C
7	3.7	24	40	24.0	20.0	20.5	19.5	20.0	20.5	20.0	20.5	19.5	20.0	3.5	2.0	1.8	*	*	B	A	A	D	D
8	3.4	24	41	24.0	20.0	18.5	18.5	20.0	19.5	20.0	18.5	18.5	20.0	2.0	2.0	1.5	2.0	2.0	D	C	C	E	C
Ave.	3.54		39.6	24.5	20.2	20.4	19.3	20.3	20.5	20.2	19.8	19.3	20.3	2.07	1.95	2.14	1.84	2.0	C	A-	B+	E+	D+

there was little difference in the effect of separating old milk as compared with fresh milk separated at similar temperatures on the distinctness of the skim milk layer, as the old milk also gave a much less distinct layer at 120° than 80° or 90° F. and raising the temperature from 120° to 145° increased the distinctness to a slight extent.

Effect of Pasteurization of Milk Prior to Separation

In view of the results given in the literature in regard to the effect of temperature on the creaming of milk, surprising results were obtained in the study of pasteurization upon the skim milk layer forming in cream.

The results of separating milk after heating to 145° F. momentarily; after pasteurizing at 145° F. for 30 minutes; after pasteurizing at 145° F. and cooling to 120° F.; after pasteurizing at 160° F. for 15 minutes; and after raising the milk pasteurized at 160° F. to 180° F., indicate with the exception of the milk separated at 160° F. for 15 minutes, that the pasteurization had little influence upon the amount of the skim milk layer. When milk pasteurized at 160° F. for 15 minutes was skimmed at that temperature it was found that a smaller volume of skim milk appeared than at any other temperature of pasteurization. These results are shown in Tables 1, 2, and 3.

It was found that heating milk to 145° F. and separating immediately resulted in a slightly more distinct skim milk layer than that obtained in the check sample at 90° F., and that pasteurizing at 145° F. for 30 minutes made for a marked increase in the distinctness of the layer. Pasteurization at 160° F. for 15 minutes, or at this same exposure followed by raising the temperature to 180° F. momentarily, before separating, gave a slightly more distinct skim milk layer than when the milk was heated only to 145° F. momentarily. These results are indicated in table 3. However, since temperatures of 160° and 180° F. as well as pasteurizing at 145° F. for 30 minutes, gave only a slight increase in distinctness as compared to that shown by heating to 145° F., these results indicate that the higher temperatures of heating milk, 160° and 180° F., did not appreciably increase or decrease the distinctness of the layer as compared with the usual exposure of 145° F. for 30 minutes.

Effect of Pasteurization of Cream

Raw Standardized Cream The results obtained by pasteurizing raw standardized cream are given in Table 5. Pasteurizing cream at each of the five degree intervals from 145° to 160° F. for 30 minutes yielded a skim milk layer of less volume and greater distinctness than did raw cream. The different temperatures of pasteurization used between 145° and 160° F. apparently had no marked influence on either the volume or distinctness of the layer. Approximately 1.9 per cent skim milk layer appeared in the cream obtained from the pasteurized lots as compared to 2.5 per cent from the raw cream.

Cream from Pasteurized Milk Pasteurizing standardized cream at 145° F. and 160° F. for 30 minutes apparently had no appreciable effect either on the volume or on the distinctness of the skim milk layer as shown by the results in Table 6. This cream was secured by mixing pasteurized whole milk and cream from pasteurized milk.

Table V. Effect of Different Temperatures of Pasteurization of Raw Standardized Cream

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream per cent	Fat Test of Std. cream per cent	Skim Milk Layer 48 hours at 35-40° F. per cent Pasteurization Temperature degrees F. Time - 30 min.					Distinctness of Skim Milk Layer Pasteurization Temperature degrees F. Time - 30 min.				
				Un-Past. Check	145	150	155	160	Un-Past. Check	145	150	155	160
1	90 - 100	48.5	20.0	2.5	2.3	2.4	2.2	2.0	E	C	C	C	C
2	85 - 110	41.5	20.0	2.5	1.5	1.5	1.5	1.5	D	C	C	C	C
3	85 - 110	45.0	20.0	2.3	2.0	2.0	1.8	1.9	D	C	C	C	C
4	85 - 110	55.0	20.0	2.7	2.0	2.0	2.1	2.0	D	B-	B-	B-	B-
Ave.		47.5		2.5	1.95	1.98	1.9	1.85	D-	C+	C+	C+	C+

Table VI. Effect of Different Temperatures of Pasteurization of Standardized Cream

Secured from Pasteurized Milk

Trial No.	Pasteurization of Milk Temp. deg.F.	Time Min.	Temperature of Separation degrees F.	Fat Test of Cream per cent	Fat Test of Std. Cream per cent	Skim Milk Layer 48 hours at 35-40° F. per cent Un-Past. Check	Past. 145° F. 30 min.	Past. 160° F. 30 min.	Distinctness of Skim Milk Layer Un-Past. Check	Past. 145°F. 30 min.	Past. 160° F. 30 min.
1.	144	30	144	36.0	20.0	2.0	2.2	2.0	B-	B-	B-
2	144	30	144	36.0	20.0	-	2.2	2.0		B-	B-
3	144	30	130	41.5	20.0	1.7	1.7	1.6	C+	B-	C+
4	144	30	130	41.5	20.0	-	1.7	1.6		C+	C+
Ave.				38.8		1.85	1.95	1.8	B- to C+	B-	B- to C+

Effect of High Temperature of Pasteurization on the Milk Versus on the Cream Used in Standardization

The results of pasteurizing the raw cream, after standardizing to approximately 20 per cent; of pasteurizing the high test raw cream before standardizing with raw skim milk; and of pasteurizing the skim milk before standardizing with raw cream, are given in Table 7. The pasteurization was done at 170° F. for 20 minutes in cans placed in hot water. These results indicate there was little difference in the amount of the skim milk layer due to high temperature of pasteurization of the skim milk as compared to the same treatment on the cream before standardizing. The detrimental effect was much greater, however, when the cream was pasteurized after standardizing. When the cream and skim milk were secured from pasteurized milk rather than from raw milk similar results were obtained. These results are shown in Table 8. The distinctness, however, was much greater when the skim milk was pasteurized before standardizing, in the case of raw products, while there was little difference in the distinctness with the different treatments when the cream and skim milk were secured from pasteurized milk.

Effect of Standardizing Pasteurized Cream with Milk Processed in Various Ways

High test cream was pasteurized at 145° F. for 30 minutes and then standardized with (1) raw whole milk, (2) pasteurized whole milk, and (3) skim milk from pasteurized milk. The results, as given in Table 9, indicate that there was no marked difference in the volume of the serum layer obtained from the cream standardized with the different products.

Table VII. Effect of High Temperature of Pasteurization of (1) Raw Standardized Cream; (2) High Testing Cream before Standardization with Raw Skim Milk; and (3) Skim Milk before Standardization with Raw Cream

Trial No.	Fat Test of Milk %	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of cream and skim milk		Fat Test of Std. Cream per cent			Skim Milk Layer 48 hours at 35–40° F. per cent			Distinctness of Skim Milk Layer		
				Temp. deg.F.	Time Min.	Cream Past. after std.	Cream Past. before std.	Skim Milk Past.	Cream Past. after std.	Cream Past. before std.	Skim Milk Past. before std.	Cream Past. after std.	Cream Past. before std.	Skim Milk Past. before std.
1	3.5	90	40.0	170	20	20.0	20.0	21.0	3.0	*	3.0	C+	C+	B+
2	3.5	90	40.0	170	20	20.0	20.5	20.0	*	2.0	1.5	E+	C	D
3	3.3	90	36.0	170	20	20.5	20.5	20.5	4.0	2.0	2.2	C–	B	A
4	3.6	90	35.0	170	20	18.0	23.0	22.5	4.5	2.0	1.0	C–	C–	A
5	3.5	90	40.0	170	20	20.0	20.0	20.0	6.0	3.0	3.0	C+	C	B
6	3.5	90	40.0	170	20	20.0	20.0	20.0	4.0	2.5	4.0	D	D+	B
Ave.	3.48		38.5			19.8	20.7	20.7	4.3	2.3	2.45	C–	C	B

Table VIII. Effect of High Temperature of Pasteurization of (1) Standardized Cream; (2) High Test Cream before Standardization; and (3) Skim Milk before Standardization.

(Both Milk and Cream Secured from Pasteurized Milk, 145° F. 30 min.)

Trial No.	Fat Test of Milk %	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream and Skim Milk		Fat Test of Std. Cream per cent			Skim Milk Layer 48 hours at 35-40°F. per cent			Distinctness of Skim Milk Layer		
				Temp. deg.F.	Time Min.	Cream Past. after std.	Cream Past. before std.	Skim Milk Past.	Cream Past. after std.	Cream Past. before std.	Skim Milk Past. before std.	Cream Past. after std.	Cream Past. before std.	Skim Milk Past. before std.
1	3.5	145	44.5	170	20	21.0	21.0	20.5	6.0	3.0	2.0	E-	E	E
2	3.5	145	45.5	170	20	20.5	20.0	20.0	5.0	1.8	2.0	E	C-	D
3	3.3	145	39.0	170	20	20.0	20.0	19.5	5.0	2.0	2.0	C-	C+	B
4	3.6	145	46.0	170	20	20.0	19.0	20.0	7.0	3.0	2.5	E+	E	E
5	3.5	145	46.0	170	20	20.0	20.0	20.0	8.0	3.0	2.5	D-	D+	E+
6	3.5	145	45.5	170	20	20.0	20.0	-	6.0	2.0	-	D	D+	-
Ave.	3.48		44.6			20.25	20.0	20.0	6.17	2.47	2.2	D-	D	D

Table IX. Effect of Standardizing Pasteurized Cream with (1) Raw Whole Milk; (2) Pasteurized Whole Milk, and (3) Skim Milk from Pasteurized Milk

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Fat Test of Std. Cream per cent Std. with: Raw Whole	Past. Whole	Skim from Past. Milk	Skim Milk Layer 48 hours at 35-40°F. per cent Cream Standardized with: Raw Whole	Past. Whole	Skim from Past. Milk	Distinctness of Skim Milk Layer Cream Standardized with: Raw Whole	Past. Whole	Skim from Past. Milk
1	90 - 100	46.5	145	30	20.5	20.0	-	1.5	1.7	-	D	C	-
2	90 - 100	45.5	145	30	21.0	20.0	20.0	2.0	1.8	1.8	C	C	C
3	90 - 100	45.5	145	30	21.0	21.0	20.5	2.0	1.8	2.0	D	C	C
4	90 - 100	44.5	145	30	21.0	20.5	20.5	2.0	2.0	2.0	B-	B	B
5	90 - 100	44.0	145	30	20.0	20.0	20.5	*	2.5	2.5	D	C+	C-
Ave.		45.2			20.7	20.3	20.4	1.88	1.98	2.08	C-	C+	C+ to C

The distinctness of the layer, however, was less in every case when raw whole milk was used in standardizing as compared with pasteurized whole milk, or pasteurized skim milk.

Effect of Standardization

Effect of Separating High Test Cream and Standardizing Back Versus Separating Low Test Cream   Since many milk plant operators are of the opinion that high test cream standardized back to a low fat content gives a greater skim milk layer than cream separated at a lower fat content which requires less standardizing, an attempt was made to prove or disprove this assumption. Table 10 was made by taking the averages from Tables 1 and 2 of both high test standardized cream and low test unstandardized cream separated at 90°, 120°, and 145° F. The results show a tendency toward higher volumes of skim milk layer in the high test cream standardized back to approximately 20 per cent as compared with the cream separated as near 20 per cent as possible and not standardized. However, with many difficult readings due to the indistinctness of the skim milk layers in the cylinders in this experiment, definite conclusions should not be drawn. There was apparently no significant differences in the distinctness of skim milk layer between the standardized and unstandardized cream.

Effect of Standardizing with Whole versus Skim Milk   It has been assumed by some milk dealers that the skim milk layer is greater in volume when high testing cream is standardized with skim milk than when whole milk is used as the standardizing medium. The results of standardizing raw cream

Table X. Effect of Standardizing High Fat Content Cream Back to Approximately 20 per cent Butterfat. Averages Taken from Tables I and II.

No. Trials	Fat Test of Milk %	Fat Test of Cream per cent Temperature of Separation degrees F.			Fat Test of Std. Cream Heat Treatment Prior to Separation Heated to degrees F.			Skim Milk Layer 48 hours at 35-40°F. Heat Treatment Prior to Separation Heated to degrees F.			Distinctness of Skim Milk Layer Heat Treatment Prior to Separation Heated to degrees F.		
		90	120	145	90	120	145	90	120	145	90	120	145
6	3.48	38.5	42.3	41.8	19.9	20.1	20.6	2.2	2.38	2.0	B+	D-	D
6	3.48	20.8	19.5	20.6	20.8	19.5	20.6	1.83	2.04	2.0	B-	D	C-

with both raw whole and raw skim milk as given in Table 11 and the results of standardizing pasteurized cream with pasteurized whole and with pasteurized skim milk as given in Table 9 indicate that there was little difference in either the amount of the skim milk layer or in its distinctness due to this factor. When pasteurized products were used less volume of skim milk layer appeared in the cream than when raw products were standardized. This appears to substantiate the former results obtained showing that pasteurization decreased the skim milk layer. In studying the effect of standardization before as compared with after pasteurization, raw cream was standardized with raw whole milk and pasteurized. The results were compared with those obtained by pasteurizing the high test cream before standardizing with pasteurized milk. The data given in Table 12, although showing variations in results, indicates that the skim milk layer was somewhat greater in volume when the standardization was done prior to pasteurization as compared to standardizing with pasteurized products. An average skim milk volume of 1.9 per cent was found when standardized before pasteurizing as compared to 1.5 per cent when standardization was done after pasteurizing. There seemed to be no marked difference in distinctness as a result of the two methods.

Effect of Temperature of Standardization Since temperature had been found to exert an effect on the appearance of the skim milk layer in the processes of separation and pasteurization it was thought possible that the temperature of the milk and cream at the time of mixing in standardization might have an influence. However, the results of four trials run on the same day, mixing hot and cold cream and milk in all possible com-

Table XI. Effect of Standardizing Raw Cream with (1) Raw Whole Milk and (2) Raw Skim Milk

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Fat Test of Std. Cream per cent Std. with		Skim Milk Layer 48 hours at 35–40° F. per cent Cream Standardized with		Distinctness of Skim Milk Layer Cream Standardized with	
			whole	skim	whole	skim	whole	skim
1	90 - 100	44.5	21.0	21.0	2.0	2.0	C	D
2	90 - 100	44.0	20.0	20.0	2.5	3.0	D	D
3	90 - 100	46.0	20.0	23.5	2.0	2.5	B	D
4	85 - 110	45.0	20.5	20.0	2.3	2.3	D	D
5	85 - 110	41.5	20.5	20.0	2.5	2.5	D	D
6	85 - 110	55.0	20.0	20.0	2.5	2.7	D+	D
Ave.		46.0	20.3	20.8	2.3	2.5	C–	D

Table XII. Effect of Standardizing Cream Before vs. After Pasteurization. (1) Cream Pasteurized After Standardizing with Raw Whole Milk. (2) Raw Cream Pasteurized Before Standardizing with Pasteurized Whole Milk.

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Fat Test of Std. Cream per cent Standardization Before Past.	Fat Test of Std. Cream per cent Standardization After Past.	Skim Milk Layer 48 hours at 35–40°F. per cent Cream Standardized Before Past.	Skim Milk Layer 48 hours at 35–40°F. per cent Cream Standardized After Past.	Distinctness of Cream Layer Cream Standardized Before Past.	Distinctness of Cream Layer Cream Standardized After Past.
1	90 - 100	46.5	145	30	21.0	20.5	1.5	0.9	B	B
2	90 - 100	45.5	145	30	20.0	21.0	2.0	1.6	C	B
3	90 - 100	45.5	145	30	20.5	20.5	2.0	1.2	C	C
4	90 - 100	44.5	145	30	20.5	22.5	2.2	1.8	B+	B
5	90 - 100	44.0	145	30	20.0	20.0	1.8	2.0	C+	C +
Ave.		45.2			20.4	20.9	1.9	1.5	B–	B–

binations, indicate that the temperature of neither the cream nor the milk had any appreciable effect on the amount or distinctness of the skim milk layer when raw cream was standardized with raw skim milk. These results are given in Table 13.

Effect of Standardizing Cream Fresh versus Standardizing After Storing 24 Hours Results of recreaming and agitation of stored milk as noted in the literature suggested that there might be a difference in "Creaming off" when the cream was standardized fresh as compared with standardizing milk and cream stored at 35° to 40° F. for 24 hours. Table 14 gives the experimental results of a study of this influence with pasteurized cream and milk, indicating that there was a slightly greater serum layer when the cream was standardized fresh, whereas standardization after storing gave a layer of considerably greater distinctness. Observation of the bottled cream showed that this difference in distinctness was probably great enough to deserve the consideration of the milk dealer.

Effect of Agitation of Cream After Storing

Cream was stored in the cold storage room at 35–40° F. for 24 hours and agitated violently to determine if such agitation, after the fat was in a hardened condition, had any influence on the skim milk layer. Table 15 gives the observations made on this cream as compared with the same cream set fresh without agitation. It was found that agitation of pasteurized cream after storing 24 hours has no significant effect upon the volume of the skim milk layer. The stored, agitated cream did, however, give a more distinct layer.

Table XIII. Effect of Temperature of Standardizing. Raw Cream Standardized with

Raw Skim Milk

Trial No.	Temperature of Separation degrees F.	Fat Test of Milk %	Fat Test of Cream %	Fat Test of Std. Cream per cent				Skim Milk Layer 48 hours at 35–40° F. per cent				Distinctness of Skim Milk Layer			
				Hot Cream & Hot Milk	Hot Cream & cold Milk	Cold Cream & Hot Milk	Cold Cream & Cold Milk	Hot Cream & Hot Milk **	Hot Cream & Cold Milk **	Cold Cream & Hot Milk **	Cold Cream & Cold Milk **	Hot Cream & Hot Milk	Hot Cream & Cold Milk	Cold Cream & Hot Milk	Cold Cream & Cold Milk
1	85 - 110	3.4	52.5	21.0	20.0	20.5	20.5	2.0	2.0	2.0	2.0	C	C	C	C
2	85 - 110	3.4	52.5	20.5	20.0	20.0	20.0	2.0	2.0	2.0	2.0	C	C	C	C
3	85 - 110	3.4	52.5	20.0	20.5	20.5	20.5	2.0	2.0	2.0	2.0	C	C	C	C
4	85 - 110	3.4	52.5	20.5	20.0	20.0	20.0	2.0	2.0	2.0	2.0	C	C	C	C
Ave.				20.5	20.1	20.25	20.25	2.0	2.0	2.0	2.0	C	C	C	C

** Hot cream was at 145° F.
Hot milk was at 145° F.
Cold cream was at 60° F.
Cold milk was at 56° F.

Table XIV. Effect of Standardizing Cream Fresh versus Standardizing After Storing Cream and Milk 24 hours at 35–40° F. Pasteurized cream Standardized with Pasteurized Milk.

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream		Fat Test of Std. Cream per cent		Skim Milk Layer per cent				Distinctness of Skim Milk Layer			
			Temp. deg.F.	Time Min.	Std. Fresh	Std. After 24 hr.	Std. Fresh		Std. after 24 hours		Std. Fresh		Std. After 24 hours	
							48 hours	120 hours	48 hours	144 hours	48 hours	120 hours	48 hours	144 hours
1	90 - 100	45.0	145	30	20.5	20.5	2.2	5.0	2.0	4.0	C–	D	B–	D+
2	90 - 100	47.0	145	30	20.0	18.5	2.0	4.5	1.8	4.0	C	E	B–	D+
3	90 - 100	38.0	145	30	17.5	20.0	2.0	4.5	1.8	3.5	C–	E	B–	D+
4	90 - 100	40.0	145	30	20.0	20.0	2.0	3.5	1.7	3.0	C–	E	B–	C–
5	90 - 100	41.5	145	30	20.5	20.5	1.6	4.0	1.6	3.5	C–	E	B+	D+
6	90 - 100	47.0	145	30	20.0	20.0	1.8	4.0	1.5	4.0	D	D	C+	C
7	90 - 100	40.0	145	30	20.0	19.5	1.8	4.5	1.8	4.0	C–	D	B–	C–
Ave.		42.7			19.8	19.9	1.91	4.29	1.75	3.71	C–	E+	B–	C–

Table XV. Effect of Agitating and Storing Standardized Cream Held 24 Hours at Low Temperature (35–40° F.)

Trial No.	Temperature of Separation degrees F.	Fat Test Cream %	Pasteurization of Cream		Fat Test of Std. Cream %	Skim Milk Layer 48 Hours at 35–40° F. per cent		Distinctness of Skim Milk Layer	
			Temp. deg.F.	Time Min.		Un-agitated Set Fresh	Agitated After Storing 24 hr. 35–40° F.	Un-agitated Set Fresh	Agitated After Storing 24 hr. 35–40° F.
1	90 – 100	44.5	145	30	20.5	2.0	2.2	C	A
2	90 – 100	44.0	145	30	20.0	1.8	2.0	C+	B–
3	90 – 100	44.0	145	30	20.0	2.0	2.3	C–	B–
4	90 – 100	44.5	145	30	20.0	2.2	2.3	C	B–
5	90 – 100	44.5	145	30	20.0	*	2.2	D	C+
6	90 – 100	44.5	145	30	20.5	2.5	2.3	C–	B–
7	145	20.0	–	–	20.0	2.0	2.0	C	B
8	145	20.0	–	–	20.0	1.9	2.0	C	B
9	145	20.0	–	–	20.0	2.0	2.0	C	B–
Ave.					20.1	2.05	2.14	C	B

Effect of Method of Cooling

As evidence was given in the review of literature to show that rapid cooling of pasteurized milk gave a greater cream volume than slow cooling, a study of this factor was made with pasteurized cream. The rapid cooling was done over a surface cooler and the slow cooling accomplished by occasional gentle agitation of the cream set in cold water. The results, as presented in Table 16, indicated that the speed of cooling pasteurized cream had little effect upon the volume or distinctness of the resulting skim milk layer.

Effect of Temperature of Creaming

The results of various creaming temperatures upon the appearance of the skim milk layer are given in Table 17. These results indicate that there was no appreciable difference in the amount or distinctness of the layer at ice water temperature, 32° F., as compared with 35 to 40° F. Later work, which was done after an accurate temperature controlled, electric refrigerator was obtained and the higher temperature constantly maintained at 39 to 41° F., gave results indicating that ice water temperature yielded a slightly smaller serum layer and one which was also slightly more distinct than the layer which formed at 39 to 41° F. This small difference, however, was not enough to be of commercial importance. Higher temperatures gave less distinct layers as the temperature was raised. The amount of the layers could not be observed in the cylinders due to lack of distinctness of separation but the bottles showed larger amounts at 56° F. and 68 to 70° F. with the latter temperature giving the greater amount.

Table XVI. Effect of Fast and Slow Cooling of Cream. Fast Cooling over Surface Cooler, Slow Cooling in Can Placed in Cold Water

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Fat Test of Std. Cream %	Skim Milk Layer 48 hours at 35-40° F. per cent: Fast Cooled	Skim Milk Layer 48 hours at 35-40° F. per cent: Slow Cooled	Distinctness of Skim Milk Layer: Fast Cooled	Distinctness of Skim Milk Layer: Slow Cooled
Treatment A - Cream standardized before pasteurizing.									
1	90 - 100	46.5	145	30	21.0	1.5	1.6	B	B+
2	90 - 100	45.5	145	30	20.0	2.0	2.0	C	C
3	90 - 100	45.5	145	30	20.5	1.9	2.1	C	C
4	90 - 100	44.5	145	30	20.5	2.2	2.0	B+	B-
5	90 - 100	44.0	145	30	20.0	1.8	2.0	C+	C-
Ave.		45.2			20.4	1.88	1.94	B-	C+
Treatment B - Cream standardized after pasteurization with pasteurized milk.									
1	90 - 100	46.5	145	30	20.5	.9	1.1	B	B+
2	90 - 100	45.5	145	30	21.0	1.6	1.5	B	B
3	90 - 100	45.5	145	30	20.5	2.0	2.0	C-	D
4	90 - 100	44.5	145	30	22.5	1.8	1.6	B	C
5	90 - 100	44.0	145	30	20.0	2.0	2.0	C-	D-
Ave.		45.2			20.9	1.66	1.64	C+	C
Treatment C - Cream standardized after cooling from pasteurizing temperature.									
1	90 - 100	45.5	145	30	20.5 - 20.5	1.4	1.6	B	B
2	90 - 100	45.5	145	30	21.0 - 19.5	2.0	2.0	C	C
3	90 - 100	44.5	145	30	20.5 - 21.0	2.0	1.7	C	D
4	90 - 100	44.0	145	30	20.0 - 20.0	2.2	2.0	D+	D
Ave.		44.9			20.5 20.25	1.9	1.83	C	C-

Table XVII. Effect of Temperature of Creaming

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Time Min.	Fat Test of Std. Cream %	Skim Milk Layer 48 hours per cent: 32° F. Ice Water	35-40°F. air	39-41°F. air	56°F. Water	68-70°F. air	Distinctness of Skim Milk Layer: 32°F. Ice Water	35-40°F. air	39-41°F. air	56°F. Water	68-70°F. air
1	90 - 100	45.5	145	30	20.0	1.7	1.5	-	*	*	C	C	-	D	E-
2	90 - 100	45.5	145	30	20.5	1.8	1.9	-	*	*	C	C	-	D	E-
3	90 - 100	45.5	145	30	20.5	1.8	1.8	-	*	*	C	C	-	E+	F
4	90 - 100	45.5	145	30	21.0	2.0	2.0	-	*	*	C	C	-	E	F
Ave.		45.5			20.5	1.83	1.8		*	*	C	C		D-	F+
Treatment B - Cream secured from pasteurized milk (144°F. 30 min.), standardized and pasteurized.															
5	144	36.0	145	30	20.0	2.0		2.2			B		B-		
6	144	36.0	145	30	20.0	1.8		2.0			B		B-		
7	144	36.0	145	30	20.0	1.9		2.2			B		B-		
8	144	36.0	145	30	20.0	1.8		2.0			B		B-		
9	144	36.0	(check)		20.0	1.8		2.0			B		B-		
Ave.		36.0			20.0	1.86		2.08			B		B-		

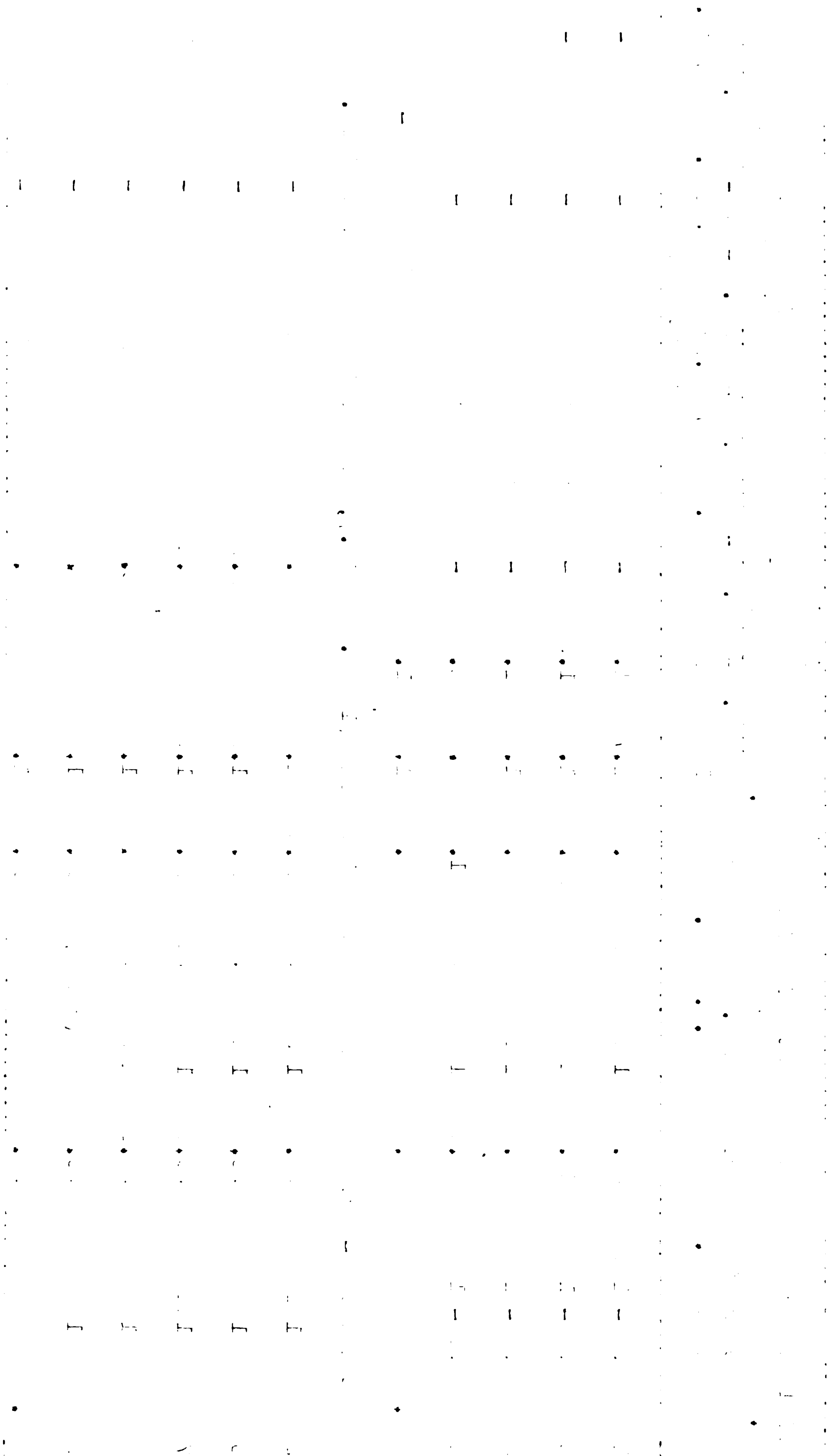

Table XVIII. Effect of Time of Creaming.

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Standardization Treatment of Milk	Fat Test of Std. Cream %	Skim Milk Layer at 35–40° F. per cent hours 24	48	72	96	144	192	Distinctness of Skim Milk Layer hours 24	48	72	96	144	192
1	90	19.5	-	-		19.5	*	2.0	3.0	*	*	*	E	E	E	E	E	E
2	90 - 100	46.5	145	30	raw whole	20.5	1.2	1.5	2.5	*	*	*	C	D	D	D	D-	D-
3	90 - 100	46.5	145	30	Past. whole (145 - 30)	20.0	1.2	1.7	2.5	3.0	4.0	*	C	C	C	C	D-	D-
4	90 - 100	46.5	145	30	Skim(from past.milk 145 - 30)	20.0	1.0	1.6	1.8	2.0	*	*	E	E	D	D	D-	D-
5**	90 - 100	46.5	145	30	raw,whole	21.0	1.0	1.5	2.2	3.1	4.0	*	C	B	B	C	C-	C-
6**	90 - 100	46.5	145	30	raw,whole	21.0	1.3	1.6	2.4	2.9	4.0	4.5	C	C	C	C	C-	C-
Ave.						20.33	1.14	1.65	2.4	2.75	4.0	4.5	D+	D+	C- to D+	D+	D	D

** Standardized before pasteurizing

Effect of Time of Creaming

Several samples of cream were observed at various intervals to determine the effect of time of creaming on the appearance of the skim milk layer. Table 18, showing these results, indicates roughly that there was a gradual increase, the volume of the skim milk layer becoming gradually less in rate as the time increased. The amounts were difficult to determine, however, especially after 96 hours as the skim milk layers in the cylinders became less distinct. The distinctness seemed to increase for some 48 to 72 hours and then gradually decreased. Many observations in the study of the various factors were made at 96 hours in addition to the 48 hour observations, as a check on the first readings. It was always very evident that the distinctness was less at the 96 hour observation. In studying the effect of storing the milk and cream a day before standardizing, in which a comparison of the stored, standardized sample was made with the check sample set raw on the fifth and sixth days of creaming respectively, it was found in every case as shown in Table 14 that the samples were considerably less distinct after creaming five and six days than after creaming only 48 hours. The skim milk layers were slightly over twice as great in volume after the longer period of creaming.

Effect of Viscolization of Raw Cream

Effect of Temperature and Pressure of Viscolization Raw standardized cream was viscolized at both 145 and 160° F. at 500, 1000, 1500, 2000, and 2500 pounds pressure per square inch. The results given in Table 19

Table XIX. Effect of Viscolization of Standardized Raw Cream

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Fat Test of Std. Cream %	Temp. of Viscolization deg.F.	Skim Milk Layer 48 hours at 35-40° F. per cent, Viscolization Pressure Pounds: 500	1000	1500	2000	2500	Distinctness of Skim Milk Layer, Viscolization Pressure Pounds: 500	1000	1500	2000	2500
Treatment A - Viscolized at 145° F.														
1	90 - 110	48.0	20.0	145	0.75	0.3	none	none	none	D**	D**	D***	B***	G
2	90 - 110	48.0	20.0	145	0.75	none	none	none	none	D**	D+**	D***	G	G
3	90 - 110	36.0	20.0	145	none	none	none	none	none	C-**	C-**	C-***	G	G
4	85 - 110	51.5	20.0	145	none	none	none	none	none	B**	B**	B***	B***	G
Ave.		45.88	20.0							C-	C-	C-	-	G
Treatment B - Viscolized at 160° F.														
1	90 - 110	48.0	20.0	160	0.75	none	none	none	none	G	G	G	G	G
2	90 - 110	48.0	20.0	160	none	none	none	none	none	G	G	G	G	G
3	90 - 110	36.0	20.0	160	0.3	none	none	none	none	D**	E**	G	G	G
4	85 - 110	51.5	20.0	160	none	none	none	none	none	D**	F***	G	G	G
Ave.		45.88	20.0									G	G	G
Treatment C - Un-viscolized at 145° F. (Check)														
1	90 - 100	48.0	20.0			2.2					D			
2	90 - 100	48.0	20.0			2.2					D+			
3	90 - 100	36.0	20.0			1.5					B-			
4	85 - 100	51.5	20.0			2.5					D			
Ave.		45.88	20.0			2.1					C- to D+			
Treatment D - Un-viscolized at 160° F. (Check)														
1	90 - 100	48.0	20.0			1.8					D+			
2	90 - 100	48.0	20.0			1.8					D+			
3	90 - 100	36.0	20.0			1.5					D			
4	85 - 100	51.5	20.0			1.9					B			
Ave.		45.88	20.0			1.75					C-			

** Small layer

***Trace

show that low pressures greatly reduced the amount of "Creaming off" as compared with the unviscolized cream and that the volume of the layer was reduced by increases in pressure until the layer was entirely eliminated. Since "Creaming off" was sometimes noted in the bottles where no separation of cream and serum was apparent in the cylinders this was tabulated in the results. A "Small layer" indicates that an appreciable amount of separation took place and would probably be noticed by the cream buyer. A "Trace" indicates a very small layer, often noticed only after careful observation of the samples and would probably never be evident to the consumer. It was found that at low pressures where the cream layer was not entirely eliminated, the small remaining layer was generally more distinct than the check, un-viscolized samples. Viscolization at 160° F. as compared with viscolization at 145° F. generally gave a less distinct skim milk layer at low pressures, when a serum layer appeared. The layer was also usually entirely eliminated at a lower pressure when processed at 160° F. as compared to 145° F., thus indicating that viscolization is more efficient at high than at low temperatures. Viscolizing raw cream at 1500 pounds pressure per square inch at 145° F. or 1000 pounds pressure at 160° F. ordinarily eliminated the skim milk layer entirely or reduced the layer to the extent that it would probably have passed unnoticed by the consumer.

Effect of Viscolizing High Test Cream   Attempts to eliminate the skim milk layer by viscolizing high test cream before standardizing with unviscolized milk proved unsuccessful as shown by the results given in Table 20. As compared with the un-viscolized cream in Table 19, the skim milk layer was always considerably reduced in volume due to this treatment. The treatment, however, gave a much more distinct skim milk layer, thus overcoming the advantage of the reduced volume. In the first run of this series with 51.5 per cent cream, viscolizing at 1500 pounds pressure per square inch, gave cream so viscous that it could hardly be poured and resembled partly whipped cream. It was found that even this high fat content cream, when standardized with un-viscolized milk, gave an appreciable skim milk layer. Since 1500 pounds pressure gave cream too heavy to handle well in the first lot, viscolization of high test cream at this pressure was discontinued.

It was always apparent that the higher the pressure and the higher the fat content, the greater was the viscosity of the cream.

Effect of Viscolizing Only a Portion of the Cream As has already been shown, viscolizing 20 per cent cream at 2500 pounds pressure always entirely eliminated the skim milk layer. Comparing the results with those obtained with un-viscolized cream, it was found that mixing 10 per cent of viscolized cream with un-viscolized cream decreased the volume from 2.1 to 1.18 per cent or approximately 44 per cent. The treatment had no significant influence on the distinctness as compared with the check samples which had not been viscolized. The results of the mixed samples are given in Table 21 and may be compared with the un-viscolized samples in Table 19.

Feathering

Feathering tests run on three of the four series of viscolized cream gave no feathering whatsoever even when the cream had been processed at a pressure of 2500 pounds per square inch.

Table XX. Effect of Viscolizing Raw Cream before Standardizing with Un-viscolized Raw Milk

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Fat Test of Standardized Cream per cent Pressure of Viscolization in pounds			Temperature of Viscolization deg. F.	Skim Milk Layer 48 hours at 35-40° F. per cent Pressure of Viscolization in pounds			Distinctness of Skim Milk Layer Pressure of Viscolization in pounds		
			500	1000	1500		500	1000	1500	500	1000	1500
1	85 - 110	51.5	20.5	20.0	20.0	145	1.5	1.0	1.0	A	A	A
2	90 - 100	36.0	20.5	20.5	-	145	1.2	0.9	-	A	A	-
3	90 - 100	48.0	21.0	18.5	-	145	1.3	1.4	-	B	B+	-
4	90 - 100	48.0	21.0	22.0	-	145	1.3	1.0	-	B	A	
Ave.		45.88	20.75	20.25			1.33	1.08		A- to B+	A to A-	A

Table XXI. Effect of Viscolizing a Portion of the Cream at High Pressure

(2500 pounds)

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Fat Test of Standardized Cream %	Temperature of Viscolization degrees F.	Pressure of Visco-lization pounds	Skim Milk Layer 48 hours at 35-40°F. 10% viscolized 90% un-viscolized	Distinct-ness of Skim Milk Layer
1	90 - 100	48.0	20.0	145	2500	1.5	D+
2	90 - 100	48.0	20.0	145	2500	1.5	E
3	90 - 100	36.0	20.0	145	2500	0.7	C
4	85 - 110	51.5	20.0	145	2500	1.0	C
Ave.		45.88	20.0			1.18	D+

Effect of Addition of Salts

Detailed results of the addition of sodium carbonate, calcium chloride, di-calcium phosphate, sodium citrate, mono-calcium phosphate, and the check cream samples, both diluted with water equal to the various amounts of the salt solutions added, and undiluted cream, are shown in Tables 22 to 27 inclusive. The averages of these results are given in Table 28. The addition of 0.1 per cent sodium carbonate gave a considerably increased volume and a slightly more distinct layer than the check samples. The addition of 0.3 and 0.5 per cent decreased the amount as compared with 0.1 per cent but a partial precipitation of the curd took place as demonstrated by the clear whey which was left in the bottom instead of the usual serum. The addition of calcium chloride in the various amounts apparently had no marked influence on the amount of the serum layer, but 0.3 and 0.5 per cent resulted in a less distinct layer. Di-calcium phosphate in the amounts added apparently had no measurable effect on either the amount or distinctness of the skim milk layer. One-tenth per cent sodium citrate evidently had no marked effect on the volume or distinctness of the layer, but 0.3 and 0.5 per cent increased both the volume and distinctness to a very marked extent. This may have been due to a partial precipitation of the casein for the serum was only slightly milky at the bottom indicating that the greater portion of the casein had been carried up with the fat.

The addition of 5 cc., 15 cc. and 25 cc. of a saturated mono-calcium phosphate solution increased the volume of the serum with a very great increase in volume with the most concentrated sample. This salt also re-

Table XXII. Effect of Addition of Salts to Pasteurized Cream

I. Sodium Carbonate

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Fat Test of Standardized Cream %	Skim Milk Layer 48 hours at 35–40° F. per cent — per cent Sodium Carbonate .1	.3	.5	Distinctness of Skim Milk Layer — per cent Sodium Carbonate .1	.3	.5
1	90 - 100	45.0	145	30	20.0	3.3	2.0	2.0	C+	A+**	A+**
2	90 - 100	45.0	145	30	20.0	2.9	2.0	2.0	C+	A+**	A+**
3	90 - 100	44.0	145	30	20.0	4.2	2.5	2.0	B-	A+**	A+**
4	90 - 100	44.0	145	30	20.0	4.0	2.6	1.8	B-	A+**	A+**
Ave.		44.5				3.6	2.28	1.95	B- to C+	A+	A+

Table XXIII. II. Calcium Chloride

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Temp. deg.F.	Time Min.	Fat Test of Standardized Cream %	per cent Calcium Chloride .1	.3	.5	per cent Calcium Chloride .1	.3	.5
1	90 - 100	45.0	145	30	20.0	1.6	1.5	1.5	C-	D	D
2	90 - 100	45.0	145	30	20.0	1.6	1.5	1.5	C-	D	D
3	90 - 100	44.0	145	30	20.0	2.0	2.0	2.0	C-	D	D
4	90 - 100	44.0	145	30	20.0	1.8	2.0	2.0	C-	D	E
Ave.		44.5				1.75	1.75	1.75	C-	D	D-

** Clear whey at bottom

Table XXIV. Effect of Addition of Salts to Pasteurized Cream

III. Di-calcium Phosphate

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Fat Test of Standardized Cream %	Skim Milk Layer 48 hours at 35–40° F. per cent — per cent Di-calcium Phosphate .1	.3	.5	Distinctness of Skim Milk Layer — per cent Di-calcium phosphate .1	.3	.5
1	90 - 100	45.0	145	30	20.0	2.0	1.8	1.8	D+	C-	C-
2	90 - 100	45.0	145	30	20.0	2.0	1.8	1.7	D+	C-	C-
3	90 - 100	44.0	145	30	20.0	2.0	1.8	2.0	C-	C-	C-
4	90 - 100	44.0	145	30	20.0	1.8	2.0	2.0	C-	C-	C-
Ave.		44.5				1.95	1.85	1.88	C- to D+	C-	C-

Table XXV. IV. Sodium Citrate

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Temp. deg.F.	Time Min.	Fat Test of Standardized Cream %	per cent Sodium Citrate .1	.3	.5	per cent Sodium Citrate .1	.3	.5
1	90 - 100	45.0	145	30	20.0	1.5	2.8	2.5	C-	A+**	A+**
2	90 - 100	45.0	145	30	20.0	1.5	2.8	2.5	C-	A+**	A+**
3	90 - 100	44.0	145	30	20.0	1.9	3.7	5.0	C-	A+**	A+**
4	90 - 100	44.0	145	30	20.0	1.7	4.0	3.8	C-	A+**	A+**
Ave.		44.5				1.65	3.33	3.45	C-	A+	A+

** Whey slightly milky at bottom

Table XXVI. Effect of Addition of Salts to Pasteurized Cream

V. Mono-calcium Phosphate - Saturated Aqueous Solution

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Time Min.	Fat Test of Standardized Cream %	Skim Milk Layer 48 hours at 35-40° F. per cent, number cc. Mono-calcium Phosphate 5	15	25	Distinctness of Skim Milk Layer, number cc. Mono-calcium phosphate 5	15	25
1	90 - 100	45.0	145	30	20.0	2.0	1.5	8.0	D+	D**	D ***
2	90 - 100	45.0	145	30	20.0	1.8	1.5	8.5	D+	D**	D ***
3	90 - 100	44.0	145	30	20.0	2.5	3.0	9.0	C-	D**	D+***
4	90 - 100	44.0	145	30	20.0	3.0	3.0	7.5	C-	D**	D ***
Ave.		44.5				2.33	2.25	8.25	C- to D+	D	D

Table XXVII. VI. Check Samples

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Temp. deg.F.	Time Min.	Fat Test of Standardized Cream %	No. cc. Water Added to 500 cc. Sample: none	5	15	25	No. cc. Water Added to 500 cc. Sample: none	5	15	25
1	90 - 100	45.0	145	30	20.0	1.8	1.7	1.7	1.8	C-	C-	C-	C-
2	90 - 100	45.0	145	30	20.0	1.7	1.8	1.7	1.8	C-	C-	C-	C-
3	90 - 100	44.0	145	30	20.0	1.8	-	2.0	2.0	C-	-	C-	C-
4	90 - 100	44.0	145	30	20.0	1.8	-	2.0	2.1	C-	-	C-	C-
Ave.		44.5				1.78	1.75	1.85	1.93	C-	C-	C-	C-

** Curd slightly coagulated
*** Curd coagulated

Table XXVIII. Effect of Addition of Salts to Pasteurized Cream.

Summary Tables XXIV - XXIX Incl.

Salt Added	No. Trials	Temp. of Separation deg.F.	Fat Test of Cream %	Pasteurization of Cream Temp. °F.	Pasteurization of Cream Time Min.	Fat Test of Std. Cream %	Skim Milk Layer 48 hours at 35-40° F. per cent				Distinctness of Skim Milk Layer			
							per cent salt added				per cent salt added			
							None	.1	.3	.5	None	.1	.3	.5
Sodium Carbonate	4	90-100	44.5	145	30	20.0	-	3.6	2.28	1.95	-	B- to C+	A+	A+
Calcium Chloride	4	90-100	44.5	145	30	20.0	-	1.75	1.75	1.75	-	C-	D	D-
Di-calcium Phosphate	4	90-100	44.5	145	30	20.0	-	1.95	1.85	1.88	-	C- to D+	C-	C-
Sodium Citrate	4	90-100	44.5	145	30	20.0	-	1.65	3.33	3.45	-	C-	A+	A+
							cc. solution added				cc. solution added			
							None	5	15	25	None	5	15	25
Mono-calcium Phosphate	4	90-100	44.5	145	30	20.0	-	2.33	2.25	8.25	-	C- to D+	D	D
							cc. water added				cc. water added			
							None	5	15	25	None	5	15	25
Check Samples	4	90-100	44.5	145	30	20.0	1.78	1.75	1.85	1.93	C-	C-	C-	C-

duced the distinctness of the layer to a slight extent, particularly when 15 cc. and 25 cc. additions of the solution were made. The 15 cc. concentration caused a slight precipitation of the curd, and the 25 cc. concentration caused a considerable precipitation which was noticed during the agitation of the samples at the time the solution was added.

Effect of Addition of Gelatin

Very interesting results were obtained by adding small amounts of gelatin as Table 29 indicates. It was found that by adding 0.1 per cent gelatin, the amount of the layer was probably increased slightly, although accurate readings were difficult due to the fact that this amount of the colloid gave a layer of considerable less distinctness than the check samples containing no gelatin. Two-tenths per cent gelatin on the other hand gave a reduction of approximately 25 per cent in the skim milk layer volume as compared to the check sample but showed a layer of much greater distinctness. With the exception of one trial where a trace of layer was evident, it was found that 0.3 per cent gelatin eliminated and 0.4 per cent always entirely eliminated the layer.

Effect of Addition of Evaporated Milk and Skim Milk Powder

Since it is understood that condensed milk solids are being added at a few commercial plants in an attempt to control the skim milk layer in bottled cream trials were made to determine the effect of adding evaporated milk and skim milk powder. These were added in 0.5, 1.0, 2.0, and 5.0 per cent amounts with the results given in Table 30. One-half

Table XXIX. Effect of Addition of Gelatin to Raw Milk Prior to Separation

Trial No.	Fat Test of Milk %	Temp. of Separation °F.	Fat Test of Cream per cent: Per cent Gelatin added to milk					Skim Milk Layer 48 hours at 35–40° F. per cent: Per cent Gelatin added to milk					Distinctness of Skim Milk Layer: Per cent Gelatin added to milk				
			None	0.1	.2	.3	.4	None (check)	0.1	.2	.3	.4	None (check)	0.1	.2	.3	.4
1	3.5	145	21.0	22.0	24.0	25.0	25.5	2.3	2.0	1.7	0.4	None	B	C–	A	A**	G
2	3.5	145	–	21.5	22.0	23.0	–	–	2.0	1.6	None	None	–	C–	A	G	–
3	3.6	145	20.5	22.0	22.0	22.5	23.0	2.8	3.0	0.8	None	None	C	F+	A	G	G
4	3.6	145	–	21.5	21.5	21.5	–	–	3.0	1.5	None	–	–	F+	A	G	–
5	3.5	145	20.0	21.0	21.0	21.5	21.5	2.0	3.0	1.2	None	None	C	D	A+	G	G
6	3.5	145	–	20.5	21.0	21.5	–	–	3.0	1.7	None	–	–	D	A	G	–
Ave.	3.53		20.5	21.4	21.9	22.5	23.3	2.37	2.66	1.42			C+	D–	A	–	G

** Trace

Table XXX. Effect of Addition of Evaporated Milk to Pasteurized Cream

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Fat Test of Std. Cream per cent	Skim Milk Layer 48 hours at 35-40° F. per cent — Per cent Evaporated Milk Added: None	.5	1.0	2.0	5.0	Distinctness of Skim Milk Layer — Per cent Evaporated Milk Added: None	.5	1.0	2.0	5.0
1	90 - 100	45.0	145	30	20.5	2.0	2.0	1.5	1.5	None	D	C-	D	E	G
2	90 - 100	45.0	145	30	20.5	2.0	2.0	1.5	1.5	None	C	C-	D	E	G
Ave.		45.0			20.5	2.0	2.0	1.5	1.5		C-	C-	D	E	G

Table XXXI. Effect of Addition of Skim Milk Powder to Pasteurized Cream

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream %	Temp. deg.F.	Time Min.	Fat Test of Std. Cream per cent	Per cent Skim Milk Powder Added: None	.5	1.0	2.0	5.0	Per cent Skim Milk Powder Added: None	.5	1.0	2.0	5.0
1	90 - 100	45.0	145	30	20.5	2.0	2.0	2.0	2.0	None	D	C	C-	D	E
2	90 - 100	45.0	145	30	20.5	2.0	2.0	2.0	2.0	None	C	C	C-	D	E
Ave.		45.0			20.5	2.0	2.0	2.0	2.0		C-	C	C-	D	E

per cent of evaporated milk had no marked influence on either the volume or distinctness of the layer. The amount was apparently decreased some and the distinctness decreased to a considerable extent by one and two per cent additions, the effects being greater when two per cent was added. The addition of five per cent of evaporated milk eliminated the layer entirely.

The results fail to indicate that the skim milk powder, in any of the percentages added had an influence on the amount of the layer although accurate observations were difficult when the larger amounts were added. No separation was evident in the cylinders when five per cent powder was added, but a layer was discernible in the bottled cream. It was apparent, from the results, that although from one to five per cent skim milk powder was an aid in lessening the distinctness of the skim milk layer, powder did not eliminate it entirely as did evaporated milk added at the rate of five per cent.

Effect of Addition of Casein

The results of four trials in adding 0.5 per cent casein are given in Table 32, and indicate clearly that casein, added in this amount, increased the volume of the skim milk layer. The check samples gave an average layer of 1.75 whereas the sample to which casein had been added averaged 3.88 per cent. There was, therefore, an increase in the layer of approximately 120 per cent due to the addition of casein. There also seemed to be a tendency for the distinctness of the layer to be increased although this effect was not pronounced.

Table XXXII. Effect of Addition of Casein to Cream

Trial No.	Temperature of Separation degrees F.	Fat Test of Cream per cent	Pasteurization of Cream Temp. deg.F.	Pasteurization of Cream Time Min.	Fat Test of Std. Cream per cent	Skim Milk Layer 48 hours at 35–40° F. per cent: Check	Skim Milk Layer 48 hours at 35–40° F. per cent: 0.5 per cent casein	Distinctness of Skim Milk Layer: Check	Distinctness of Skim Milk Layer: 0.5 per cent casein
1	90 - 100	45.0	145	30	20.0	1.8	3.0	C-	C
2	90 - 100	45.0	145.	30	20.0	1.6	3.2	C-	C
3	90 - 100	44.0	145	30	20.0	1.8	4.8	C-	C+
4	90 - 100	44.0	145	30	20.0	1.8	4.5	C-	C+
Ave.		44.5			20.0	1.75	3.88	C-	C to C+

DISCUSSION

In view of the results obtained in this study it is impossible to explain many of the findings upon our present limited theories in regard to cream rising. Some of the results tend to complicate, rather than to simplify, the search for the fundamental causes responsible for the phenomena of cream rising.

The results obtained from separating fresh milk at various temperatures indicate that the condition of the fat at the time of separation had an influence upon the distinctness of the skim milk layer. The layer was most distinct when the separation was done under conditions when the fat globules were partially in the solid and partially in the liquid state. These results support the belief that the distinctness, in this case, is due to a more exhaustive rising of the fat globules made possible by the influence of the separator in aiding the clumping of the globules under these conditions. The obtaining of the least distinct layer at 120° F. is probably best explained as being due to the greater amount of breaking up of the fat globule clusters, and possibly also, to the breaking up of the globules themselves, to a slight extent, at this temperature.

It was always noted that heating either the whole milk prior to separation, the cream following separation, or the skim milk before its use in standardizing raw cream always resulted in a more distinct skim milk layer. Pasteurizing the raw skim milk before standardizing raw cream always gave a more distinct serum layer than pasteurizing the cream before standardizing with raw skim milk. These results on the distinctness were obtained whether there was a measurable change in the volume of the serum layer or not, although in many cases the layer was decreased.

The effect of heat treatment of the milk and the cream on the volume of the skim milk layer is difficult to correlate with any definite cause because of variations in results. In general, however, when there was a measurable effect on the skim milk layer volume, due to the heat treatment, there was a decrease in volume. A more distinct skim milk layer, as well as a layer of less volume was, in general, the result of heating the milk and cream. This relationship between the volume of layer and its distinctness is to be expected as greater grouping of the fat clusters in cream rising make both for an increased cream layer, or less serum layer, and also for a more exhaustive creaming, which promotes a more distinct cream line.

It is well to keep in mind, nevertheless, that the volume of the cream that is formed is probably dependent upon the exhaustiveness of creaming and upon the size and rigidity of the clusters that are formed. The latter is, without doubt, far more important in affecting the volume of the skim milk layer in cream. The former, while probably of considerable importance in milk, is of minor importance in affecting the volume of the skim milk layer in cream, due to the relatively small volume of this layer.

The explanation of a decreased serum layer, as well as a more distinct one, in cream, as a result of pasteurization is a difficult one to make. The results indicate greater clustering of the fat globules, as a result of pasteurization which is just opposite the effects that have been obtained in milk. The increased concentration of fat globules in cream as compared to milk, which would make for greater chance of contact and, therefore, greater coalescence of the globules in cream as compared to milk, may be a factor in explaining the results obtained. The elimination through separation of the small residual fat globules, which are continually in motion due to Brownian movement, may also be a factor as their movement would probably aid in preventing the permanent coalescence of the fat globules and might even disintegrate forming clusters.

Differences in interfacial tension and adsorption may also be involved. It is possible that there may be a change in the ratio of albumin and globulin to calcium caseinate brought about by separation and concentration of the fat. It has been demonstrated, as was shown in the review of literature, that the whey colloids, lactalbumin and lacto-globulin aided cream rising, whereas calcium caseinate was a deterrent to cream rising, and the effect of each was increased by pasteurization.

It has been stated in the literature that the fat actually seems to protect milk against the detrimental effects of pasteurization. The increased fat content in cream may, therefore, be a factor in making for a more distinct skim milk layer, as well as a layer of less volume when raw cream is pasteurized. Whatever the heat action may be in cream that effects the creaming phenomena, it is apparently as complete, due to heating at 145° F. for 30 minutes as at 150°, 155°, or 160° F. for the same period.

The more distinct skim milk layer due to pasteurization may possibly be due, in part at least, to a precipitation of some of the serum

colloids, probably calcium caseinate, and the removal of a large part of this precipitate from the skim milk layer through a filtering action exerted by the large clusters of fat globules formed in the cream. The increased distinctness as a result of pasteurizing the skim milk used to standardize raw cream supports the belief that the effect of heat upon the distinctness is an effect upon the serum and, therefore, lends evidence in favor of this explanation.

The precipitation of the same colloidal constituent or constituents, into larger aggregates on aging at low temperature, possibly as a result of change in hydrogen ion concentration, would also help to explain the results secured in which it was noted that the distinctness decreased after 48 to 72 hours creaming. Here the fat has already risen and the precipitated colloids would be left in the serum. The change in size of the particles would account for a change in the appearance of the serum layer.

The opposite effect of high temperature pasteurization, 170° F. for 20 minutes, on the cream, which gave increased skim milk layer volumes may have been due to the "oiling off" of some of the fat which was observed to occur. This pasteurization was done by setting the cans in hot water and stirring frequently.

Re-pasteurization of cream from pasteurized milk apparently did not enhance the effect of heating the milk to any appreciable extent. This indicates that the effect of heat is complete, or nearly so, as a result of the first exposure.

The more distinct skim milk layer formed as a result of agitating after storing and standardizing after 24 hours storage may have been due, in part at least, to the fact that the fat globule clusters, which had formed, were not easily broken up by agitation at a cold temperature. These large clusters may have exerted a filtering action on the single globules and very small clusters. This would result in a more complete separation of the fat from the serum and would, therefore, give a more distinct skim milk layer. The increased distinctness as a result of viscolizing only a portion of the cream can also be explained on this basis as viscolizing at 145° F. is known to create large clumps of fat. The smaller serum volume in case of the standardized cream, which was handled with a minimum of agitation, was probably due to little breaking up of clusters that had formed. Since these clusters were of hardened fat they were quite rigid and would not pack closely, thereby increasing the cream volume and reducing the skim milk layer. When the cream was thoroughly agitated the clusters were broken up to a greater extent and, therefore, the smaller clusters packed more closely giving a greater skim milk layer.

The increase in volume of the skim milk layer on standing after some 48 to 72 hours was, without doubt, due to the gradual closer packing of the fat globule clusters.

The increased volume and decreased distinctness of the skim milk layer resulting from increases in temperature of creaming were probably due both to a less exhaustive creaming, and to a closer packing of the globules since the higher temperatures give a less rigid structure to the fat clusters.

The explanation of the greater efficiency of viscolization at 160° F. as compared to 145° F. was probably due to greater dispersion and less clumping of the fat globules at the higher temperature.

Since the higher the pressure and the higher the fat content, the greater the viscosity of the cream obtained by viscolization, it indicated that greater fat clumping takes place with increases in pressure and percentage of fat, assuming that the increase in viscosity may be attributed both to the clumping of the fat globules and to a fixation of a portion of the serum through adsorption and also to the trapping of some serum within the clusters.

The mechanism of the action of gelatin is not thoroughly understood. It is believed that the addition of 0.2 per cent gelatin accelerated the clumping as a result of adsorption while the separation of free serum is entirely eliminated by the addition of from 0.3 to 0.4 per cent due to the gelatine colloid greatly increasing the viscosity, thus preventing the rising of the fat globules. The results of adding 0.1 per cent gelatin indicated that limited adsorption of the colloid may be a deterrent to fat clumping and cream rising.

The cause of the effect of adding evaporated whole milk and powdered skim milk in decreasing the separation of the serum layer is not completely understood. The increase in viscosity, however, is believed to be a contributing factor.

Though the skim milk layer was not always most distinct under conditions causing a decreased layer, in general, there was an inverse relationship between the volume and distinctness of the layer.

Until very small layers amounting only to a trace were formed, as was obtained in the results of viscolization, it is believed from observations on this work, that the distinctness is as important a factor as the volume in drawing the attention of the consumer to the existence of the layer.

The writer is aware of the impossibility of explaining satisfactorily in all cases the results obtained in this study. Milk is one of the most complex natural appearing colloids and, for that reason, since little is yet definitely known concerning the complex phenomenon of cream rising, it is realized that many unknown, but yet fundamental factors may be exerting an influence that cannot be eliminated from the experiment. The complexity of it all makes definite explanations difficult. The above discussion is, therefore, offered as a possible partial explanation of some of the results obtained after careful consideration of the many factors involved.

CONCLUSIONS

1. The separation of fresh milk, after receiving at 55° to 65° F., at temperatures ranging from 90° to 180° F. had little influence on the volume of the skim milk layer. Separating at the receiving temperature resulted in an increased skim milk layer as compared to the higher temperatures of separation.

Freshly received milk gave a more distinct skim milk layer when separated at the receiving temperature, 55° to 65° F., or when raised to 90° F. than when separated after raising to 120 or 145° F. Fresh milk heated to 120° F. and separated at that temperature gave a less distinct layer than when separated at any other temperature. When the milk was cooled from pasteurization temperature, however, and separated at 120° and 90° F. there was no measurable difference in distinctness.

2. Storing milk at a low temperature prior to separation at 80°, 90°, 120°, and 145° F., had little influence upon the volume of the skim milk layer appearing in cream as compared with that secured from fresh milk. When separated at 60° F. the stored milk gave a reduced layer as compared to that obtained from fresh milk. Separation of fresh milk at 55° to 65° F. gave a more distinct layer than did old milk separated at 60° F. Storing had no appreciable influence on the distinctness of the serum layer at the 90°, 120°, and 145° F. temperatures of separation.

3. Heating milk prior to separation at temperatures of 145° F. for 30 minutes and 180° F. momentarily had no marked effect upon the volume of the skim milk layer. Pasteurizing milk at 160°F. for 15 minutes decreased the volume of the layer.

Heating the milk to 145° F. momentarily before separation increased the distinctness of the skim milk layer as compared with lower temperatures. Holding the milk for 30 minutes at 145° F. or pasteurizing at higher temperatures increased the distinctness of the layer. The higher temperatures of pasteurization, 160° and 180° F., did not appreciably change the distinctness as compared with the usual exposure of 145° F.

4. Pasteurizing raw cream at 145°, 150°, 155°, and 160° F. for 30 minutes decreased the volume and increased the distinctness of the skim milk layer. The different temperatures of pasteurization had no apparent effect on either the volume or the distinctness of the layer.

5. Pasteurizing cream standardized to 20 per cent, secured from milk pasteurized at 145° and 160° F. for 30 minutes had no appreciable effect either on the volume or on the distinctness of the skim milk layer.

6. High temperature pasteurization, 170° F. for 20 minutes, of high test cream before standardization as compared to the same treatment on the skim milk before standardization, gave little difference in the volume of the skim milk layer, whereas, high temperature pasteurization of the standardized cream gave a greatly increased layer. This was true with both raw products and products secured from pasteurized milk.

Pasteurizing the raw skim milk at high temperatures before standardizing gave a more distinct serum layer than when pasteurizing the raw high test cream before standardizing or when pasteurizing the standardized 20 per cent cream. There was no marked difference in the distinctness of the serum layer due to the exposure of the high test cream and skim milk secured from pasteurized milk to high temperatures prior to standardization.

7. Standardization of pasteurized cream with raw whole milk, with pasteurized whole milk and with skim milk secured from pasteurized milk gave no appreciable differences in the volume of the skim milk layer. Standardization with raw whole milk gave a less distinct layer than standardization either with pasteurized whole milk or with skim milk secured from pasteurized milk. There was no apparent difference in distinctness when pasteurized whole milk and when skim milk from pasteurized milk were used in standardization.

8. No definite conclusions can be drawn in regard to the effect of standardizing back high test cream as compared to separating low test cream on the volume of the skim milk layer, although there seemed to be a tendency for the cream standardized back to give a slightly greater layer. There was no apparent difference in the distinctness of the layer between the standardized and unstandardized cream.

9. There was little difference in either the amount or the distinctness of the skim milk layer as a result of standardizing raw cream with raw whole milk as compared to standardizing with raw skim milk.

10. Standardization after pasteurizing the cream and the milk at 145^{o} F. for 30 minutes gave a skim milk layer of slightly less volume than when the cream was standardized previous to pasteurization. There seemed be little difference in the distinctness as a result of the two methods.

11. The temperature of the milk and cream at the time of standardization had no measurable influence upon either the volume or the distinctness of the skim milk layer.

12. Standardization of milk and cream stored at a low temperature for 24 hours gave a skim milk layer of slightly less volume and a layer of considerably increased distinctness when compared with the layer in cream standardized with fresh milk and cream.

13. Agitating pasteurized cream which had been stored at 35 to 40° F. for 24 hours had no significant influence upon the volume of the serum layer. The layer was more distinct than that in the cream set fresh.

14. The speed of cooling pasteurized cream apparently had little effect upon the volume, or the distinctness of the skim milk layer.

15. An increase in the temperature of creaming above 32° F. increased the volume and decreased the distinctness of the skim milk layer.

16. The volume of the skim milk layer increased gradually and with decreasing rate as the cream was held. The distinctness seemed to increase for some 48 to 72 hours and then gradually decreased.

17. Viscolizing cream at 2500 pounds pressure always eliminated the serum layer. Low pressures reduced the volume of the layer but increased its distinctness.

Viscolizing at 160° F. at all pressures was found to be more efficient than viscolizing at 145° F. When the serum layer appeared it was always less distinct at low pressures. Furthermore, the layer was eliminated entirely at a lower pressure when processed at 160° F. than when processed at 145° F.

18. Viscolizing high test cream and standardizing with unviscolized milk greatly reduced the volume of the skim milk layer, but greatly increased the distinctness of the layer.

19. Mixing 10 per cent of cream viscolized at 145° F. with unviscolized cream reduced the layer almost 50 per cent as compared with the layer forming on unviscolized cream. The distinctness was not influenced to any marked extent.

20. The salts added gave various results. Di-calcium phosphate apparently had no influence either upon the volume or upon the distinctness of the layer. Calcium chloride, while having no apparent effect upon the volume, decreased the distinctness to some extent. The other salts added, sodium citrate, sodium carbonate, and mono-calcium phosphate apparently did not influence "creaming off" until amounts were added that partially or totally precipitated the casein.

21. The addition of 0.1 of one per cent gelatin decreased the distinctness and apparently increased the amount of the layer. Two-tenths of one per cent gelatin reduced the amount of the layer considerably, but gave a very distinct skim milk layer. From 0.3 to 0.4 of one per cent entirely eliminated the separation of the serum from the cream.

22. Skim milk powder, in the amounts added failed to have a measurable effect upon the volume of the skim milk layer. The distinctness became less with increases in the amount of the skim milk pwoder added. The addition of five per cent of the powder, although it did not eliminate the layer, reduced its distinctness to a great extent.

23. The addition of five per cent evaporated whole milk entirely eliminated the serum layer. Smaller amounts, down to one per cent, reduced both the volume and the distinctness of the layer. The influence was greaer on the distinctness than on the volume.

24. The addition of 0.5 of one per cent casein increased the volume of the layer and apparently increased the distinctness slightly, although not to a pronounced extent.

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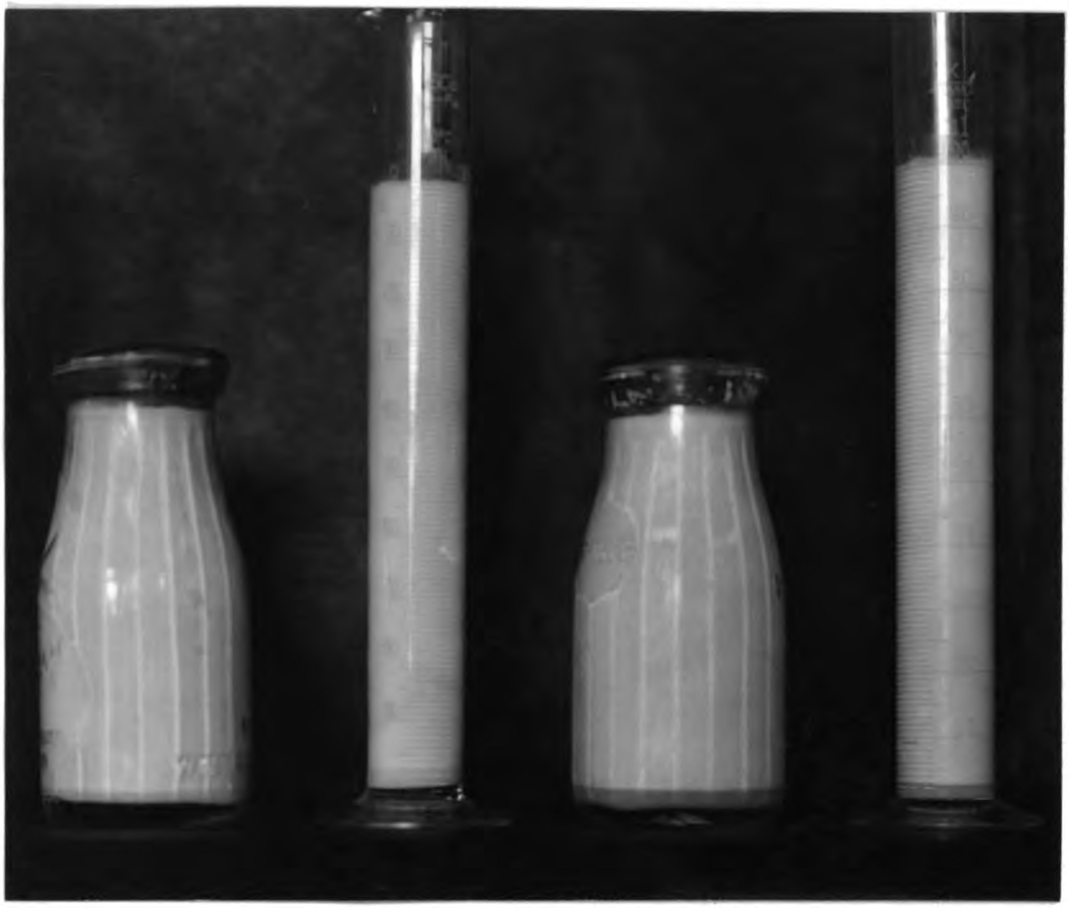

Showing the Separation of the Skim Milk Layer from Cream

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