THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Elmer Olin Anderson for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

O. H. Eckles
Chairman

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Date July 8 1922

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THE UNIVERSITY OF MINNESOTA

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Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Elmer Olin Anderson final oral examination for the degree of

Master of Science.

We recommend that the degree of

Master of Science

be conferred upon the candidate.

C. H. Eckles
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PHYSICAL-CHEMICAL FACTORS INFLUENCING CREAM RISING OF MILK

BY

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Introduction

The essential qualities of market milk which appeal to the consumer are richness, cleanliness, sweetness and safety. From the standpoint of protecting the health of the consumer the most important of these qualities is safety. Pasteurization of milk is generally accepted as a means of providing a safe milk supply for the public not because it is ideal but because it is practicable.

In order to keep the milk free from contamination after pasteurization the milk bottle has come into common use. With the use of this type of container the appearance of the bottled milk becomes an important factor among the milk dealers as well as to the public. The public desires a deep cream layer on bottled milk because the public erroneously judges the richness of the milk by the depth of the cream layer. The milk dealer who cannot supply pasteurized milk with as deep a cream layer as that of his competitors is often subjected to severe complaints by the public, that the milk is not up to the standard requirements.

The constant demand by the public for deep cream layers on pasteurized milk has resulted in the investigation of some of the factors that decrease the volume of the cream layer. The results of various investigators have shown that by careful handling of the milk before, during and after pasteurization, cream volumes of sufficient depth can be secured which will satisfy the consuming public.

However, it is not at all uncommon to find samples of milk with the same percentage of fat showing differences in the depth of the cream layer on both raw or pasteurized milk. In pasteurized milk the underlying cause may be due to differences in the methods of processing or to the effect of heat on the different constituents of milk. If the cause for these differences can be determined, such data probably would be of value to the milk dealer in his attempts to produce milk with a deep cream layer and still be within the margin of marketing safe milk to the consumer.

Most of the previous investigations on the creaming ability of raw and pasteurized milk have been studied from the practical point of view. The effect of the influence of many of the various methods of treatment has been determined but the fundamental cause for many of the results has not been definitely established. A study of the problem makes it evident that the fundamental factors involved are for the most part physico-chemical in nature. This aspect of the problem has been given very little study. Recent advances in physical chemistry, particularly from the colloidal standpoint, make it possible, however, to study the variations in the creaming of milk from these newer points of view.

Review of Literature

Before reviewing the literature it would be well to differentiate between two phrases commonly confused when reference is made to the depth of the volume of cream that rises to the surface of bottled milk. The phrases "cream line" and "cream layer" have been used synonymously. Harding (1921) differentiates between the "cream layer" and the "cream line", stating that, "As the cream layer forms there is developed a more or less distinct line of demarkation between the layer of cream and the fat-poor milk below. This line of demarkation is quite properly called the cream line." In this work when reference is made to the "cream line", it is meant the line of demarkation between the layer of cream and the lower layer or skim milk.

Further, when reference is made to the "cream layer", it is meant the depth of the cream rising to the top of the milk. A few writers are quoted who have used the term "cream line" when "cream layer" is actually meant.

Factors Influencing Cream Rising of Raw Milk

Factors such as the viscosity, the percentage of solids-not-fat, and the size of the fat globules, which influence the depth of the cream layer are applicable to both raw and pasteurized milk; therefore, they will be discussed under the heading, "Factors Influencing Cream Rising of Pasteurized Milk".

As pasteurization of milk was not used extensively by milk dealers until the twentieth century the early investigations regarding cream rising of milk dealt with the readiness and completeness with which cream would rise on raw milk when set in deep and shallow pans. Thus, Babcock (1891) found when milk contained a high percentage of fat there was less loss in the skim milk, the loss in the skim milk increasing as the percentage of butterfat decreased. The percentage of fat in the skim milk in the former case was .12 per cent and increased to .44 per cent for the low testing milk. Babcock also found that delayed setting of milk for creaming was conducive to less efficient creaming but at Maine (1890) and Cornell (1891) it was found that there was practically no difference between the creaming of milk set directly after milking and that which was delayed. At these two stations it was reported that cooling milk several degrees before setting resulted in no advantage to its creaming.

Robertson (1891) observed that there was an increase in the percentage of fat lost in the skim milk with an advance in the stage of lactation of the cow. His figures from mixed milk set in deep cans in water at 38° F., show that the loss was 15.93 per cent with fresh cows while with cows from eight to eleven months in milk the loss increased to 31.11 per cent.

Whitcher (1889), Morrow and Farrington (1890), Wing and Smith (1890), Cooke (1891 a, b), Wing (1892), and others determined the efficiency of various methods used at that time.

At the New York Experiment Station (1891) an experiment was conducted which illustrates the difference in the creaming of milk differing in the relative size of the fat globules. It was found that Ayrshire milk although containing less fat was after 6.75 hours richer in fat in the lower layer or skim milk than the Jersey skim milk.

Several investigators have ascribed the cause for rapid creaming of milk to large fat globules and an irregular grouping of the same while the cause of the slower creaming milks has been ascribed to the fact that the fat globules were smaller and the characteristic grouping of the large fat globules was absent. For example, Henseval (1902) observed that the slow creaming type of milk showed

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very little grouping of the fat globules and the larger fat globules were more or less irregular in outline. The rapid creaming milk showed the presence of many fat globules, often occurring in groups. In studying a sample of milk in which the cream rose rapidly Wolff (1909) observed that the fat globules were large and irregular.

Investigating the cause of poor creaming Barthel (1903) found that when milk was churned for five minutes at 50° C. and then pasteurized at 75° C. the skim milk contained .69 per cent butterfat while the unchurned milk gave a skim milk containing .12 per cent butterfat. When the milk was churned at 5.5° C. the fat in the skim milk was the same as for unchurned milk. Barthel also found that when milk was emptied out of a vat by means of a steam ejector, the skim milk contained more fat than when emptying the vat without pressure. This result was attributed to the fact that the agitation produced by the steam ejector broke up the fat globules.

Marcas (1903, 1904) found that ordinary milk creamed completely in 6 to 8 hours at 10 to 14° C. while slow creaming milk required 12 hours at 10 to 14° C. Occasionally no difference between the layers on the two types of milk was apparent at the end of 24 hours. However, Barthel (1904) reported that more fat remained in the skim milk of slow creaming milks whether separated by gravity or centrifugal separation.

Factors Influencing Cream Rising of Pasteurized Milk

The factors influencing the cream rising of pasteurized milk are essentially the same as those influencing cream rising of raw milk with the exception that when milk is heated a change undoubtedly occurs in the physical structure of the milk.

Babcock (1889) points out that the size of the fat globules, the percentage of solids-not-fat and the temperature at which the milk is creamed influences the rising of cream and indicates that the viscosity of the milk serum hinders or accelerates the rising of the fat globules.

Stocking (1917) states that, "the conditions which most commonly affect the creaming process are size of fat globules, the percentage of solids-not-fat and the viscosity of the serum."

Heineman (1919) makes the statement that creaming is influenced by the origin of milk, the temperature at which the milk is creamed, the size of the fat globules and the viscosity of the milk.

Kilbourne (1915) investigated the causes that contribute to the loss of cream layer on pasteurized milk and found that of the various factors involved, the most important are:

1. The temperature to which the milk is heated.
2. The length of time the milk is held at the high temperature.
3. The temperature of the heating medium with which the milk comes in contact during the heating process.
4. The clarification of milk.
5. The type of apparatus used in heating milk.
6. The amount of agitation to which the milk is subjected, especially when hot.

Kilbourne believed that other factors might possibly affect the cream layer, namely:

1. The age of the milk at pasteurization.
2. The grade of the cows that produced the milk.
3. The freezing of milk before pasteurization.

Hammer (1916) gives as the external factors affecting creaming:

1. The individual animal.
2. The breed.
3. The stage of lactation.
4. The temperature at which milk is held when creaming.
5. Centrifugal separation and remixing.

The factors that tend to obliterate the cream layer in pasteurized milk according to Vanderleck (1917), are:

1. Clarification of milk.
2. Agitation of milk.
3. The temperature of the heating medium.
4. The temperature of the hot milk.
5. The length of time the milk is held at the high temperature.
6. The type of the pasteurizer.

Clement (1921) states that the factors influencing the creaming of pasteurized milk are:

1. The temperature of pasteurization.
2. The type of apparatus used.
3. The temperature and time of holding.
4. The amount of agitation, especially when hot.

Hunziker (1921 a) believes that the depth of the cream layer depends on two fundamental factors, those which control the completeness and rapidity with which the fat rises to the top and those which control the volume of non-fatty constituents carried into and held in the cream layer. The first factor deals with the readiness and completeness of fat separation and depends on the temperature and manner of heating. Regarding the first factor he states, "The albumin in the milk that comes in contact with the high temperature of heating medium is precipitated and to that extent it hinders the fat globules from rising to the surface and it diminishes the non-fatty constituents which are carried into the cream. This has a tendency to act as a network in the milk, hindering the fat globules from rising to the surface and the contraction of the albumin particles, due to heat, also makes them heavier so that the law of gravity prevents them from being carried upward into the cream." This may be true for temperatures higher than 145° F., but at this temperature no appreciable chemical changes occur, according to Rupp (1913), who finds that the albumin is not coagulated at 145° F. Babcock (1895) could find no change on heating milk at 65° C.(149° F.) and Richmond (1920) states that when milk is heated to 70° C. the albumin is not precipitated but is changed into a form "which is precipitated by acids, magnesium sulphate, and other precipitants of casein."

The second factor deals with the volume of non-fatty constituents in the cream layer and Hunziker states, "It is influenced by the manner of heating, cooling and the rapidity with which the fat comes to the top. If milk is cooled rapidly to 70° F. or lower, the cream layer is not diminished but if cooling is retarded or interrupted it is impossible to secure a good cream line. The reason appears to be the granulation or crystallization of the butterfat due to holding milk at temperatures between the solidification and melting point of the butterfat for a considerable period of time. When the butterfat granulates or crystallizes in this manner it relinquishes much of the non-fatty constituents. In this manner the volume of non-fatty constituents which the fat globules are capable of carrying into the cream line is very greatly reduced. By cooling rapidly this granulation does not seem to take place. The fat solidified in this manner incorporates the natural amount of non-fatty constituents and carries them into the cream layer."

Many of the above quoted factors influencing cream rising are essentially the same and for convenience in discussing them they have been summarized as follows: (1) the size of the fat globules; (2) the percentage of solids-not-fat in the milk; (3) the viscosity of the milk; (4) the temperature of creaming and pasteurization; (5) agitation; (6) the type of pasteurizing apparatus used; (7) miscellaneous.

Influence of the Size of Fat Globules. The fat globules rise through the milk because their specific gravity is less than that of the milk serum. Collier (1891) explained why the larger fat globules rise to the surface first by pointing out that, "the resistance which the globules meet in rising increases with the square of their diameter, while their ascensional force or bouyancy increases as their volume increases or as the cubes of their diameters." In his experiments with Jersey and Ayrshire milk he found that after about 6 hours setting the Ayrshire milk contained more fat in the lower layer.

Stocking (1917) states that the reason why milk from breeds such as the Jersey and Guernsey creams more readily than that of the Holstein and Ayrshire, is because the former breeds have a larger number of fat globules in their milk.

One can account for this difference in the creaming ability of milk from various breeds by the fact that the smaller globules have a larger surface area in proportion to their mass than the larger globules. When small fat globules are produced naturally or by breaking up the large fat globules the interfacial tension is increased momentarily. Following the increased interfacial tension the colloidal particles rush into the surface increasing the concentration of milk serum around the fat globule. This increases the weight of the film around the globule and lessens the tendency for it to rise. When this difference in interfacial tension adjusts itself the large fat globules rise more readily because of the relatively lower concentration of solid matter in the milk serum film around them.

Babcock (1889) states that "the greater difference in the specific gravity of the serum and the fat, other factors being the same, the more rapidly will the cream rise and the less the volume will it occupy after a given time. The difference in the specific gravity of the fat and the milk serum depends upon the nature and the amount of the solids-not-fat."

In milk from individual animals, Hammer (1916) found that while the cream layers varied from 17 to 29 sixteenths of an inch (the fat content varied from 3.2 to 5.4 per cent) there was no correlation between the percentage of fat and the depth of the cream layer.

Influence of the Percentage of the Solids-not-fat. - Babcock (1889) states that, "The higher the percentage of solids-not-fat in the serum the more slowly and more imperfectly will the cream separate. This condition, however, is somewhat modified by the size of the fat globules, for the resistance of the serum is much less with large fat globules than with small ones. Large fat globules and a small amount of solids-not-fat are therefore favorable to creaming, while small globules and a high percentage of solids-not-fat are opposed to creaming."

Influence of the Viscosity of the Milk. - Changes in the cream rising ability of milk have been attributed to changes in the viscosity but as far as is known by the writer no definite work has been submitted to correlate the viscosity with the changes in the depth of the cream layer.

The viscosity of milk, as pointed out by Babcock and Russell (1896), is due to the solids in solution and to the suspended substances among which they included casein and fat. Kohler (1909) states that the viscosity of milk is chiefly due to the casein of milk because when this protein was taken out of the milk serum the viscosity fell considerably. Kohler made 300 tests on the viscosity of milk (the milk being secured from various parts of Germany and produced under different conditions), and found the viscosity of milk ranged from 1.7 to 2.00 averaging 1.85 as compared with water with a value of 1.0.

Woll (1895) found that pasteurized milk has a lower viscosity than raw milk. The viscosity as determined by a Babcock viscosimeter showed a value of 265 for raw milk and 256 for the pasteurized milk.

Babcock and Russell (1903) explain this reduction in viscosity as follows, "In raw milk the fat globules are found under low power of the microscope to be more or less aggregated in clusters. On the other hand, an examination of pasteurized milk shows a homogeneous distribution of the fat globules throughout the milk."

Babcock (1889) states that, "the more viscous cream is, the more resistance will it offer to the separation of the cream and the greater will be the volume of cream after a given time."

Saeland (1905) believed that variations in the amount of cream produced on the milk could not be attributed solely to changes in the percentage of fat in the milk. According to his view, the real reason must be sought in the difference in the viscosity of milk and to changes in the physical structure of the casein.

Hunziker (1916) states that the rapid formation of the cream layer on milk heated below 145° F. is in all probability due to the fact that heat destroys the viscosity of the milk.

Heineman (1919) makes the statement that,"at low temperatures with an increased viscosity the cream is richer."

<u>Influence of Temperature of Creaming and Pasteurization.</u> - The temperature at which milk is held for creaming greatly influences the depth of the cream layer which is formed. Babcock (1889) states that a high temperature is more

favorable for creaming than a low one. Undoubtedly this is true as far as the completeness of creaming is concerned but for the development of a deep cream layer it is not true. At ice water temperature the depth of the cream layer is considerably greater than that of milk creamed at room or ice-box temperature. This difference is undoubtedly due to the packing of the fat globules.

Hammer (1916) states that there is less difference between the specific gravity of the fat and the milk serum at high temperatures and consequently the fat rises more rapidly resulting in the packing of the fat globules giving a comparatively shallow cream layer. At ice water temperatures where there exists a greater difference between the specific gravity of the fat globules and the milk serum the large fat globules rise very little faster than the smaller globules and the fat globules are thus held further apart producing a deeper cream layer. The evidence presented to support this view was that samples of milk which had creamed at ice water temperature showed a decrease in the cream layer when placed at room temperature. On the other hand samples of milk creamed at room temperature showed an increase in the depth of cream layer when placed at ice water temperature.

When milk is heated to pasteurizing temperatures, another factor is introduced which reduces the amount of cream which will rise to the top, namely that of heating. Milk heated to 145° F. decreases the cream layer to some extent but the creaming ability of such milk is entirely adequate when compared to that of raw milk, although milk dealers have considerable difficulty in securing an adequate cream layer when they say they are pasteurizing at the above mentioned temperature. When milk is pasteurized at temperatures higher than 145° F. there is a marked diminution of the cream layer and in some cases the fat globules fail to rise.

Thus, Farrington and Russell (1889) found that milk pasteurized at 140° F. gave a cream layer nearly equal to that of raw milk. When they pasteurized at 155° F. the cream layer was decreased and the cream line was less sharp.

Rosenau (1909) states that, "heating milk for half an hour at a temperature of 150° F. (65° C.) or over, has the effect of entirely preventing the rising of cream or of delaying it very materially." Later, Rosenau (1912), pointed out that, "milk may be heated to 145° F. for an hour without markedly influencing the cream line. If the milk is heated somewhat higher than this, say 148° F. for 30 minutes or for a longer time, the cream layer will blend with the milk below."

Ward (1909) reports that, "exposure to 160° F. for one minute, or longer exposure to 140° F. are both safe."

Michels (1909) makes the statement that heating of milk to 155° F. for one minute or 145° F. for thirty minutes decreases the cream layer.

Savage (1912) points out that, "at 71° C. (159.8° F.) the milk is affected and cream will not rise properly."

Weigman (1914) reports that if milk is heated to 75° C. creaming fails to take place.

Kilbourne (1916) ran a series of eight experiments conducted in as many milk plants in the city of New York and showed that milk could be heated to 145°F. and held for 30 minutes without injury to the amount of cream that rises, but was at a loss to explain why cream failed to rise in one instance when the milk was heated to 145° F.

Klein (1917) states that, "temperatures above 70° C. (158° F.) destroy the cream line entirely. A temperature of 65° C. (149° F.) for ten minutes has no effect, but as the time of exposure at this temperature is increased the formation of the cream layer is delayed more and more, until finally after 40 minutes exposure, it does not form at all. Milk may be heated at 63° C. (145.4° F.) for 30 minutes and at 60° C. (140° F.) for 50 minutes without affecting the cream layer."

Vanderleck (1917) obtained a reduction of 4 per cent in the cream layer when pasteurizing at either 142° F. or 146° F. for 30 minutes.

Richmond (1920) reports a loss of cream layer of 2.38 per cent in milk that had been pasteurized at 70° C.

Richmond and Boseley (1920) found that when milk is pasteurized at 70°C. the quantity of cream that rises is about half that of fresh milk.

Harding (1921) published the results of 401 trials on the effect of pasteurizing temperatures on the cream layer. He found, "that the cream rising on milk pasteurized at 142° F. is distinctly more abundant than that rising on milk pasteurized at 144° F. As the temperature of pasteurization rises above 144° F. the decrease in cream becomes rapidly more pronounced. Taking the volume of cream obtained at 142° F. as a basis of calculation the loss in the volume as the pasteurizing temperature is increased to 145° F. amounts to slightly more than 10 per cent; at 146° F. it has increased to 16.6 per cent; and at 148° F. it has increased to approximately 40 per cent by volume."

Several investigators have found that heating of milk sometimes enhances the depth of the cream layer and the time for complete creaming is shortened.

Thus, Kersten (1911), observed an increase in the creaming ability of milk heated for short periods of time.

Burri (1916) found when heating 100 cc. samples of milk to temperatures ranging from 55° to 62° C. and allowing them to cream in graduated cylinders at 18° C. that the rapidity of creaming was increased. In all cases the depth of the cream layer had reached its maximum at the end of two hours. After this time the depth of the cream layer decreased slightly. Burri attributes this decrease to a certain disturbance created by the fat globules during the first hour, which when it subsides naturally reduces the cream layer. In the raw milk creaming was not complete until the milk had stood 21 to 22 hours. Milk pasteurized at 61° C. produced the deepest cream layer, namely, 12.5 ccm after standing 22 hours while the raw milk produced 7.25 ccm cream. At 63° C. 1.5 ccm more cream was produced on the pasteurized milk than on the raw milk. When samples of milk were pasteurized at temperatures above 64° C. very little cream rose to the surface, there being only 1.75 ccm of cream produced after 22 hours when the cream was pasteurized at 70° C. for 30 minutes.

According to Professor Peter of the Swiss Dairy School (Hunziker 1921), heating of milk at pasteurization temperature or 145° F. for 30 minutes, does not destroy the cream layer nor diminish it but produces a deeper cream layer. Peter pasteurized different lots of milk at temperatures ranging from 131° F. to 147.2° F. The samples were placed in glass bottles graduated with a centimeter scale and allowed to cream at room temperature. The cream layers were measured at intervals of one hour. The results of these experiments show that when milk was pasteurized at temperatures ranging from 131° to 145.4° F., inclusive, creaming was more rapid than that of raw milk and the formation of the cream layer was practically complete at the end of 2 hours. The milk which had been heated to 141.8° F. for 30 minutes gave the deepest cream layer reported, namely, 12.5 cm after standing 22 hours while the raw milk produced a cream layer of 7.3 cm. In the case of milk heated to 145.4° F. for 30 minutes, the depth of the cream layer at the end of 24 hours was 7.5 cm as compared to 6.0 cm rising on raw milk. The experiments of

Burri and Peter corroborate each other.

Hammer and Hauser (1914) in their work on pasteurizing milk in bottles found that short exposures at various vat temperatures tended to increase the creaming ability of the milk, but when the milk was exposed at various temperatures long enough to kill about 99.99 per cent of the bacteria present such an increase was not observed.

The work of Kersten, Burri, Peter and Hammer and Hauser demonstrates that when heating milk below 145° F. for 30 minutes an increase in the depth of the cream layer results and the time for complete creaming is reduced.

Hammer and Hauser (1918) in their work on the uniformity of heating milk in the final package found a variation in the cream layer of 7. to 25.0 sixteenths of an inch when taking bottles indiscriminately from the three tiers of cases of milk. When they compared samples of milk taken from each tier, the top tier showed a shallower cream layer and the bottom tier a deeper cream layer with only small variations in the depth of the cream layer from bottles of the same tier. The water surrounding the top tier being at a higher temperature than that surrounding the lower tier is given as the cause for this variation, because the milk in the bottles of the top tier would be heated to a higher temperature and the creaming ability consequently reduced. To determine the amount of cream that had risen, large test tubes an inch in diameter were used, which were filled to a depth of 6 inches and placed at ice water temperature over night.

Influence of Agitation. - Under this subject the following factors have been grouped, namely: beating, agitating hot or cold milk in the vat, clarification, separation and homogenization.

The Effect of Beating. - Agitation as a factor in decreasing the rising of cream has been extensively studied, especially from the standpoint of the effect of the clarifier. Any form of agitation undoubtedly breaks up the larger fat globules. This was shown by Barthel (1904) who found that when milk was subjected to strong mechanical action it creamed less perfectly. The decrease in the volume of cream is due to the fact that the smaller fat globules which are produced rise less rapidly.

Hammer (1916) found that by beating raw milk with an egg beater for 5 or 10 minutes the cream layer decreased only slightly when the milk was creamed at room temperature. In some cases the beaten milk differed from the unbeaten milk creamed at room temperature in that the beaten milk had a cream layer with an indistinct cream line while at ice water temperature the cream seemed to be thrown into large lumps that gave the cream line an irregular appearance. When raw milk was agitated rapidly in a small shaking machine for periods of 10 to 40 minutes, Hammer found that at first there was a slight decrease followed by an increase as compared to the check sample. In the samples of agitated milk showing an increase the cream layer seemed to be foamy and this was attributed to the incorporation of air. Neither of the two forms of agitation reduced the cream layer materially.

<u>The Effect of Agitating Hot or Cold Milk in Vats.</u> - Vanderleck (1917) found that agitating milk during the pasteurization and holding process reduced the cream layer. At 143° F., for 30 minutes it was reduced 6 per cent, at 145°F. for 30 minutes the reduction was 10 per cent and at 146° F., for 30 minutes the cream layer was reduced 13 per cent. The check sample showed a cream layer of 17 per cent by volume. In two cases where the milk was pumped a "considerable distance" while hot (the milk having been pasteurized at 142-143° F., and stirred during the holding process) it showed a loss of 5 per cent in cream volume.

Harding (1921) pointed out that agitating cold milk pasteurized in a vat to distribute the fat reduced its creaming ability about one-third.

The Effect of the Clarifier. - When the clarifier was introduced in the market milk industry it was at first looked upon with disfavor because it was believed that the fat globules would be broken up by the centrifugal force when passing through the machine and consequently materially reduce the cream layer. The work that has been done shows that clarification decreases the cream layer to some extent but the decrease is too small to be of practical importance.

Kilbourne (1916) reports the result of one trial in which clarification reduced the cream layer from 19.5 per cent to 17 per cent by volume. The percentage of fat in the milk was 3.8 and the samples were creamed at ice water temperature for 11 hours.

Hammer (1916) found in 12 trials that the cream layer of raw milk was reduced from 23.9 to 22.6 sixteenths of an inch by clarification. The creaming tests were made in Nessler tubes filled to a line nine inches from the bottom and the readings were made after standing in ice water after 24 hours. He states, "A comparison of clarified and unclarified milk in bottles show practically no difference in the cream line."

In 35 trials, McInerney (1917) found that the cream layer was reduced by clarification from 10.38 per cent to 8.27 per cent by volume. He attributes this reduction to the fact that when milk passes through the clarifier some of the fat globules are broken up by the action of centrifugal force and therefore more small fat globules are present in the clarified milk than in the raw milk.

Judkins and Downs (1918) reported an average reduction in raw milk of .43 per cent by volume for 7 tests due to clarification, the milk having been creamed for 24 hours. At the end of 24 hours the difference in the cream volume between the clarified and raw milk was .36 per cent. By clarifying pasteurized milk the average reduction in the depth of the cream layer was 1.1 per cent at the end of 24 hours with the same reading at the end of 48 hours.

Clarification has little influence on the depth of the cream layer of raw or pasteurized milk according to Hammer and Hauser (1918), who found that by clarifying 21 samples of raw and 22 samples of pasteurized milk the cream layer was reduced on an average from 21.0 to 19.6 sixteenths of an inch and from 22.6 to 21.7 sixteenths of an inch respectively when the samples were held in ice water for 24 hours.

Hunziker (1921b) points out that clarification or filtering of milk does not diminish the cream layer.

The Effect of Separation and Homogenization. - The effect of separation is essentially the same as that of clarification and as it is seldom an important factor in causing a reduced cream layer in market milk its study has been limited. Hammer (1916) found that running milk through a separator and then mixing the cream and the skim milk commonly causes a slight decrease in the depth of the cream layer and in the rate of rising of the cream.

While homogenization of market milk is seldom practiced it is interesting to note that Hammer (1916) failed to secure a cream layer on milk which had been homogenized, while Parker (1917) states that a milk dealer who homogenized his cream and then returned it to the skim milk found that it formed a more bulky cream layer than before.

Influence of the Type of Pasteurizing Apparatus. - The type of pasteurizing apparatus is linked to some extent with agitation because it can influence creaming only in so far as it tends to break up the fat globules. Therefore it may not be out of place at this point to give a brief description of the types of pasteurizing units (especially their mode of operation) which are mentioned in this work.

A pasteurizing unit may consist of one or two parts. In the "flash process" there is only one heater but in the "holder process" there is a heater and also a holder. In some types of pasteurizing units the heater also serves as the holder. In the bottle process of pasteurization the heating and holding is accomplished in one machine. Kilbourne (1916) and also Ayres (1912) have grouped the different types of pasteurizers according to their mode of operation and in general the following discussion is in accordance with their arrangement.

Types of Heaters. - A type of heater used by Kilbourne (1916) in his experiments, the results of which will be discussed later, consisted of a cylinder surrounded by a water jacket which is heated by a steam discharge into the water pipe connected thereto. Within the cylinder is a revolving drum to which the milk is carried through the milk outlet, and which in revolving, by centrifugal action spreads the milk in a film over the surface. This film passes between the drum and the hot water jacket and is finally discharged through the outlet with a force sufficient to raise it several feet.

In the tubular type of pasteurizer the milk flows through tubes which are encased by another tube usually heated by hot water, the water being heated by a steam jet introduced into the water before it enters the tubes. The hot water flows in the opposite direction to that of the milk, thus utilizing the maximum heating power of the water and raising the temperature of the milk gradually.

Another type of pasteurizer is commonly known as the tank or batch system of heating milk. Various makes of vats have been placed on the market, some of which are insulated and heated by hot water jackets and in others by revolving screws or coils of pipe. These vats may be used as a heater, holder or cooler. Another vat system is known as the "spray vat system" in which one tank is contained within another but instead of being cooled by a water jacket filling the space between the inner and outer tank, it is cooled by a spray of cold water from a pipe that runs along its upper edge, the spray being delivered in such a way that the jets unite to form a film which runs down the outer surface of the inner tank and away at the bottom. The milk is agitated by blades fixed to a mechanism that travels on the top frame of the vat, thereby eliminating all danger of oil contamination.

Types of Holders. - Holders may be classified into two types, the absolute and the continuous. In the absolute holders the milk is held in the insulated or jacketed tanks for a definite period of time and at the pasteurizing temperature.

There are three main types of absolute holders.

1. The combined heating, holding and cooling vats - otherwise known as the vat or batch system.

2. A tank divided into two or more compartments each of which has at the bottom an outlet valve that is operated by an arm connected to the center shaft that passes up through the machine and makes one revolution in 30 minutes. At the top of the shaft is a distributing trough that fills the compartments. The emptying device is so arranged that while the rest of the compartments are full, two are being emptied. In this way each compartment is held 30 minutes, after which it is automatically emptied.

3. This type of holder consists of 8 shallow pans arranged in two tiers and supported in an insulated copper lined case with enameled sides. The intake from the heater discharges automatically and alternately into the top pan of each tier, the milk being held in each pan one-fourth of the total time selected for the holding period and then being automatically passed to the pan below.

The holders of the continuous type are less satisfactory than the absolute. The milk passes slowly to the cooler and is kept at pasteurizing temperatures along its course long enough to insure thorough pasteurization. There are three general types:

1. In the first type the apparatus consists of an upright cylindrical tank or two or more such tanks arranged in a series. The milk is fed in at the top and passes out at the bottom into another tank and if a single tank is used the outlet pipe is carried up nearly to the top of the tank and downward to the cooler, therefore permitting no milk to discharge from the tank until the milk in the tank reaches the level of the top of the outlet pipe.

2. In the second type the holder consists of horizontal tanks with cross partitions to retard the flow of milk through the tank from one end to the other.

3. In the third type or horizontal tubular holder the milk enters the topmost series of tubes and passes back and forth, until it passes out of the bottom tube.

In the continuous type of holder part of the milk may be pasteurized longer than the rest due to the fact of the unequal movement of the different parts of the milk stream.

The Effect of the Apparatus. - The experimental work along this line is decidedly limited, Kilbourne (1916) being the only investigator giving results comparing several types of pasteurizers. He found that when heating milk in vats of the "batch" type, all the same make, located at three different plants, gave different results. At the first plant a cream layer of 8, 13, and 15 per cent by volume was produced on milk pasteurized at 146° F. The cream volume of raw milk was not determined and the fat content of the milk was not stated. At another plant with 3.8 per cent milk the raw milk showed a cream volume of 17 to 19 per cent while the milk pasteurized at 145° F. produced a cream volume of 12 to 15 per cent. At the third plant using the "batch" system the volume of cream on the raw milk was 15 per cent but no cream rose on milk pasteurized at 145° F. It is interesting to note in this case that the heating medium was 158° F., being 7° F. lower than that of the heating medium used in the first plant and 12° F. lower than that used in the second plant.

When employing a type of heater mentioned above and holding the milk in an absolute holder, Kilbourne found in one plant that milk having 3.9 per cent fat produced on raw milk a cream layer of 15 per cent by volume but that this was decreased to 10.5 per cent when pasteurized at 145° F. At another plant using the same type of machines the raw milk gave a cream layer of 11 per cent by volume while the cream layer in milk pasteurized at 145° F. had decreased to 7 per cent.

Kilbourne's experiments would seem to indicate that the type of pasteurizer influences the cream rising of milk, but as the samples of milk were read after standing for irregular periods of time ranging from 45 minutes to ten and three-fourths hours the experiments mean very little.

Vanderleck (1917) states that the cream layer of milk is not destroyed when using a "reliable" pasteurizer, but he failed to explain what was meant by the term "reliable." He pointed out, however, that a milk dealer secured a 14 per cent cream layer by volume on pasteurized milk when a "reliable" pasteurizer was used.

Harding (1921) states that machines of the same make vary as widely in their effect on the cream layer as do machines of different makes.

Miscellaneous Factors. - Some work has been done showing the effect on the cream layer by factors which could not be properly included in the preceding discussion.

The addition of sucrate of lime or viscogen to the milk commonly caused an increase in the cream layer according to Hammer (1916), but the amount used was no index as to the depth of the cream layer.

Babcock and Russell (1896) observed that by the addition of sucrate of lime the viscosity of pasteurized milk increased. They attributed this increase in viscosity to the grouping of the fat globules.

The hypothesis of Babcock and Russell cannot be correct inasmuch as changes in viscosity were encountered in their own experiments which were not accompanied by a grouping of the fat globules. The causes which bring about an increase in viscosity of milk have not been determined. At least one factor involved, however, must be the marked shift in the hydrogen ion concentration towards the alkaline side of neutrality which follows the addition of the alkaline sugar compound. Zoller (1921) has shown that the maximum viscosity of alkali caseinates occurs at a P_H 9.1 to 9.25 which must be approached when calcium sucrate is added to milk. This theory is further substantiated by the work of Chick and Martin (1912) who found that the viscosity of sodium caseinogenates solutions increased by increasing the concentration of the solution.

The addition of egg albumin to milk has the opposite result of calcium sucrate. Hammer (1916) points out that the addition of egg albumin to milk decreases the depth of the cream layer. The quantity of egg albumin did not influence the results as Hammer found in 12 trials that 30 cc. of egg white per pint of milk did not decrease the cream layer anymore than did 5 cc.

A review of the literature shows that from the data presented an adequate cream layer can be secured on pasteurized milk and that clarification or agitation reduces the depth of the cream layer but the reduction is too small to be of practical importance.

The question of the factor of breed, stage of lactation, and viscosity as influencing the depth of the cream layer as well as other factors are, in the opinion of the writer, as yet imperfectly understood.

General Plan of Experiment

It has been shown experimentally, as the review of literature reveals, that an adequate cream layer can be secured on pasteurized milk. But, as changes occur in the depth of the cream layer in pasteurized and raw milk for which no satisfactory explanation has been advanced, the study of creaming in this work deals to a large extent with the cause of these changes.

When milk is pasteurized certain changes undoubtedly occur in the chemical and physical structure of the milk constituents, especially those in colloidal solution. Apparently, one of these changes is the increase in the hydrogen ion concentration or in other words the P_H value decreases. This was observed by Van Slyke and Baker (1919) who found that in milk in which the CO_2 had been removed by vacuum exhaustion before heating, the P_H value decreased from 6.60 to 6.56; but in milk in which they did not remove the CO_2 the P_H value remained constant, both before and after heating. On the other hand, Zoller (1921) reports a drop in the P_H value of 0.10 to 0.20 when the milk is pasteurized, even though no mention was made of removing the CO_2 from the milk. The significance of these changes in the P_H values as far as creaming is concerned, lies in the decreased viscosity when milk is pasteurized. For instance, Zoller found that the decrease in the P_H value when milk was pasteurized was accompanied by a viscosity decrease from 71.0 to 69.0, as measured by a MacMichael viscosimeter. This decrease in viscosity is presumably due to the partial dehydration of the hydrophilic colloids. A low viscosity would undoubtedly cause the production of a comparatively shallow cream layer. Now, providing a change could be brought about in the milk to increase the viscosity, the reduction of the cream layer could probably be largely restored. The work of Chick and Martin (1912) on sodium caseinogenate solutions gave a possible clue that changes in the hydration of the casein would materially change the viscosity of the milk. They found that with a given solution of sodium caseinogenate, the viscosity increased with a decreasing temperature and with increasing concentrations of the solution, the viscosity increased. Both of these phenomena are ascribed by Chick and Martin to the increased hydration of the colloidal particles at the decreasing temperature. Therefore it seems plausible that changes in the hydration of the hydrophilic colloids, especially the casein, would change the viscosity of the milk sufficiently to account for the variations in the depth of the cream layer, when milk is heated and creamed at different temperatures. A hydration of the albumin and globulin may also be involved. Hunziker (1921 a) believes that a partial coagulation of the albumin during pasteurization is responsible, in part, for the effect of pasteurization on creaming. The coagulation of albumin is essentially a dehydration process.

With the idea in mind that variations in the depth of the cream layer would be accompanied by a corresponding change in the viscosity of the milk, a study of milk from different breeds was undertaken to determine the possibility of a breed relation and its connection with the depth of the cream layer on raw and pasteurized milk. Furthermore, mixed milk was pasteurized at different temperatures to determine if a change in viscosity could be correlated with an increase or decrease in the depth of the cream layer. In this connection the influence of pasteurizing skim milk on the cream rising ability of milk was also determined.

As the experiments progressed it was found advisable to expand this plan of attack to include the effect of certain practical applications, such as the influence of pumping and agitation during pasteurization; and the more fundamental factors, such as the influence of the principal proteins in the milk, namely lactalbumin and calcium caseinate,on the depth of the cream layer.

Experimental Methods

In general the methods used in the experiments closely followed the description given below and wherever qualifications of the methods were necessary adequate explanations will be given when the data are presented.

Kind of Milk Used. - The milk used in the experiments was secured from the University Farm herd, except in the case of the experiments conducted at various milk plants. As far as possible the milk was obtained from the same cows in order that the milk might be of uniform quality and the results secured be comparable. Whenever mixed milk was used it consisted of one-third part Jersey and Guernsey and two-thirds part Holstein. This represented as near as possible the average market milk handled by the milk plants in the Twin Cities. For the breed experiments, milk from Jerseys and Guernseys constituted one standard and milk from Holsteins the other. In all cases the milk was secured from the same cows, although no attention was paid to the stage of lactation, as it was necessary at times to use all the Jersey and Guernsey milk produced by the Station herd.

Standardization of the Milk. - With the exception of some of the viscosity experiments all the milk used was standardized to 3.5 per cent fat (as determined by the Babcock method), in order that the results might be comparable as far as the percentage of fat was concerned. In the experiments with natural milk no attempt was made to control the percentage of solids-not-fat, aside from securing milk from the same animals. In the experiments with artificial milk the percentages of calcium caseinate was definitely standardized.

Type of Apparatus Used. - In the pasteurizing experiments it was necessary to use different types of apparatus, depending upon the amount of milk heated. For large volumes of milk a 150 gallon "Jensen Cream Ripener" or a pasteurizing apparatus of the "batch" or "vat" system was used. When small batches of milk were used, that is, about 20 pounds, the pasteurizing process was accomplished in a shotgun can immersed in a vat of hot water.

Creaming Temperature and Method of Measuring the Cream Layer. - In determining the depth of the cream layer rising on the milk, the samples were placed in 200 cc. graduated glass cylinders (with flat bottoms). The milk was placed in the glass cylinders at a temperature of 80° F. (unless otherwise stated). Four glass cylinders were filled for each sample of milk, two of which were placed in a thermostat where the temperature was maintained at 0° C. by means of cracked ice. The other pair were placed in a common refrigerator where the temperature ranged from 9 to 12° C. At the end of the creaming period the depth of the cream layer was measured and divided by 2 in order to express the reading in percentage of the total volume.

The above temperatures were chosen as the standard creaming temperatures because if a change in viscosity could be correlated with an increase or decrease in the depth of the cream layer, it would probably stand out more clearly at 0° C. than at 9 to 12° C. The latter temperature was more specifically chosen for the reason that this represents the average temperature of the refrigerators in the milk plants and in the home.

Determination of the Percentage of Fat in the Lower Layer. - The percentage of fat in the lower layer or skim milk was determined in the following manner. Holes were bored in the side of the 200 cc. graduated glass cylinders near the base and the hole was stoppered with a small rubber stopper. After the milk had creamed at the desired temperature for the proper length of time, the lower layer was slowly drained off through this outlet to within one-fourth of an inch of the cream layer. The skim milk thus secured was tested for fat by the Babcock method.

Determination of the Percentage of Fat in the Cream Layer. - As direct determination of the percentage of fat in the cream layer was impracticable the percentages of fat reported were calculated by the use of the following formula, viz:

$$\frac{(100 - X) \times (Z - Y)}{X} \times 100 = \text{the percentage of fat in the cream layer.}$$

when, X = the percentage cream layer by volume,

Y = the total fat in the lower layer,

Z = the total fat in the milk,

100 = the volume of milk.

Determination of the Specific Gravity and the Percentage of Solids-not-Fat. - The specific gravity of the milk was determined by the Dairy Division lactometer and the results secured served as a basis for calculating the percentage of solids-not-fat in the milk.

Determination of the Acidity. - The acidity of the milk was determined in terms of the hydrogen ion concentration, measured electrometrically on a Leeds-Northrup potentiometer, the voltage measured at 25° C. between a calomel electrode and a hydrogen electrode, the millivolt reading secured being converted to P_H values by the use of the tables P_H, H^+, and OH^- values as calculated by Schmidt and Hoagland (1919).

Determination of the Viscosity. - At this point it may not be out of place to define viscosity and briefly discuss subject matter related thereto. As the factors that contribute to the viscosity of milk have been discussed in the "Review of Literature", they will not be discussed again.

Definition. - Viscosity as defined by Hatschek (1919) is the resistance offered by a liquid to shearing, stirring or flowing. Washburn (1915) defines viscosity as "the internal friction or the resistance experienced by molecules in moving around the interior of a body." Washburn further states that "the unit of viscosity called the coefficient of viscosity or simply the viscosity is defined as the force required to move a layer of substance of unit area, through a distance of unit length, in unit time, past an adjacent stationary layer a unit distance away."

Means of Expression. - Deeley and Parr (1913) suggest that the unit of viscosity should be expressed in C.G.S. units and suggest the word Poise, for Poiseuille, "demonstrated that when a liquid flows through a capillary tube of considerable length, at constant temperature, the viscosity is constant at all rates of shear, provided the flow is not turbulent."

Bingham and Jackson (1917) state that "if the suggestion of Deeley and Parr is accepted and the absolute C.G.S. unit of viscosity be known as the poise, then it is convenient to use the submultiple of this unit, which is one-hundredth as large and may therefore be called the centipoise (cp)." They found that the centipoise is almost exactly the viscosity of water at 20° C. or 1.0050 cp.

Method Used in Determining the Viscosity. - The determination of the viscosity of the milk was made with the MacMichael (1920) viscosimeter which consists of a disk suspended in a cup of fluid by a No. "00" torsion wire about 10 inches long running down through the stem of the plunger and fastened near the bottom. The head of the torsion wire is triangular and is held between two grooved pins at the top of the standard. The graduated dial at the top of the plunger is secured to the stem by a friction disk, permitting adjustment to the zero mark to its proper place. Finer adjustments are made by means of a steel pointer at the top of the standard.

In this work the MacMichael viscosimeter was operated by modifying the method to conform in general with that used for the Doolittle (1893) torsion viscosimeter. In the latter viscosimeter the dial is measured off into 360° and allowed to make two complete arcs, readings being taken at the end of the first and second swings, the degree of retardation being indicative of the viscosity.

In modifying this method, the MacMichael disk which is measured off to 300°, is rotated to the left one revolution and then allowed to slip back one complete revolution of the disk. The force created carries the disk through the milk until the arc is complete and the angular deflection noted. This deflection subtracted from 297.5° or the reading secured by rotating the disk in the air gives the degree of retardation or the comparative viscosity of the milk.

Calibrating the Viscosimeter. - According to Herschel (1920) it is necessary not only to calibrate the MacMichael instrument with a liquid of known viscosity, but the calibrating sample should not be very greatly different from the sample to be tested, because the disturbing factors such as turbulence, centrifugal force and the change in the clearance between the disk and the cup.

In calibrating the instrument sugar solutions of 12, 30 and 40 per cent by weight were used because the comparative viscosity of these solutions closely agreed with the readings obtained for milk at 0 to 25° C. The sucrose used in preparing the solutions for calibration was of good quality granulated cane sugar. The sugar was weighed, placed in a standard volumetric flask and dissolved in distilled water and standardized at 20° C.

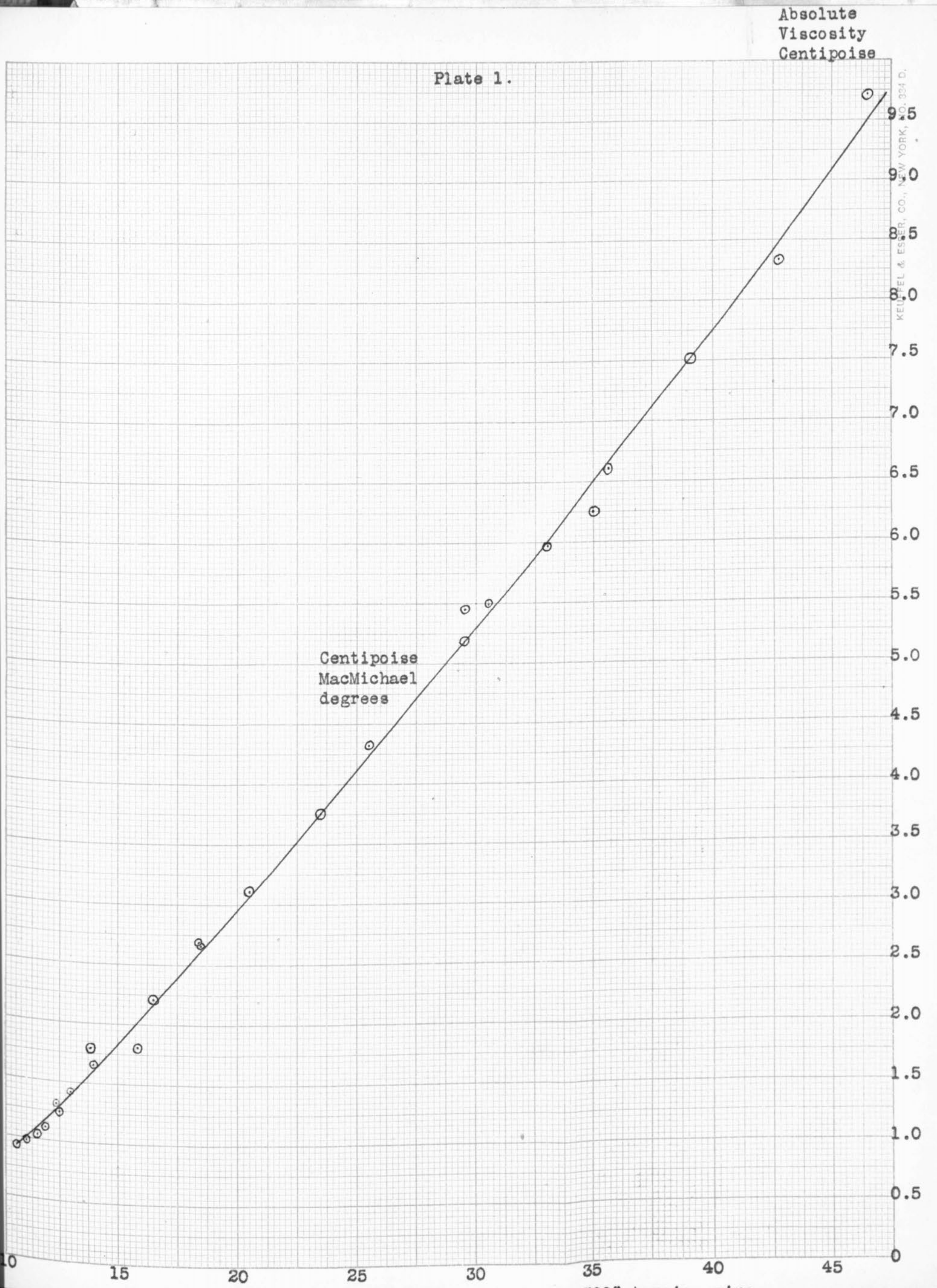
From Bingham and Jackson's (1917) work it was found that sugar solutions of 12, 30 and 40 per cent would give the desired fluidity of milk. Washburn (1915) states that the fluidity is the reciprocal of viscosity. Therefore the viscosities of the sugar solutions were calculated from its reciprocal and the comparative viscosities of the sugar solutions as obtained in the above mentioned method were converted to viscosity in centipoise as shown graphically in Plate I.

The following table shows the comparative viscosities obtained on distilled water and sugar solutions using the MacMichael viscosimeter, operated by a modified Doolittle method. The viscosity curve was obtained from these figures.

Table No. 1

Comparative Viscosity of Distilled Water and Sugar Solutions at Different Temperatures with a No. "00" Torsion Wire

Degrees C.	Distilled Water	Sugar Solution 12 per cent	30 per cent	40 per cent
0	14.1	17.5	29.07	42.5
1	___	___	___	41.0
2	___	___	___	39.62
3	___	___	26.5	38.5
4	___	___	___	___
5	___	15.87	___	___
6	___	___	24.5	34.5
9	___	15.12	23.5	31.5
10	12.33	___	___	___
12	12.0	14.5	22.0	29.25
14	12.0	___	___	___
15	___	13.89	20.58	26.67
16	11.83	___	___	___
18	11.5	13.12	19.55	___
20	11.5	___	___	___
21	___	12.82	18.50	___
22	11.0	___	___	___
24	___	12.5	18.25	___
25	10.5	12.5	17.50	___



MacMichael Degrees - Doolittle Method - "00" torsion wire.

Experimental

Preliminary Experiments. - Inasmuch as it was the purpose of this work to study the influence of viscosity on the depth of the cream layer as well as subsequent variations in the depth of the cream layer under different methods of treatment, it was deemed advisable to determine first some of the factors that influence the viscosity of raw milk when held at creaming temperatures. Providing variations could be found in the viscosity of the raw milk when creamed at 0° C. the results might be of value in accounting for differences in the depth of the cream layer on raw and pasteurized milk. With this purpose in mind, raw milk from different breeds was secured to study the variations in the viscosity as influenced by the hydrogen ion concentration (as expressed in P_H), the temperature, and the percentages of fat and solids-not-fat. Milk from individual animals of four breeds was used, namely, Jerseys, Guernseys, Ayrshires and Holsteins. The milk was secured at night and in the morning and mixed in proportionate amounts in the ratio of 1 cc per pound of milk. The milk was not standardized, as it was the purpose to study the factors influencing viscosity without reference to the depth of the cream layer. Viscosity readings were made on the fresh milk at 0° and 25° C. and again at 0°C. after the milk had stood at that temperature for 24 hours. The data presented in Table 2 are averages for 2 Ayrshires, 5 Jerseys, 11 Guernseys, and 19 Holsteins derived from Tables I, II, III, IV, V, and VI in the appendix.

Table 2

Factors Influencing the Viscosity of Milk From Different Breeds.

Breed	Jersey	Guernsey	Ayrshire	Holstein
Fat, per cent	5.62	4.77	4.62	3.41
Viscosity in cp				
at 25° C. at once	2.77	2.37	2.39	1.90
at 0° C. at once	5.67	5.18	5.16	4.57
at 0° C. after standing	5.71	5.44	5.88	4.63
P_H at 25°C.	6.47	6.44	6.70	6.44
Specific gravity at 60° F.	1.0340	1.0336	1.0331	1.0325
Solids-not-fat, per cent	9.64	9.37	9.13	8.81

Plate 2

Influence of fat and solids-not-fat on the viscosity of milk at 25°C.

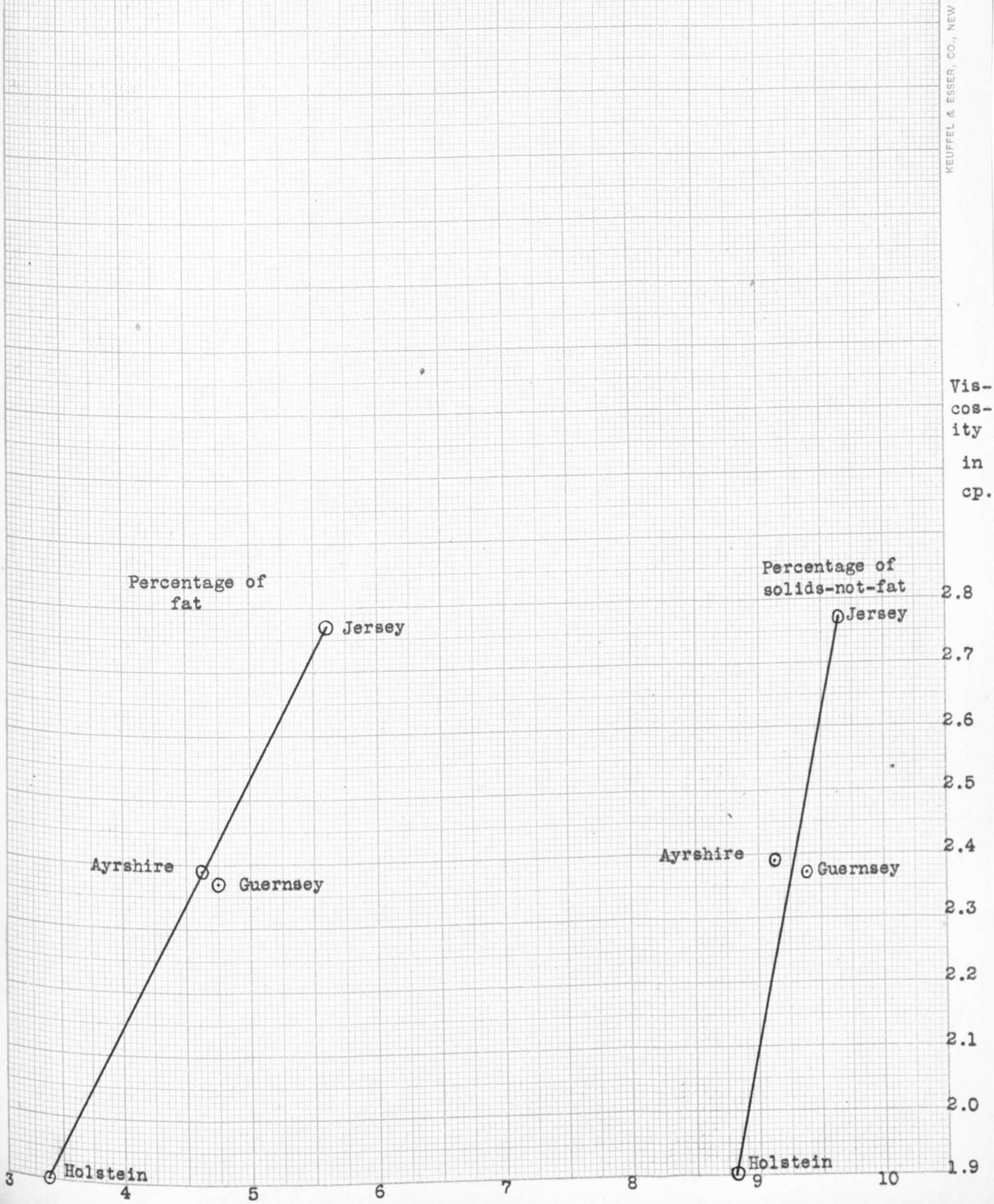
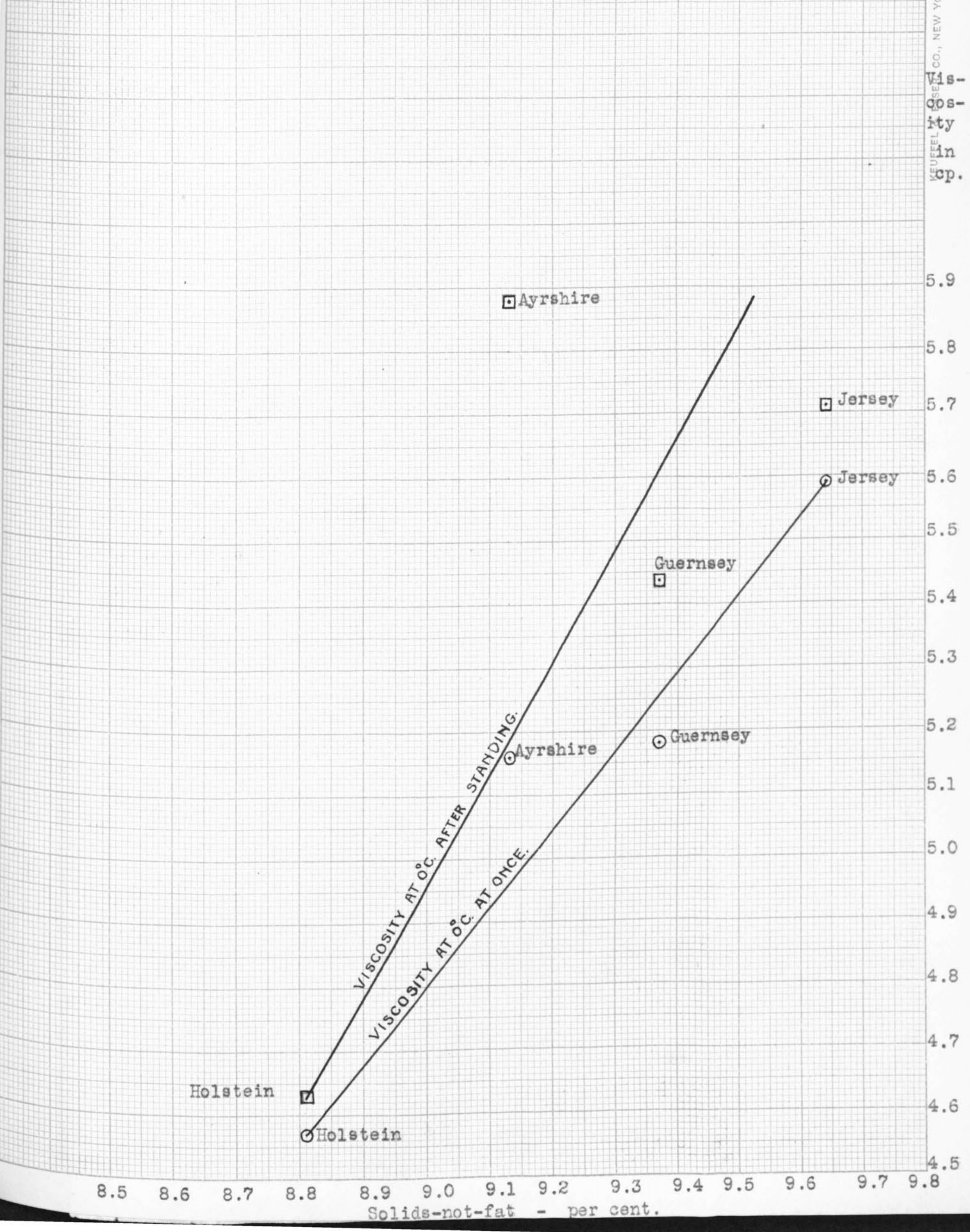


Plate 3

Correlation between viscosity at 0° C. (before and after standing) and percentage solids-not-fat.



The data presented in the table as well as that shown graphically in Plates 2 and 3 distinctly shows a breed relation to the viscosity of the milk. This does not necessarily mean that the percentage of fat in the milk, as it varies with the different breeds, influences the viscosity to any great extent. Although Plate 2 shows an increase in the viscosity with a corresponding increase in the percentage of fat, the real explanation is found in the percentage of solids-not-fat in the milk. From the graph it will be seen that while the viscosity of the milk increases with an increase in the percentage of fat, the change occurs within a range of 3.41 to 5.62, while in the case of the percentage of solids-not-fat the ratio of the increased viscosity falls in the relatively narrow range of 8.81 to 9.64. The influence of the percentage of the solids-not-fat on the viscosity of the milk is therefore much greater than the fat. For example, the Jersey milk with a percentage of solids-not-fat and fat of 9.64 and 5.62 respectively has a viscosity of 5.71 after standing at 0° C. for 24 hours as compared to the viscosity of 4.63 for Holstein milk with 8.81 per cent solids-not-fat and 3.41 per cent fat. This difference in viscosity is also evident when determinations were made on the fresh milk at 25° and 0° C. Had the fat contributed immensely to the viscosity of the milk a greater difference should have been manifested. These results are in harmony with Kohler's (1909) work, who found that the fat content of milk did not influence the viscosity to any appreciable extent. The difference in the viscosity between the Guernsey and the Ayrshire milk probably would have been greater, had a larger number of samples been available for viscosity determinations.

In general the milks with a high specific gravity were accompanied by a higher viscosity. When the milks are classified according to breed this also holds true. For example, the viscosity of Jersey milk was 5.71 with a specific gravity of 1.0340 as compared to Holstein milk having a viscosity at 0° C. (after standing 24 hours) of 4.63 with a specific gravity of 1.0325. The difference between the specific gravities of the Guernsey and Ayrshire milks did not correspond to the viscosities at 0° C. after standing, although a correlation was apparent at 0° C. when the determination was made on fresh milk. The variations in the specific gravities of the milks from the different breeds is accounted for by the percentages of the solids-not-fat in the milk. The increased viscosities with the greater percentages of solids-not-fat in the milk bears out the findings of Chick and Martin (1912). They found that by increasing the concentration of sodium caseinogenate in the solution, the viscosity increased. Likewise, the milk containing a large percentage of solids-not-fat exhibited a greater viscosity. Applying these observations to the work at hand it is entirely possible to account for variations in the creaming ability of milk on the basis of a greater amount of hydrophilic colloids in the milk. In this way it would be possible to explain the differences that are commonly observed as regards the depth of the cream layer produced on milk from different breeds of cows. Thus, Jersey milk which contains a greater percentage of solids-not-fat would necessarily contain a larger amount of hydrophilic colloids and a deeper cream layer should be produced because of the increased viscosity. Again, Holstein milk with a smaller percentage of solids-not-fat probably produces a shallower cream layer because of its lower viscosity.

At 0° C. the viscosity of the milk increased on standing, namely, 0.04, 0.26, 0.72 and 0.06 cp respectively for Jersey, Guernsey, Ayrshire and Holstein milk. Kohler (1909) found that the viscosity of milk increased upon standing and attributed this increase to the formation of structures by the colloids of the milk. He believed that these structures are destroyed when the milk is shaken but are restored on standing and the viscosity of the milk recovers its original value in 12 to 24 hours. The increase in viscosity is undoubtedly due to the increased hydration of the hydrophilic colloids. When the milk is heated it is possible that the hydrophilic colloids are to some extent dehydrated and hence a decrease in the viscosity occurs. With raw milk it is observed that the viscosity increases when the milk is held at low temperatures, the increase being presumably due to the increased hydration of the hydrophilic colloids. Obviously there is a relation between the viscosity of the milk and the depth of the cream layer, since Hammer (1916) found that a deeper cream layer was secured on raw milk when the samples were creamed at ice water temperature than at room temperature. If such a relation exists it is undoubtedly due to the increased viscosity of the milk at the low temperatures and the decrease in viscosity at the higher temperatures. Therefore variations and changes in the depth of the cream layer could probably be accounted for by a corresponding change in the viscosity of the milk, whether it is raw or pasteurized. Furthermore, it may be possible to correct reductions in the cream layer of pasteurized milk by increasing the viscosity.

The influence of the hydrogen ion concentration of the milk between a range of P_H from 6.44 to 6.70 was negligible as far as its bearing upon a changed viscosity was concerned. For example, the Guernsey and the Holstein milk showed on an average a P_H of 6.44, yet the viscosity of the former was 5.44 as compared to 4.63 for the latter (as measured at 0° C. after standing 24 hours). This relation holds true whether the viscosity was taken immediately at 25° or 0° C.

Kohler (1909) points out that the viscosity is a constant characteristic for each animal and depends upon the period of gestation. This may be true for the period of gestation but the breed experiments do not show any correlation between the stage of lactation and the viscosity. The milk from fresh cows may have as high and in some instances a higher viscosity than the milk from cows in the last stages of lactation. The data in Table 3 which are taken from Tables II, III, IV, V, and VI in the appendix are submitted to illustrate that the stage of lactation apparently has no effect on the viscosity.

4-22-8M

Table 3

Influence of the Stage of Lactation on the Viscosity of Milk.

Number of cow	Breed	Stage of Lactation	Viscosity at 25° C.	at 0° C.
		days	cp	cp
309	Holstein	751	2.42	4.75
339	Holstein	25	1.87	4.75
314	Holstein	187	1.78	5.57
336	Holstein	385	1.50	4.17
500	Guernsey	6	2.42	5.54
517	Guernsey	338	2.20	6.40
517	Guernsey	345	2.17	5.46
508	Guernsey	280	2.83	5.22

The results of the preliminary experiment seemed to justify the study of variations in the depth of the cream layer from the standpoint of the viscosity of the milk, inasmuch as a considerable difference was found in the viscosity of milk from different breeds as well as an increase in the viscosity of milk on standing at the creaming temperature. These facts coupled with a high viscosity at a low temperature and a low viscosity at a higher temperature should enable one to account for variations in the depth of the cream layer on raw and pasteurized milk.

Influence of Viscosity and the Size of the Fat Globules on the Depth of the Cream Layer on Raw Milk. - Inasmuch as the preliminary experiments indicated a relation between the viscosity of the milk and the breed, the next step was to determine the influence of viscosity as affecting the depth of the cream layer on milk from different breeds and whether the greatest influence is contributed by the percentage of solids-not-fat or the relative size of the fat globules. Stocking (1917) maintains that milk from the Jersey and Guernsey breeds creams more easily than that of the Holsteins and Ayrshires, because the larger fat globules have greater mass in proportion to their surface. This fact in no way indicates that the depth of the cream layer is influenced by the size of the fat globules. Rahn (1922) has recently studied the variations in the creaming abilities of milk and has come to the conclusion that they are not due to the size of the fat globules or to the variations in viscosity. His latter conclusion is not supported by his own figures as they show that when he added gelatine in different amounts to the milk he secured a progressive increase in viscosity as well as an increase in the depth of the cream layer. For example, Rahn added 0.45, 1.35, and 1.80 per cent gelatine to milk, which increased the viscosity from 1.56 (viscosity of the raw milk without gelatine) to 1.79, 2.60 and 3.29 respectively. The cream layers after standing 44 hours were 18 mm. for the raw milk without gelatine and 24, 29 and 33 mm. respectively for the milk with 0.45, 1.35 and 1.80 per cent gelatine. Furthermore when Rahn added substances in colloidal solution to the milk, such as gelatine, gum tragacanth and gum arabic, the creaming process was hastened and more cream rose to the surface. When non-colloidal solutions, such as waterglass and lime water were added to the milk, the creaming process was hindered. Therefore, it seems logical to conclude that the higher the percentage of natural solids-not-fat in the milk (which means primarily a larger amount of hydrophilic colloids) the higher the viscosity and hence a deeper cream layer must be produced. In this way it may be possible to explain the differences in the creaming abilities of milk from different breeds.

In the milk from the Jerseys and Guernseys the solids-not-fat content and the relative size of the fat globules are practically the same, hence the milk from these breeds served as one standard for the experiment. The Holstein milk in which the solids-not-fat content is comparatively low and the size of the fat globules relatively small, was used for the other standard. The Jersey-Guernsey milk was separated and the 55 per cent cream secured was used to standardize a portion of the Jersey-Guernsey skim milk and also a part of the Holstein skim milk. The Holstein milk was treated in the same manner, using the 48 per cent cream to standardize part of the Holstein skim milk and a portion of the Jersey-Guernsey skim milk. The milk was separated by a De Laval No. 10 centrifugal separator. Thus, two standards and four types of milk were used for this experiment. One standard represented the Jersey-Guernsey milk having a comparatively high percentage of solids-not-fat, standardized in one case with relatively small fat globules and in the other with large fat globules. Likewise, the Holstein standard with a comparatively low percentage of solids-not-fat was adjusted to include the relatively large fat globules as well as the small fat globules. The data presented in Table 4 are derived from Tables VII and VIII in the appendix. Although they are taken from the pumping experiments, the results are truely indicative of the results of inter-changing the creams of the two standards of milk. In all cases the results are from raw untreated milk.

From the data presented in Table 4 it is clearly shown that the percentage of solids-not-fat in the milk with the subsequent changes in viscosity are among the determining factors in the production of a deep cream layer rather than the relative size of the fat globules. The Holstein milk containing 8.59 per cent of solids-not-fat had a viscosity of 5.32 at 0° C. after standing 24 hours and a cream layer of 11.25 per cent by volume as compared to a cream layer of 13.00 per cent with Jersey-Guernsey fat globules in the Holstein skim milk. In the latter case the viscosity had increased to 5.38 while the percentage of solids-not-fat increased to 8.61. At $9-10^{\circ}$ C. the relative proportion of the cream layer was practically the same, being 6.8 and 9.25 respectively for the Holstein milk and the Holstein skim milk with the Jersey-Guernsey fat globules. The increase in the depth of the cream layer in the latter case was accompanied by an increased viscosity.

With the Jersey-Guernsey milk a cream layer of 17.37 per cent by volume was produced, the milk having 9.35 per cent solids-not-fat and showed a viscosity of 6.05. When Holstein cream was placed in the Jersey-Guernsey skim milk the percentage of solids-not-fat decreased to 9.30 as did the viscosity to 5.93 with the development of a shallower cream layer, namely, 16.50 per cent by volume. When the milk was creamed at 9 - 10° C. the depth of the cream layer was 12.75 for the Jersey-Guernsey milk as compared to the cream layer of 11.25 for the Jersey-Guernsey skim milk with the Holstein fat.

It is evident that the higher viscosities produced at the lower temperatures are more conducive to the formation of a deep cream layer than the lower viscosities at the higher temperature. With the Holstein and Jersey-Guernsey milk the viscosity increased on standing at 0° C. The correlation between the depth of the cream layer and the viscosity is much more evident at 0° C. after standing than when the viscosity was taken at once. At 9 - 10° C. the correlation is much more evident when the viscosity is taken at once.

The production of a deep cream layer does not seem to be connected, to a great extent, at least, to the relative size of the fat globules since practically as deep cream layers were secured on the milks in which relatively different sizes of fat globules had been inter-changed with the normal fat globules of the milk. Nevertheless, the size of the fat globules have a slight influence because the cream layers with Holstein cream in the Jersey-Guernsey skim milk was slightly lower than than of the normal Jersey-Guernsey milk. Likewise, slightly deeper cream layers were produced with Jersey-Guernsey fat globules in the Holstein skim milk than with Holstein milk.

The range of P_H between 6.44 and 6.60 showed no correlation with the viscosity or the depth of the cream layer at 0° or 9 - 10° C.

The above results are substantiated by another experiment conducted along the same lines. The object of the experiment was to determine whether the results of the above experiment could be duplicated when all the factors that might influence the results were controlled. In all cases the milk was raw and untreated and a check sample of raw skim milk was run to determine the influence of the milk minus the fat globules on the viscosity of the milk. The data are presented in Table 5 and are derived from Table IX in the appendix.

It will be observed that the higher the percentage of solids-not-fat in the milk the higher the viscosity at both creaming temperatures. The viscosity of the milk increased on standing in all but one case, at both 0° and 12° C. The viscosities of the skim milk from both the Jersey-Guernsey and the Holstein milk was practically as great or higher than those of the whole milk. This shows more conclusively that the fat globules have very little influence on the viscosity of whole milk.

In the case of the Jersey-Guernsey milk a cream layer of 16.75 per cent by volume was produced as compared to the cream layer of 16.70 when the Jersey-Guernsey skim milk was standardized with Holstein fat. This slight decrease in the cream layer was accompanied by a decrease in the viscosity, namely, 6.41 to 6.19. At 12° C. the depths of the cream layers were not as uniform, nor did the differences in viscosity account for the variations in the depth of the cream layer.

Results very similar to the above were secured when Holstein milk was standardized with fat globules of relatively different sizes. The Holstein milk with relatively small fat globules developed a cream layer of 12.4 per cent as compared to 11.8 per cent when the Jersey-Guernsey cream was used to standardize the Holstein skim milk. The viscosities of the milks after standing 24 hours at 0° C. were 5.24 and 5.87 respectively for the Holstein milk alone and the Holstein skim milk plus the Jersey-Guernsey cream. The comparatively shallow cream layers produced in both cases were accompanied by a lower percentage of solids-not-fat and a lower viscosity as compared to the Jersey-Guernsey milk creamed at the same temperature, but the variations in the depth of the cream layer in the case of the Holstein milk creamed at 0° C. could not be explained on the basis of a lowered viscosity because the shallower cream layer was accompanied by a higher viscosity. The very slight difference in the depth of the cream layer of the Holstein milks is negligible at 0°C. When the milk was creamed at 12°C. practically the same cream layers rose on the milk when either type of cream was used to standardize the Holstein skim milk. In general the shallower cream layers were associated with a lower viscosity but in accounting for the slight variations in the cream layer this did not hold true. The milk with the higher viscosity had a slightly lower cream layer.

The increase in the viscosity of the Holstein skim milk plus the Jersey-Guernsey cream can be attributed to an additional quantity of solids-not-fat added to the milk with the cream from the milk with the higher solids-not-fat content. In the same manner the decrease in the viscosity of the Jersey-Guernsey skim milk plus the Holstein cream, as compared to the Jersey-Guernsey milk, is undoubtedly due to the decreased concentration of the solids-not-fat constituents when the Holstein cream with its lower percentage of solids-not-fat is added.

The hydrogen ion concentration as expressed in terms of P_H gave no indication that this factor could be correlated with a change in the depth of the cream layer or the viscosity. For example, the P_H ranged from 6.39 to 6.53 with viscosities ranging from 5.24 to 6.96 at 0° C. after standing 24 hours while at the same time the cream layers varied from 11.80 to 16.75 per cent by volume.

Table 4

Influence of the Viscosity, solids-not-fat and the Size of the Fat Globules on the Depth of the Cream Layer

Kind of Milk	Solids-not-fat (calc.)	P_H at $25^{\circ}C.$	Properties at 0° C. Viscosity at once	Properties at 0° C. Viscosity after standing 24 hours	Properties at 0° C. Volume of cream	Properties at 9-10° C Viscosity at once	Properties at 9-10° C Viscosity after standing 24 hours	Properties at 9-10° C Volume of cream
	per cent		cp	cp	per cent	cp	cp	per cent
Holstein	8.59	6.54	4.73	5.32	11.25	2.89	2.89	6.8
Holstein skim plus Jersey-Guernsey cream	8.61	6.44	5.79	5.38	13.00	3.13	3.13	9.25
Jersey-Guernsey	9.35	6.60	5.93	6.05	17.37	3.58	3.36	12.75
Jersey-Guernsey skim milk plus Holstein cream	9.30	6.47	6.09	5.93	16.50	3.40	3.58	11.25

Table 5

Relation of the Percentage of Solids-not-fat and the Size of the Fat Globules to the Viscosity and the Depth of the Cream Layer.

Kind of Milk	Solids-not-fat (calc.)	P_H at 25° C.	Properties at 0°C. Viscosity at once		Properties at 0°C. Volume of cream	Properties at 12° C. Viscosity at once		Properties at 12° C. Volume of Cream
			at once	after standing 24 hours		at once	after standing 24 hours	
	per cent		cp	cp	per cent	cp	cp	per cent
Jersey-Guernsey	9.61	6.49	6.17	6.41	16.75	3.25	3.25	14.50
Jersey-Guernsey Skim Milk			6.17	6.96		3.58	3.77	
Jersey-Guernsey Skim Milk plus Holstein cream	9.44	6.39	5.65	6.19	16.70	3.28	3.47	10.90
Holstein	8.79	6.45	5.00	5.24	12.40	2.78	2.93	7.50
Holstein skim milk			4.80	5.83		2.82	3.01	
Holstein skim milk plus Jersey Guernsey cream	9.11	6.53	5.65	5.87	11.80	3.01	3.07	6.40

Influence of Pasteurization on the Viscosity and the Depth of the Cream Layer. - Degree of agitation during the heating process. - Before taking up the experiments dealing directly with the changes in the viscosity of the milk as correlated with the depth of the cream layer produced on pasteurized milk, an experiment was conducted to determine whether milk should be heated slowly or rapidly to the pasteurizing temperature. It was felt that the rapidity of heating as well as the degree of agitation during the heating process had some influence on the depth of the cream layer. The object of this experiment was to determine how milk should be heated in order that a definite method might be followed in the subsequent experiments with the least possible injury to the cream layer.

The usual methods of carrying out the experiments were followed with these exceptions, namely, that one batch of milk was heated rapidly (that is, in 5 minutes) to the pasteurization temperature, while another batch was heated slowly (in 30 minutes) to the pasteurization temperature. For each standard method of heating one batch was heated with constant agitation and the other with the least possible amount of agitation or in other words, intermittent agitation. The amount of milk used for the experiments was 160 pounds. Five samples of milk were taken in each experiment represented as follows: (1) the raw untreated milk, (2) the milk heated to 145° F. in 30 minutes with constant agitation, (3) the milk heated to 145° F. in 30 minutes with intermittent agitation, (4) the milk heated to 145° F. in 5 minutes with constant agitation, and (5) the milk heated to 145°F. with intermittent agitation. The influence of heating on the viscosity and the depth of the cream layer was noted in each case. The data are tabulated in Table 6 and are derived from Table X in the appendix.

It will be noted that the viscosity of each of the heated milks is lower than that of the raw untreated milk, whether the milk was creamed at 0° or 12°C.

The depth of the cream layer also decreased with the decreased viscosity but the reduction in the cream volume is not in direct relation to the lower viscosities. On the average the decrease in the volume of the cream layer is less when the milk was agitated intermittently during the heating process. This would seem to indicate that intermittent agitation and a longer heating period hinders the formation of a deep cream layer less than constant agitation with a shorter heating period.

Table 6

Influence of Agitation During the Heating Process on the Viscosity and the Depth of the Cream Layer.

Treatment	Properties at 0° C.		Properties at 12° C.	
	Viscosity after standing 24 hours	Cream volume	Viscosity after standing 24 hours	Cream volume
	cp	per cent	cp	per cent
Raw untreated	5.69	16.07	3.22	11.87
Heated to 145 in 30 min. constant agitation.	5.67	14.62	3.10	11.62
Heated to 145 in 30 min. Intermittent agitation	5.32	15.25	3.10	11.37
Heated to 145 in 5 min. constant agitation	4.85	12.5	3.10	8.50
Heated to 145 in 5 min. Intermittent agitation	4.85	14.37	3.10	10.75

Pasteurizing mixed milk and agitating during "holding process". - In these experiments the object was twofold, namely, to determine the influence of pasteurization and agitation during the "holding process" on the viscosity of the milk and its subsequent effect on the depth of the cream layer.

The experiment on the degree of agitation during the "heating process" showed that heating milk slowly to the desired temperature with intermittent agitation tended to diminish the depth of the cream layer the least. Therefore it was deemed advisable to use this method in bringing the milk to the temperature of pasteurization in these experiments. About 400 pounds of mixed milk was used for each experiment. After the milk had been standardized it was divided into two equal parts. Half of the milk was heated to the desired temperature and held without agitation during the "holding process" and the other half was agitated during the "holding process". The milk was heated to 140°, 144°, 149° and 152° F. and held at these temperatures in a "Jensen Cream Ripener". At each pasteurizing temperature 3 samples of milk were taken, namely, the raw untreated milk, the milk heated and held without agitation and the milk heated and held while agitated. The results of the experiments are tabulated in Tables 7 and 8 and are derived from Tables XI, XII, XIII and XIV in the appendix.

The data in Tables 7 and 8 show that as a general rule the viscosity of the milk increased after standing 24 hours at 0 and 12° C. The relation between the changes in the viscosity and the depth of the cream layer as influenced by heating and agitation are graphically illustrated in Plates 4, 5, and 6. The variations in the viscosity at 0° and 12° C. taken before and after standing do not account for the differences in the depth of the cream layers, because at times a shallower cream layer was secured with an increase in viscosity and vice versa. In general the differences in the viscosities between the two creaming temperatures can be correlated with the depth of the cream layer inasmuch as a comparatively deep cream layer was accompanied by a higher viscosity and a comparatively shallow cream layer by a low viscosity.

Agitation during the "holding process" at temperatures below 145° F. did not decrease the cream volume to any appreciable extent as compared to the raw milk or the milk that had been heated and held without agitation when the milk was creamed at 0° C. On the other hand, when milks were creamed at 12° C. an appreciable increase in the depth of the cream layer was produced upon agitating during the "holding process" as compared to the raw or the unagitated milk. Furthermore, at 140° F. the cream volume of agitated milk was even greater than that of the raw milk. At 144° F. the depth of the cream layers of heated and agitated milk was exactly the same as that of the raw untreated milk.

Contrary to common belief heating milk above 145° F. and holding for 30 minutes did not destroy the creaming abilities as much as might be expected, although agitating the milk during the holding process reduced the depth of the cream layers considerably. For example, when the milk was heated and held without agitation at 149° F. the cream layer was reduced from 15.37 to 13.50 as compared to 11.62 per cent when the milk was agitated during the "holding process". When the milk was creamed at 12° C. a very slight reduction resulted due to the action of heat and mechanical agitation, being 10.50, 10.00 and 9.50 respectively for the raw milk, the milk heated and held without agitation and the milk heated and held with agitation. Furthermore, when milk was heated to 152° F. and held without agitation the depth of the cream layer was reduced from 15.87 to 11.05 per cent when creamed at 0° C. and when agitated during the "holding process" the cream layer decreased to 9.87 per cent. When the milk was creamed at 12° C. the decrease in the depth of the cream layers were slight, being, 9.80, 9.00 and 8.00 respectively for the raw untreated milk, the milk heated and held without agitation and the milk heated and held with agitation. As will be observed the depth of the cream layers were not reduced as much when the milk was creamed at 12° C. as at 0°C., when the milk had been heated and held with or without agitation.

There was no correlation between the hydrogen ion concentration as expressed in terms of P_H with the viscosity and the depth of the cream layer inasmuch

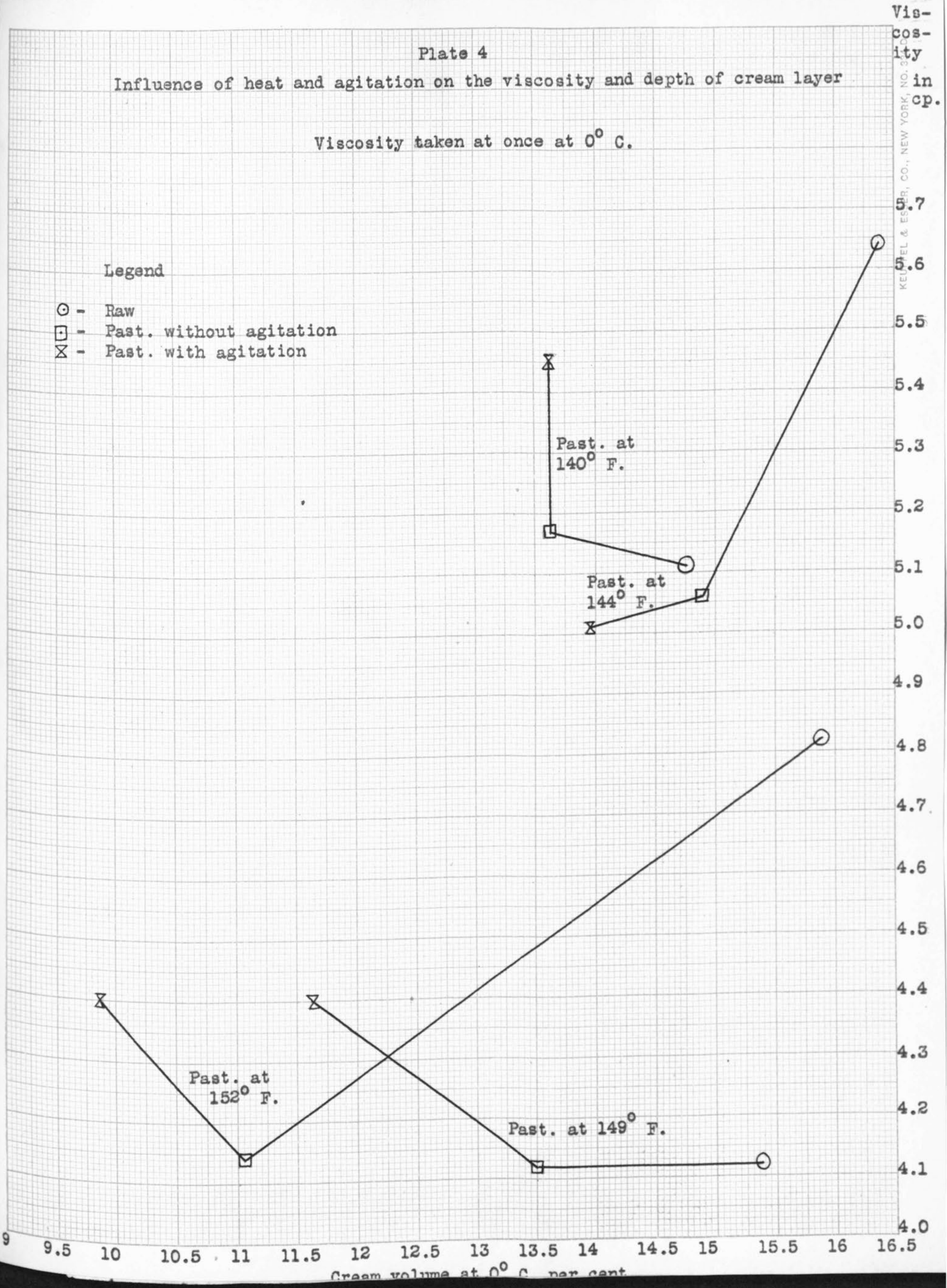
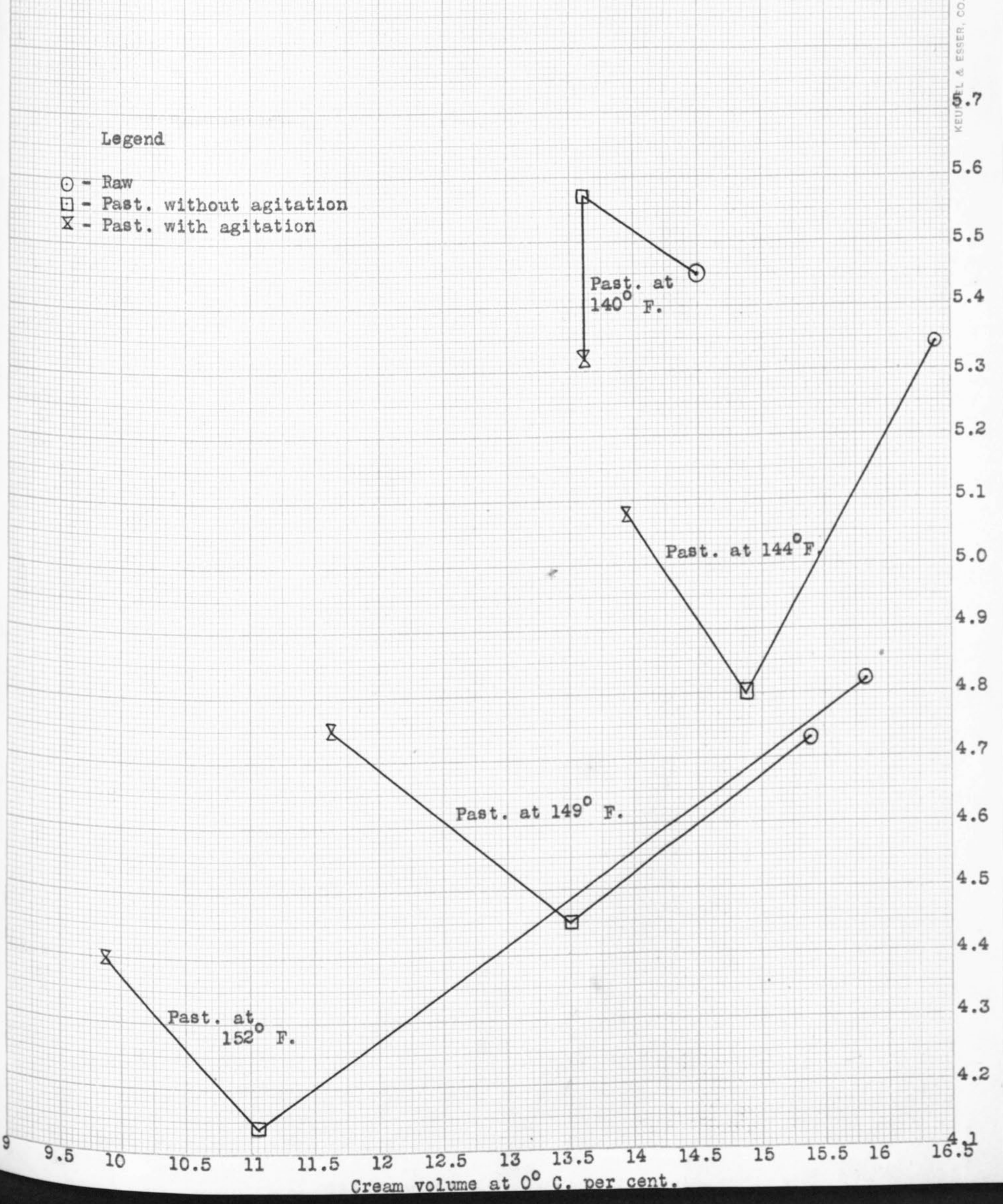


Plate 4
Influence of heat and agitation on the viscosity and depth of cream layer
Viscosity taken at once at 0° C.
Legend
⊙ - Raw
⊡ - Past. without agitation
⧖ - Past. with agitation
Past. at 140° F.
Past. at 144° F.
Past. at 152° F.
Past. at 149° F.
Vis-cos-ity in cp.
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
16.5
Cream volume at 0° C. per cent
KEUFFEL & ESSER CO., NEW YORK, NO. 3

Plate 5

Influence of heat and agitation on the viscosity and depth of the cream layer.

Viscosity taken after standing 24 hours at 0° C.



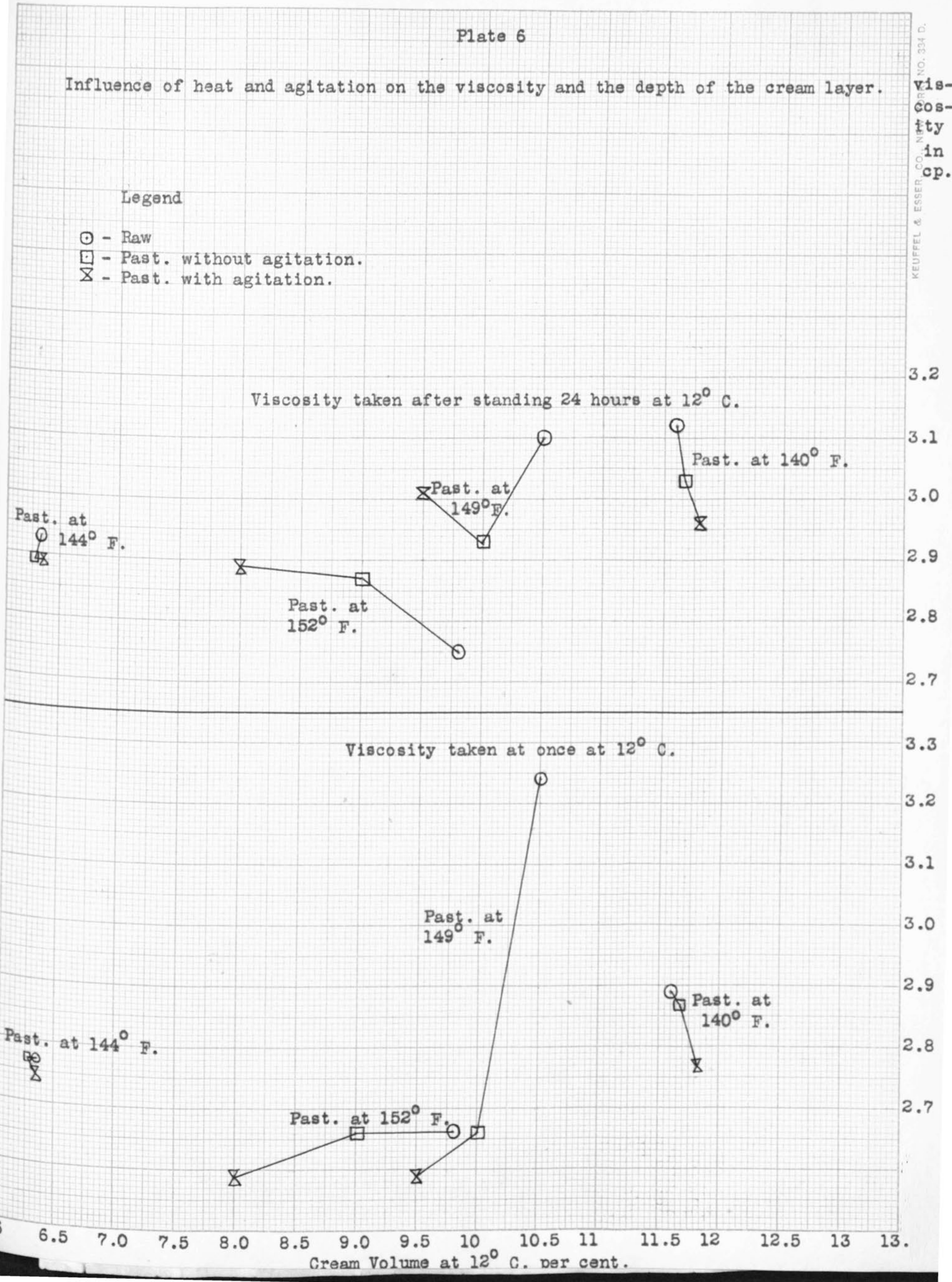


Plate 6

Influence of heat and agitation on the viscosity and the depth of the cream layer.

as the P_H ranged from 6.27 to 6.61 with a variation in the viscosity at 0° C. after 24 hours from 4.28 to 5.57 while the depth of the cream layer ranged from 9.87 to 16.37 per cent. In all cases the P_H increased on heating when the milk was agitated. When the milk was heated without agitation the P_H decreased in one instance, remained the same in another and increased in the milks heated above 145°F.

Table 7

Influence of Agitation and Pasteurization on the Depth of the Cream Layer and the Viscosity.

Treatment	Temperature of Pasteurization	Solids-not-fat (calc.)	P_H at 25° C.	Properties at 0° C.		
				Viscosity		Cream volume
				at once	after standing 24 hours	
	°F.	per cent		cp	cp	per cent
Raw untreated		9.21	6.49	5.11	5.45	14.75
No agitation	140	9.21	6.49	5.17	5.57	13.62
Agitated	140	9.21	6.54	5.45	5.32	13.62
Raw untreated		9.16	6.34	5.64	5.34	16.37
No agitation	144	9.16	6.27	5.06	4.80	14.87
Agitated	144	9.16	6.33	5.01	5.08	13.95
Raw untreated		9.19	6.60	4.12	4.73	15.37
No agitation	149	9.19	6.61	4.12	4.45	13.50
Agitated	149	9.19	6.61	4.40	4.75	11.62
Raw untreated		9.06	6.57	4.82	5.02	15.87
No agitation	152	9.06	6.59	4.14	4.28	11.05
Agitated	152	9.06	6.59	4.40	4.49	9.87

Table 8

Influence of Agitation and Pasteurization on the Depth of the Cream Layer and the Viscosity

Treatment	Temperature of Pasteurization	Solids-not-fat (calc.)	P_H at 25° C.	Properties at 12° C. Viscosity at once	Viscosity after standing 24 hours.	Cream volume
	°F.	per cent		cp	cp	per cent
Raw untreated		9.21	6.49	2.89	3.12	11.60
No agitation	140	9.21	6.49	2.87	3.03	11.67
Agitated	140	9.21	6.54	2.77	2.96	11.80
Raw untreated		9.16	6.34	2.77	2.93	11.67
No agitation	144	9.16	6.27	2.77	2.89	10.75
Agitated	144	9.16	6.33	2.75	2.89	11.67
Raw untreated		9.19	6.60	3.24	3.10	10.50
No agitation	149	9.19	6.61	2.66	2.93	10.00
Agitated	149	9.19	6.61	2.59	3.01	9.50
Raw untreated		9.06	6.57	2.66	2.75	9.80
No agitation	152	9.06	6.59	2.66	2.87	9.00
Agitated	152	9.06	6.59	2.59	2.89	8.00

Pasteurizing Holstein and Jersey-Guernsey Milk. - Although there was no correlation between the viscosity and the variations in the depth of the cream layer on pasteurized mixed milk when creamed at the same temperature it was thought that some relation might exist when milk with comparatively different percentages of solids-not-fat content was heated at the same or different temperatures. In the experiments on raw milk a considerable difference in the depth of the cream layer was found, due to the amount of hydrophilic colloids in solution. Thus, the influence of the amount of hydrophilic colloids as evidenced by the percentages of solids-not-fat in the milk may have a bearing on the reduction in the cream layers when the milk is heated.

For the experiments the two standards of milk were used, namely, Holstein and Jersey-Guernsey. In three of the experiments the milk was pasteurized as close to 62.8° C. as possible. The milk was heated and held in a 100 gallon vat. It was particularly difficult to heat the milk without going beyond the stipulated pasteurization temperature. Hence, this accounts for the variations in the temperatures in the first three experiments. Likewise, in the fourth experiment the milk was unintentionally heated to 65.8° C. When Holstein and Jersey-Guernsey milk alone was used sufficient quantities of milk were separated by a De Laval No. 10 centrifugal separator in order to increase the percentage of fat of the Holstein milk to 3.5 per cent by the addition of cream and to decrease the Jersey-Guernsey milk to 3.5 per cent fat by the addition of skim milk. When the creams were interchanged, cream testing 55 and 50 per cent respectively for the Jersey-Guernsey and Holstein was used in standardizing the milk. In these cases the cream was added to the skim milk at 80 to 90° F. Inasmuch as the amount of milk produced by the Station herd at the time the experiments were conducted was insufficient to permit experimental work on large quantities of fresh milk on the same day it was produced, it was necessary to save the milk for three consecutive days. The age of the milk may have influenced the results to some extent. The results of the experiments are summarized in Tables 9 and 10 and are derived from Tables XV, XVI, XVII and XVIII in the appendix.

The data show as in the previous breed experiments that the higher the percentage of solids-not-fat the higher the viscosity. In general the higher viscosities at 0° C. were accompanied by a deeper cream layer in the case of the raw milk and the lower viscosities at 12° C. were accompanied by a shallower cream layer. In some cases when the milk was heated to pasteurization temperatures approximately the same depth of cream layer was secured at 0 and 12° C. although the viscosities were greatly different. For example, when the Holstein milk plus the Jersey-Guernsey cream was heated and held at 65.8° C. (150.4° F.) the cream layer produced was 1.5 per cent by volume at both creaming temperatures while at the same time the viscosities were 2.89 and 4.45 respectively after standing 24 hours at 0° and 12° C.

There was no difference in the reduction of the cream layer when the Holstein and Jersey-Guernsey milk alone were pasteurized at 62.8° C. (145.04° F.) although the Jersey-Guernsey milk contained 9.47 per cent solids-not-fat while the Holstein milk contained 8.71 per cent solids-not-fat.

When the creams of the Holstein and the Jersey-Guernsey milks were interchanged the results were not comparable to the results of the unchanged milks. This was probably due to the condition of the milk, inasmuch as part of the milk was several days old.

In all cases except one the hydrogen ion concentration as expressed in terms of P_H increased upon heating. The temperature to which the milk was heated did not have any relation to the ratio of the increase in P_H. There was no correlation between the P_H and the viscosity and the depth of the cream layer at 0° or 12° C.

Table 9

Influence of Pasteurization on the Depth of the Cream Layer and Viscosity.

Kind of Milk	Temperature of Pasteurization	Solids-not-fat (calc.)	P_H at 25°C.	Properties at 12° C. Viscosity at once	Viscosity after standing 24 hours	Cream Volume
	° C	per cent		cp	cp	per cent
Holstein		8.71			2.54	13.77
Holstein	62.8	8.71		2.24	2.43	8.50
Jersey-Guernsey		9.47		2.66	2.89	14.25
Jersey-Guernsey	62.8	9.47		2.59	2.89	7.25
Jersey-Guernsey		9.81	6.50	2.32	2.63	7.00
Jersey-Guernsey	62.2	9.81	6.56	2.17	2.59	6.37
Jersey-Guernsey skim-milk plus Holstein cream		9.34	6.26	2.08	2.66	5.12
Jersey-Guernsey skim-milk plus Holstein cream	62.8	9.34	6.41	2.19	2.47	1.50
Holstein		9.19	6.42	2.32	2.24	8.50
Holstein	63.0	9.19	6.42	2.19	2.32	2.87
Holstein skim milk plus Jersey-Guernsey cream		8.99	6.48	2.08	2.01	5.75
Holstein skim milk plus Jersey-Guernsey cream	63.1	8.99	6.54	2.13	2.19	2.25
Holstein		8.69	6.42	2.32	2.32	7.12
Holstein	65.4	8.69	6.49	2.17	2.19	1.37
Holstein skim milk plus Jersey-Guernsey cream		9.11	5.72	2.24	2.43	6.0
Holstein skim milk plus Jersey-Guernsey cream	65.8	9.11	6.05	2.59	2.89	1.5

Table 10

Influence of Pasteurization on the Depth of the Cream Layer and Viscosity.

Kind of Milk	Temperature of Pasteurization	Solids-not fat (calc.)	P_H at 25° C.	Properties at 0° C. Viscosity at once	Viscosity after standing 24 hours	Cream Volume
	° C.	per cent		cp	cp	per cent
Holstein		8.71			4.05	14.25
Holstein	62.8	8.71		3.92	3.94	11.00
Jersey-Guernsey		9.47		4.56	4.84	17.00
Jersey-Guernsey	62.8	9.47		4.40	4.62	11.00
Jersey-Guernsey		9.81	6.50	4.22	4.22	16.37
Jersey-Guernsey	62.2	9.81	6.56	3.75	4.10	11.37
Jersey-Guernsey skimmilk plus Holstein cream		9.34	6.26	3.82	4.28	14.25
Jersey-Guernsey skimmilk plus Holstein cream	62.8	9.34	6.41	3.82	4.28	2.0
Holstein		9.19	6.42	4.10	4.14	15.25
Holstein	63.0	9.19	6.42	3.70	4.03	2.75
Holstein skim milk plus Jersey-Guernsey cream		8.99	6.48	3.58	3.70	11.75
Holstein skim milk plus Jersey-Guernsey cream	63.1	8.99	6.54	3.45	3.54	2.0
Holstein		8.69	6.42	3.98	4.22	10.75
Holstein	65.4	8.69	6.49	3.63	3.94	1.50
Holstein skim milk plus Jersey-Guernsey cream		9.11	5.72	3.82	4.10	6.37
Holstein skim milk plus Jersey-Guernsey cream	65.8	9.11	6.05	4.62	4.45	1.50

Pasteurizing skim milk alone and adding raw cream. - The inconsistent results secured in the breed experiments raised the question whether the reductions in the depth of the cream layers are due to the effect of heat upon the fat globules or to the change in the properties of the hydrophilic colloids. In order to determine this point the skim milk of mixed whole milk was pasteurized at 144°, 145° and 152° F. and raw cream added. The cream used to standardize the skim milk after pasteurization contained 55 per cent fat. Two of the experiments were conducted in shot-gun cans while the third was conducted on a smaller scale to ascertain whether the results secured from the first two experiments were comparable.

In the first two experiment 18 pounds of skim milk was used for each test. First the raw untreated milk was standardized to 3.5 per cent fat. Then a portion of the mixed milk was separated and the cream added. This constituted the second sample. For the third sample the raw skim milk was agitated 5 minutes and the cream added thereafter. The fourth sample was heated to 144° F. and the cream added while the skim milk was at this temperature. In the fifth sample the milk was heated to 144° F. and constantly agitated during the heating process and the fat was added while the skim milk was at the pasteurizing temperature. The same procedure was followed for the other two samples of milk as for the fourth and fifth samples with the exception that the skim milk was heated to 152° F. After the skim milk had been pasteurized the shot-gun cans were taken out of the heating medium and the cream added, the milks were then cooled to temperatures ranging between 60 and 80° F. before placing the samples at the creaming temperature. The results of the experiment are presented in Table II.

From the Table II it is seen that the influence of separating milk and then remixing the milk and cream is negligible as far as the reduction of the cream layer is concerned. The loss is so small that it is within the limits of experimental error. The depth of the cream was reduced from 13.50 to 13.25 percent by volume by passing the milk through a centrifugal separator. When the raw skim milk was agitated for five minutes and the cream added, the cream layer was reduced from 13.50 to 11.25 per cent. Heating the skim milk alone with the least possible amount of agitation reduced the cream layer of the milk from 13.50 to 6.00 per cent and when the milk was heated and agitated at 144° F. the cream layer rising was only 5.75 per cent. At the temperature of 152° F. the influence of heat on the particles in colloidal solution is even more apparent, as only a 2.00 per cent cream layer rose to the surface when the milk was heated with the least possible amount of agitation and only 1.00 per cent when the milk was agitated during the heating process.

As the cream was added to the skim milk while hot it was thought that this factor may have in some way altered the physical condition of the fat globules, so that the result was the same as if they had been heated for the entire "holding period". In order to ascertain this particular point another experiment was conducted to determine the effect of adding cream at the pasteurization temperature and at 80° F. In this case the milk was creamed at both 0 and 12° C. The results are tabulated in Table 12.

As Table 12 shows the influence of separation was nil at 0° C. but at 12° C. the volume of cream reduced from 11.25 to 6.50 per cent. It is interesting to note that the cream layers are practically the same on pasteurized milk whether the milk was creamed at 0 or 12° C. Cooling the skim milk to 80° F. before adding the cream seemed to favor the development of a deeper cream layer although the increase was very slight in case of both milks heated either at 144 or 152° F.

In both experiments a marked foaming was observed when the raw skim milk was agitated. When the cream was added this disappeard. Likewise, on the pasteurized skim milk the very excessive foaming was curbed by the addition of the

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cream and further agitation failed to produce even a marked foaming.

The excessive foaming of the skim milk raised the question whether the presence of gas in the milk may have some effect on the rising of the fat globules and hence have an influence on the depth of the cream layer. Undoubtedly some air is incorporated into the milk during the stirring process. In an effort to determine the influence of incorporated air the following procedure was carried out. Small quantities of skim milk were heated to 145° F. and then held for 30 minutes in a thermostat. Then the skim milk was placed in a filter flask and the gas removed by vacuum exhaustion before adding the cream. In each case 1000 cc. samples of milk were used. The results of the experiment are given in Table 13.

With these small batches of skim milk practically the same results were secured as with the larger quantities. Although a great difference was manifested in the depth of the cream layers at 0° C. as compared to those at 12° C. on the raw milk, these differences were not apparent at either temperature when the milk was pasteurized at 145° F. Removing the air seemed to favor the development of a deeper cream layer at 0° C. but at 12° C. a decrease occurred.

Table 11

Influence of Pasteurizing Skim Milk on the Creaming Abilities of Mixed Milk.

Treatment	Cream at 0° C.	Temperature of milk when cream was added.
	per cent	$^{\circ}$F.
Raw untreated	13.50	90
Raw milk separated plus raw untreated cream	13.25	80
Raw skim agitated 5 minutes plus raw untreated cream	11.25	80
Skim milk pasteurized at 144° F. plus raw untreated cream	6.00	144
Skim milk pasteurized and agitated at 144° F. plus raw untreated cream	5.75	144
Skim milk pasteurized at 152° F. plus raw untreated cream	2.00	152
Skim milk pasteurized and agitated at 152° F. plus raw untreated cream	1.00	152

Table 12

Influence of Pasteurizing Skim Milk on the Creaming Abilities of Mixed Milk.

Treatment	Cream Volume at 0°C.	Cream Volume at 12°C.	Temperature of milk when cream was added.
	per cent	per cent	° F.
Raw untreated	13.75	11.25	80
Raw milk separated plus raw untreated cream	13.75	6.50	80
Skim milk pasteurized at 144° F. plus raw untreated cream.	1.00	1.50	144
Skim milk pasteurized at 144° F. plus raw untreated cream	1.75	2.00	80
Skim milk pasteurized at 152° F. plus raw untreated cream	.50	.95	152
Skim milk pasteurized at 152° F. plus raw untreated cream.	.82	1.00	80

Table 13

Influence of Pasteurizing Skim Milk on the Creaming Abilities of Mixed Milk.

Treatment	Cream Volume at 0°C.	Cream Volume at 12°C.	Temperature of milk when cream was added.
	per cent	per cent	°F.
Raw untreated milk	13.5	5.50	80
Raw milk separated plus raw untreated cream	12.87	5.25	80
Skim milk pasteurized at 145°F. plus raw untreated cream	4.37	4.87	80
Skim milk pasteurized at 145° F., air evacuated for 10 minutes, plus raw untreated cream	5.00	4.37	80

Observations on the Creaming of Milk at Commercial Milk Plants. - At this point the writer would like to give some of the results secured at milk plants in the Twin Cities and at Albert Lea, Minnesota. In conjunction with Dr. R. W. Archibald and Mr. H. A. Whittaker of the Minnesota State Board of Health the writer was privileged to study the problem of cream rising on pasteurized milk under commercial conditions. Although these observations preceded the laboratory studies, the results are to be interpreted best in the light of the laboratory experiments which have been presented in the preceding pages. Six milk plants were visited, namely, the Minnesota Milk Company, Saint Paul Milk Company, Quaker Creamery Company, Franklin Cooperative Creamery Association, the Albert Lea Milk Company, and the Thomson Dairy of Albert Lea.

At the Minnesota Milk Company the milk is pumped from the first floor to the receiving tank on the second floor by a Davis-Watkins Progress Piston Pump operated at 125 strokes per minute. The milk is standardized in the receiving tank and heated to 78° F. after which it flows by gravity to the clarifier. From the clarifier it flows to a pre-heater and is then elevated 10 feet by a rotary pump to the holding vats where the milk is brought to the pasteurization temperature and held for 30 minutes absolute holding time or one hour and thirty minutes maximum holding time. The maximum holding time includes the time required to fill the tank, hold the milk and until all the milk is discharged from the vat. The milk flows by gravity from the vat to the cooler and thence by gravity to the bottler. The day the data was taken pasteurized skim milk was used to standardize the milk.

Davis-Watkins pasteurizing apparatus is employed at the Saint Paul Milk Company. The milk is received on the ground floor and elevated by a rotary pump to a tank on the third floor. The milk is heated to 65° F. and transferred to the clarifier by a rotary pump. After clarification the milk flows by gravity to the tubular heater situated on the second floor of the plant. From the heater the milk flows to the vats and is held 30 minutes after which it flows by gravity to the internal tubular cooler. From the cooler the milk flows by gravity to the bottler on the ground floor. The absolute holding time is 30 minutes and the maximum holding time 42 minutes or in other words it takes 6 minutes to fill each vat, 30 minutes for holding and 6 minutes to empty each vat.

The Quaker Creamery Company uses the vat system for both heating and holding. The raw milk is pumped from the receiving room on the first floor to the receiving tank located on the second floor. Here the milk is heated to 88° F. and is then pumped to the clarifier by means of a rotary pump. From the clarifier the milk flows by gravity to the Wizard vat where the milk is heated to the pasteurization temperature. In the process of heating the milk is agitated by coils rotating at 60 R.P.M. The milk is held for 30 minutes absolute holding time and 47 minutes maximum holding time. Seventeen minutes are required to empty the vat. During the holding period the milk is not agitated until the absolute time has elapsed, then the coils are rotated for 17 minutes or until the milk is completely discharged. From the pasteurizing vat the milk flows to the cooler and from thence to the bottler. At this plant the milk is pumped twice.

At the Franklin Cooperative Creamery Association the Davis-Watkins internal tubular heater and a series of holding vats are used. The milk is elevated from the ground floor to the receiving tank by a Davis centrifugal pump operating at a speed of 1800 R.P.M. The milk is then pumped through the pre-heater, with much agitation, where the temperature of the milk is raised to 75° F., to the clarifier. After clarification the milk is again pumped by a centrifugal pump to the internal tubular heater and from here it flows by gravity to the holding vats. The milk is held in these vats for 25 minutes absolute holding time and 27 minutes maximum holding time. Only two minutes are required to fill and empty each vat.

The milk then flows by gravity to the Davis-Watkins external cooler and thence to the bottler, all of which are located on the first floor. It should be noted that the milk is pumped three times at this plant.

The Albert Lea Milk Company provided an opportunity to study the effect of heating milk by the "spray vat" system in which milk is agitated by means of suspended paddles instead of the usual coil, and heated by throwing a continuous spray of hot water against the inner lining of the vat. At this plant the raw milk is pumped to the receiving tank by a Simplex Piston Pump operated at a speed of 25 - 60 strokes per minute. Thence it flows by gravity to the clarifier. After clarification the milk flows to the vat where the milk is heated to the pasteurization temperature and held 30 minutes absolute holding time. The milk is then cooled to 100° F. in the vat and held 30 minutes before the milk is transferred by gravity to the internal tubular cooler. From the cooler the milk flows by gravity to the bottler. At this plant the milk is pumped once and subjected to very little agitation during the heating and holding process.

At the Thomson Dairy a vat system of pasteurization very similar to that of the Minnesota Milk Company is used. The milk is not clarified or is it subjected to pumping before pasteurization as the milk flows directly from the receiving room to the vat. During the heating process the milk is agitated by coils revolving at a speed of 32 R.P.M. The absolute holding time is 30 minutes and then the milk is cooled to 110° F. in the vat and held at this temperature for 30 minutes before emptying the vat. From the vat the milk is pumped to the cooler by a Viking rotary pump operated at 240 R.P.M.

In all these plants samples were taken of raw milk, raw clarified milk, milk heated to the pasteurization temperature and milk held at the pasteurization temperature. With the exception of the milk at Thomson's Dairy, the milk described as "raw" had been pumped once. Therefore the samples are not truly representative of raw untreated milk. The samples were placed in 100 cc. graduated glass cylinders and set to cream in the company's refrigerator. The depth of the cream layer was measured after the milk had stood for about 17 to 18 hours. The data secured are presented in Table 14.

It will be noted that clarification always reduced the depth of the cream layer although the milk had been pumped once or twice before. The percentage of cream layer was reduced by clarification for the five plants from an average of 12.42 for the raw milk to an average of 10.80 for the clarified milk.

Heating the milk to pasteurization temperatures in 3 cases increased the depth of the cream layer while on the other hand heating decreased the depth of the cream layer at the other three plants.

The milk at the Minnesota Milk Company and the Albert Lea Milk Company, which was agitated during the holding process, had its cream layer reduced from 12.50 to 9.70 per cent and 13.30 to 12.00 per cent respectively. On the other hand at the Quaker Creamery Company, Thomson Dairy and the Saint Paul Milk Company where the milk was not agitated during the holding process the depth of the cream layer decreased from 13.50 to 10.20 per cent, 16.30 to 16.00 per cent by volume respectively. At the Franklin Cooperative Creamery Association the depth of the cream layer increased from 6.80 to 9.40 per cent when held at the pasteurizing temperature without agitation.

The factor of pumping as influencing the depth of the cream layer could not be ascertained directly because the milk labelled "raw milk" has been pumped once. However, general deductions from the results from the different milk plants seem to indicate that pumping caused a diminution in the depth of the cream layer. For example, at the Thomson Dairy a cream layer of 16.30 per cent was produced on the raw unpumped milk as compared to a cream volume of 6.80 per cent produced on the "raw milk" at the Franklin Cooperative Creamery Association, which had been pumped once at 54° F. In general pumping milk at a low temperature seemed to decrease the depth of the cream layer more than did pumping at relatively higher temperatures, a conclusion which is substantiated by the laboratory studies reported in the next section.

To compare the effect of the different types of apparatus on the depth of the cream layer would give erroneous results because the conditions at the milk plants were not standardized as to the method of treatment, percentages of fat and solids-not-fat in the milk and the temperature at which the milk was creamed. A general comparison of the cream volumes secured in the completely processed milk at the several plants shows, however, that the cream layers were essentially the same for the milks processed at the Minnesota Milk Company, the Quaker Creamery Company, and the Franklin Cooperative Creamery Association. Distinctly good cream layers were obtained at the Saint Paul Milk Company and the Thomson Dairy plants. The result in the case of the Saint Paul Milk Company may have been due in a large measure to the appreciably lower creaming temperature. In the case of the Thomson Dairy a high percentage of fat and a complete absence of pumping were no doubt the principal contributing factors. The somewhat better cream layer obtained at the Albert Lea Milk Company than at the Minnesota, Quaker and Franklin plants was probably due to a higher percentage of fat in the milk, a lower creaming temperature and a minimum pumping, although it is obvious that the heating process proper at this plant has a distinctly unfavorable effect on the creaming.

The influence of agitation during the "holding process" on the viscosity and the depth of the cream layer were studied in the laboratory, the results of which were presented under the heading "influence of heating milk on the viscosity and the depth of the cream layer".

Table 14

Comparison of the Factors Influencing the Depth of the Cream Layer at Different Milk Plants

Name of Plant	Description of Sample	Temperature of treatment	Number of times pumped before treatment	Amount of fat in milk	Temperature of Refrigeration.	Cream Volume
		°F.		per cent	°F.	per cent
Minnesota Milk Company	Raw	68	once	3.40	43-46	12.50
	Clarified	78	once	3.30	43-46	11.00
	Heated to Past. temp	145	twice	3.40	43-46	12.20
	Held at Past. temp	145	twice	3.45	43-46	9.70
Saint Paul Milk Company	Raw	64	once	3.50	35-38	16.00
	Clarified	65	twice	3.60	35-38	15.00
	Heated to Past. temp	143	twice	3.60	35-38	15.50
	Held at Past. temp	143	twice	3.50	35-38	15.50
Quaker Creamery Company	Raw	88	once	3.50	43	13.50
	Clarified	88	twice	3.50	43	11.00
	Heated to Past. temp	145.5	twice	3.50	43	12.60
	Held at Past. temp	145.5	twice	3.50	43	10.20
Albert Lea Milk Company	Raw	61	once	3.70	38	13.30
	Clarified	61	once	3.70	38	11.00
	Heated to Past.temp.	145.5	once	3.70	38	14.80
	Held at Past. temp	145.5	once	3.70	38	12.00
Thomson Dairy	Raw	60	none	4.00	40-42	16.30
	Heated to Past. temp	145.5	none	4.00	40-42	17.50
	Held at Past. temp	145.5	none	4.00	40-42	16.00
Franklin Cooperative Creamery Association	Raw	54	once	4.00	42	6.80
	Clarified	75	twice	4.10	42	6.00
	Heated to Past. temp	145	thrice	4.10	42	11.10
	Held at Past. temp	145	thrice	4.10	42	9.40

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Effect of Pumping Milk on the Viscosity and the Depth of the Cream Layer. Effect of pumping raw mixed milk. - - Inasmuch as the results secured at the various milk plants indicated that the amount of pumping to which the milk was subjected tended to decrease the depth of the cream layer, experiments were conducted in the laboratory to definitely determine this point. At the same time the viscosity of the milk was determined to ascertain whether the changes in the depth of the cream layer were accompanied by variations in the viscosity. Milk at 12° 17°, and 33° C. was pumped through 25 feet of hose, by a rotary pump operated at 125, 200 and 300 revolutions per minute. The data are summarized in Table 15 and are derived from Tables XIX, XX, XXI and XXII in the appendix.

The data in Table 15 show no correlation between the variations in the depth of the cream layer and the viscosities but indicate that a general relation exists between the depth of the cream layer and the viscosity when the milk was creamed at different temperatures. In general the viscosity increased after standing 24 hours at 0° or 9 - 10° C.

The amount of pumping to which the milk was subjected did not produce as large variations in the depth of the cream layer as might be expected. For example pumping the milk six times at various speeds at 12° C. decreased the cream layer from 14.00 to 13.00 per cent while pumping the milk three times at the same temperature produced the same decrease.

Pumping the milk at 12° or 17° C., regardless of the amount or speed of the pump, decreased the depth of the cream layer more than did pumping at 33° C.

Harding (1921) states that the creaming ability of milk can be largely restored by heating the pumped milk to 90° F. In order to ascertain whether this was possible about 40 pounds of mixed milk was pumped through 25 feet of hose by a rotary pump and afterwards heated to 90° F. The results are given in Table 16.

This simple experiment substantiates Harding's contention. Not only was the creaming ability of the milk restored but a deeper cream layer was secured when the pumped milk was heated to 90° F. and then allowed to cream at 32° F.

Table 15

Influence of Pumping Raw Milk on the Viscosity and the Depth of the Cream Layer

Kind of milk	Treatment			Properties at 0° C.			Properties at 9-10° C		
	Times pumped	Speed of pump	Temperature of milk	Viscosity at once	Viscosity after standing 24 hours	Cream volume	Viscosity at once	Viscosity after standing 24 hours	Cream volume
		R.P.M.	°C.	cp	cp	per cent	cp	cp	per cent
Mixed	none			3.63	4.17	14.00	2.66	2.77	11.75
Mixed	2	125							
	1	220	12	3.86	4.77	13.00	2.89	2.19	10.00
Mixed	(2	(125							
	(2	(220							
	(2	(300	12	3.86	4.01	13.00	2.66	2.87	10.00
Mixed	none			4.24	3.94	13.62	3.12	3.36	11.95
Mixed	2	125	12	4.98	4.28	13.00	3.01	2.68	11.55
Mixed	2	300	12	4.98	3.70	12.45	2.89	2.89	9.10
Jersey-Guernsey	none			5.08	6.64	15.45	3.31	3.40	12.87
Jersey-Guernsey	2	125	17	5.55	5.88	14.87	3.33	3.47	12.17
Jersey-Guernsey	2	300	17	5.57	5.46	13.95	3.12	3.40	12.50
Mixed	none			5.42	5.62	12.87	3.28	3.01	11.95
Mixed	2	125	33	5.42	5.11	12.90	3.01	3.05	10.25
Mixed	2	300	33	5.08	5.23	12.12	2.89	3.12	10.62

Table 16

Influence of heating Pumped Milk to 90° F. on Restoring Its Creaming Ability

Treatment	Temperature of Treatment	Cream Volume at 32° F.
	°F.	per cent
Raw untreated		13.00
Raw milk pumped once at 300 R.P.M.	45.5	12.00
Raw milk pumped once at 300 R.P.M. and heated to 90° F.	45.5	13.25

Relation of Size of Fat Globules to Effect of Pumping. - - Although the experiments on pumping mixed milk showed that the decreases in the depth of the cream layer due to pumping are not large and that the variations in the depth of the cream layer can not be accounted for by the changes in viscosity, it was thought that the larger the size of the fat globules the more easily they could be broken up, the result being greater loss in the depth of the cream. Therefore, Holstein and JerseyGuernsey milk as well as the milks with interchanged creams were pumped twice at 32° C. and 9° C. by a rotary pump operated at a speed of 300 R.P.M. These two temperatures were chosen because it was found in the experiments on pumping raw mixed milk that the greatest differences in the depth of the cream layer due to pumping would occur at these temperatures. As the speed and the number of times of pumping did not influence the decrease in the depth of the cream layer to any appreciable extent, the speed of 300 R.P.M. was adopted and the milk was pumped twice to subject the milk to the greatest amount of agitation. The data of the experiments are summarized in Table 17 and are derived from Tables VII and VIII in the appendix.

The data in Table 17 show no correlation between the variations in the depth of the cream layer and the viscosities but indicate that a general relation exists between the depth of the cream layer and the viscosity when the milk was creamed at different temperatures.

Pumping Holstein or Jersey-Guernsey milk alone at 8.88° C. caused a greater reduction in the depth of the cream layer than pumping the milk at 32° C. This reduction was comparatively as great at 0° or 12° C. On the other hand when Jersey-Guernsey and Holstein creams were interchanged a greater reduction occurred in the depth of the cream layer when the milks were pumped at 32° C. and creamed at 0° C. than when pumped at 9° C. However, when the milks were creamed at 12° C. the reduction in the depth of the cream layer was the greatest in the cases when the milk was pumped at 9° C. The decreases in the cream layer cannot be correlated with a decreased viscosity inasmuch as a lower viscosity was accompanied by a deeper cream layer when the Jersey-Guernsey milk alone was pumped at 32° C., and a higher viscosity was associated with a shallower cream layer in the milk pumped at 9° C. These decreases possibly are due to experimental errors inasmuch as the depth of the cream layer was lower on the milk pumped at 9° C. than at 32° C. when the milk was creamed at 12° C.

Pumping the milk did not decrease the depth of the cream layer of the Jersey-Guernsey milk alone with the relatively large fat globules to any appreciably greater extent than did the pumping of the Holstein milk alone with the relatively small fat globules. Interchanging the creams did not alter the conditions to any appreciable degree. For example, the Holstein skim milk with the Jersey-Guernsey cream produced a cream layer of 13.00 per cent on the unpumped milk as compared to the cream layers of 12.00 and 12.80 per cent respectively for the milk pumped at 32° and 9° C. Furthermore, the Jersey-Guernsey skim milk with the Holstein cream produced a cream layer of 16.50 per cent on the unpumped milk as compared to 14.83 and 15.20 per cent respectively for the milk pumped at 32° and 9° C.

Table 17

Comparison of the Influence of Pumping on the Properties of Raw Holstein and Jersey-Guernsey Milk Alone and With Interchanged Cream

Kind of Milk	Treatment			Properties at 0° C.			Properties at 9-10° C.		
				Viscosity		Cream	Viscosity		Cream
	Times pumped	Speed of pump	Temperature of milk	at once	after standing 24 hours	volume	at once	after standing 24 hours	volume
		R.P.M.	°C.	cp	per cent	percent	cp	per cent	per cent
Holstein	none			4.73	5.32	11.25	2.89	2.89	6.80
Holstein	twice	300	32	5.46	5.29	11.67	3.01	2.83	7.00
Holstein	twice	300	9	5.10	5.15	11.00	3.32	2.89	5.70
Holstein skim-milk plus Jersey-Guernsey cream.	none			5.79	5.38	13.00	3.13	3.13	9.25
	twice	300	32	5.03	4.87	12.00	2.89	3.13	8.83
	Twice	300	9	4.75	5.46	12.88	3.13	3.13	8.75
Jersey-Guernsey	none			5.93	6.05	17.37	3.58	3.36	12.75
Jersey-Guernsey	twice	300	32	4.87	5.39	17.62	3.58	3.94	12.12
Jersey-Guernsey	twice	300	9	6.17	5.70	16.55	3.48	3.43	11.00
Jersey-Guernsey skim milk plus Holstein cream	none			6.09	5.93	16.50	3.40	3.58	11.25
	twice	300	32	5.79	5.63	14.83	3.63	3.36	9.25
	twice	300	9	7.12	5.93	15.20	3.77	3.82	8.15

Influence of the Proteins of Milk on the Depth of the Cream Layer. - As far as is known by the writer no experiments have been conducted to determine the influence of the two principle proteins of milk, namely, lactalbumin and calcium caseinate, on the creaming ability of milk.

Influence of lactalbumin. - Hunziker (1921 a) believes that the particles of albumin are dehydrated when milk is pasteurized and that the particles of albumin which come in contact with the heating surface are precipitated. According to Hunziker's theory the precipitated albumin forms a network in the milk and hinders the fat globules from rising. Providing this is true to any appreciable degree, then the fat globules should remain in the lower layer to a greater extent when a liquid containing albumin is heated to pasteurization temperature. Rahn (1922) has recently studied the influence of the addition of colloids, such as, gum arabic, gum tragacanth and gelatine on the creaming ability of boiled milk. By adding these colloids to the milk and afterwards boiling it, Rahn secured a cream layer nearly three times as large as that produced on the boiled milk without the addition of colloidal material. In the milk in which the colloidal content of the milk was increased, less fat remained in the skim milk than in the raw untreated milk. Furthermore the cream layer which was produced on the boiled milk with the addition of these colloids was practically as large as that of the raw untreated milk. Rahn concludes that the inability of boiled milk to cream properly is not due to the hindering of the movement of the fat globules by the coagulated albumin.

In order to ascertain the influence of the natural amount of lactalbumin in the milk on its creaming abilities a number of experiments were conducted on milk whey. The casein was removed from the milk by coagulating it with rennet extract in the usual manner as that employed in the making of American Cheddar cheese. It was thought that the amount of lactalbumin in the whey might have considerable influence on the resulting cream layer. Therefore Holstein and Jersey-Guernsey milk constituted the two standards of milk from which the whey was secured. The milk was separated and about 125 pounds of the skim milk containing 0.03 per cent fat was used for each of the experiments. The acidity of the milk was not increased by ripening because a whey with a P_H value as near to that of fresh milk as possible was desired. The casein was coagulated at a temperature of 88° - 91° F. by the addition of rennet extract. The curd was then cut and allowed to shrink at 90° F. During this process the whey was stirred very little. The whey was then drained off, filtered to remove the small particles of casein, cooled to 60° F. and placed in the refrigerator (at 35° F.) until the experiments were conducted. The total nitrogen content of each batch of whey was determined by the Kjeldahl method and the percentage of total protein was calculated by the use of the factor 6.38.

The whey secured from both the Jersey-Guernsey and the Holstein skim milk was standardized with Jersey-Guernsey and Holstein cream which was obtained from fresh cream testing 57 and 55 per cent fat respectively. Standardizing the milk with natural cream necessarily causes the addition of some casein to the whey but the amount added was considered too small to be of importance in affecting the results. The whey was heated to 80°F. before the cream was added. The whey-milk was then pasteurized in shot-gun cans immersed in a vat of water. During the heating process the whey-milk was constantly agitated with a stirring rod. The shot-gun cans containing the whey standardized with the two kinds of cream were pasteurized at the same time. When the pasteurization temperature was reached the whey-milk was allowed to stand without agitation except when temperature readings were taken. These readings were taken every five minutes. No visible difference was noticed between the raw and the pasteurized whey-milk which would account for the differences in the depth of the cream layer. The results of the experiments are summarized in Table 18.

The data in Table 18 show that a deeper cream layer was produced on the whey-milks with a normal P_H after they had been pasteurized than on the raw whey-milks. The Holstein whey containing 0.96 per cent protein produced a deeper cream layer with the Jersey-Guernsey cream than with the Holstein cream when raw or pasteurized and whether it was creamed at 0° or 12° C. When the Jersey-Guernsey whey containing 1.08 per cent protein was standardized with Holstein and Jersey-Guernsey cream practically the same cream layers were produced on the raw whey-milk but a deeper cream layer was produced when the Jersey-Guernsey whey plus the Holstein cream was pasteurized and creamed at 0° and 12° C. than when the Jersey-Guernsey whey plus the Jersey-Guernsey cream was treated in the same manner. The whey containing the highest percentage of protein was more conducive to the development of a deeper cream layer at 12° C. than at 0° C. It will be noticed also that less fat remained in the lower layer of the whey-milk after it has been pasteurized than when raw, and that as a general rule the cream layer was less packed in the pasteurized whey-milk than in the raw whey-milk as evidenced by the percentage of fat in the cream layer and the depth of the cream layer.

When the Jersey-Guernsey whey having a P_H value of 6.12 (which is much lower than that of fresh milk) was standardized with Jersey-Guernsey and Holstein cream a deeper cream layer was secured with the Holstein cream than with the Jersey-Guernsey cream. Furthermore, very little fat remained in the lower layer whether the whey-milk was raw or pasteurized, and the cream layer with the Holstein cream was much looser than that with the Jersey-Guernsey cream.

The hydrogen ion concentration as expressed in P_H values decreased on pasteurization in the experiments with the Jersey-Guernsey whey containing 1.08 per cent protein but in the other experiments it increased or remained constant.

Table 18

Comparison of the Influence of Pasteurization on the Properties of Standardized Whey from Holstein and Jersey-Guernsey Milk

Treatment	Kind of cream added	Kind of whey	P_H of whey-milk at 25° C.	Protein in whey	Specific gravity of whey milk at 15.5° C.	Cream Volume at 0°C.	Cream Volume at 12°C.	Fat in lower layer at 0°C.	Fat in lower layer at 12°C	Fat in cream layer at 0°C	Fat in cream layer at 12°C
				per cent		per cent	per cent	per cent	per cent	per cent	per cent
Raw	Holstein	Holstein	6.34	0.96	1.0247	11.50	5.00	2.00	1.90	28.08	33.90
Pasteurized	Holstein	Holstein	6.42	0.96	1.0247	16.27	7.75	1.95	1.75	21.02	24.33
Raw	Jersey-Guernsey	Holstein	6.36	0.96	1.0250	17.00	7.00	1.57	1.32	24.22	32.39
Pasteurized	Jersey-Guernsey	Helstein		0.96	1.0250	20.00	9.00	1.55	1.27	21.05	25.99
Raw	Jersey-Guernsey	Jersey Guernsey	6.53	1.08	1.0264	14.00	8.87	0.57	1.40	21.50	25.06
Pasteurized	Jersey-Guernsey	Jersey-Guernsey	6.45	1.08	1.0264	14.25	12.50	0.25	0.32	23.50	25.72
Raw	Holstein	Jersey-Guernsey	6.48	1.08	1.0263	13.62	7.50	0.80	1.60	20.61	26.93
Pasteurized	Holstein	Jersey-Guernsey	6.46	1.08	1.0263	15.75	13.75	0.40	0.45	20.08	22.63
Raw	Jersey-Guernsey	Jersey-Guernsey	6.12	1.10	1.0259	7.62	11.00	0.82	0.50	35.90	27.27
Pasteurized	Jersey-Guernsey	Jersey-Guernsey	6.12	1.10	1.0259	7.62	9.50	1.45		28.34	
Raw	Holstein	Jersey-Guernsey	6.12	1.10	1.0258	23.50	17.75	0.02	0.02	14.82	19.62
Pasteurized	Holstein	Jersey-Guernsey	6.12	1.10	1.0258	26.62	18.12	1.01	0.02	13.10	19.22

Influence of Calcium Caseinate. - In order to determine the influence of calcium caseinate on the depth of the cream layer it was necessary to make a synthetic milk in which the calcium caseinate was dispersed in colloidal solution.

The casein from which the calcium caseinate milk was made was precipitated by dilute hydrochloric acid (1 part 31.45 per cent HCL to 8 parts of water). The casein was precipitated from 122 pounds of skim milk. The skim milk was warmed to 35° C. and was slowly and continuously stirred while the precipitating acid was poured in a small stream. The acid was added until the milk "broke", giving a clear whey. Most of the whey was then drained off. The casein was then stirred thoroughly to break up the clumps. More acid was added until a P_H of 4.6 was reached, which represents the point at which the casein exists in the freest possible state. The rest of the whey was then drained off, the casein collected and placed in a cheese press to expel as much of the whey as possible. The casein waa then washed in water with a P_H adjusted to 4.8 by the addition of dilute hydrochloric acid. Each batch of wash water consisted of about twice the volume of the skim milk from which the casein was secured. After each pressing the whey was broken up into as fine particles as possible by rubbing the clumps between the hands. The casein remained in the wash water for 19 hours and was stirred three times during this interval. At the end of 19 hours the wash water was drained off and the casein collected and placed in a cheese press to expel as much of the water as possible. The curd was then placed in wash water with a P_H of 4.6 and broken up and stirred. The casein remained in this water for 8 hours and was stirred three times during the period of standing. The same procedure was carried out in this instance as before and then the casein was placed in a third batch of wash water adjusted to a P_H of 4.6. The casein remained in this wash water for a period of 16 hours during which the casein was stirred three times. Again the water was drained off, the casein pressed and was placed for the fourth time in water with a P_H of

4.6. The casein was washed for 8 hours and was stirred three times during this interval. After this washing the wash water showed a P_H value between 4.6 and 4.7 indicating that most of the calcium had been removed from the casein. The wash water was then drained off and the casein pressed to remove the excess water.

The nearly pure isoelectric casein prepared in the manner just described was made into calcium caseinate milk by the following proceedure. The casein was broken up as fine as possible with the hands and with the aid of a mortar and pestle it was dispersed in a small amount of distilled water. The casein was then placed in the refrigerator over night. The following morning the casein was finely ground in a mill, after which 40 grams of calcium carbonate and 10 grams of tri-calcium phosphate was thoroughly mixed with the casein and then placed in the refrigerator for 48 hours. At the end of this time the casein presented a glossy and jelly-like appearance. The casein was then milled and after milling it was very doughy. A small amount of distilled water and an excess of calcium carbonate was then added and thoroughly mixed with the hands and milled three times to expose every particle of casein to the action of the calcium carbonate. After milling the casein mixture had the consistency of thick cream. The mixture was placed in the refrigerator for 18 hours after which the following procedure was carried out. After standing the casein mixture resembled a jell. It was milled once after which distilled water was added until the mixture was pasty. The casein mixture was then milled three times after which more distilled water was added. Again the mixture was milled three times. The consistency of the mixture then resembled that of thick cream. Distilled water was added until the mixture was thin and creamy. Apparently the casein was now in colloidal solution in the form of calcium caseinate. The calcium caseinate milk was clarified by a De Laval Clarifier No. 105 to remove the excess calcium carbonate. The total nitrogen of the solution was determined by the Kjeldahl method and the percentage of casein present was calculated by the use of the factor 6.38.

As the calcium caseinate milk contained 6.63 per cent casein it was necessary to standardize the solution to the average casein content of Jersey-Guernsey and Holstein milk in order that experiments might be conducted on the artificial milk. Eckles and Shaw (1913) found that the average casein content for Jersey milk is 2.93 and for Holstein milk is 2.36. As there is not enough difference in the casein content between the Jersey and Guernsey milk, the casein content for the Jersey milk was adopted as the basis for the work representing the Jersey-Guernsey milk which has been chosen as one of the standards in this work. The calcium caseinate milk was then standardized to the proper percentage of fat by the addition of distilled water. The calcium caseinate milk representing the casein content for the Holstein and Jersey-Guernsey milk were each standardized to 3.5 per cent fat by adding Holstein and Jersey-Guernsey cream testing 51.5 and 56.5 per cent respectively. The standardized calcium caseinate milks were then pasteurized at 145° F. in the same manner as in the whey experiments. The results of the experiments are tabulated in Table 19.

From Table 19 it will be observed that the hydrogen ion concentration as expressed in P_H is slightly above that of natural milk. However they are all uniformly even, varying only .03 P_H in the raw milk and .04 P_H in the pasteurized milk. When pasteurized the P_H decreased slightly and this decrease was accompanied by a decrease in the depth of the cream layer but the decrease in the depth of the cream layer was not proportional to the decrease in the P_H value.

The specific gravity of the calcium caseinate milk plus the cream from both the Holstein and the Jersey-Guernsey milk ranged from 1.0070 to 1.0079 as determined by the Westphol balance at 15.5° C. Due largely to the fact that the specific gravity in the calcium caseinate milks plus cream are much lower than that of whey-milk or natural milk, a normal cream layer was not produced. In fact on the raw calcium caseinate milk containing 2.39 per cent casein standardized with Holstein cream and having a specific gravity of 1.0075, a cream layer of 3.00 per cent only was produced. On the same calcium caseinate milk standardized with Jersey-Guernsey cream and having a specific gravity of 1.0070, a cream layer of only 5.87 per cent developed on the raw milk. On pasteurizing the calcium caseinate milk representing the Holstein content and standardized with Holstein and Jersey-Guernsey cream the depth of the cream layer was reduced from 3.00 to 2.00 per cent and 5.87 to 2.67 per cent respectively. It is interesting to note that a deeper cream layer was always produced on the milk creamed at 12° than at 0° C. whether the milk was raw or pasteurized.

As would be expected the calcium caseinate milk standardized to represent the Jersey-Guernsey casein content had a higher specific gravity than that representing the Holstein casein content. The specific gravities were 1.0076 and 1.0079 respectively for the calcium caseinate milk standardized with Holstein and Jersey-Guernsey cream. A deeper cream layer was produced on the 2.93 calcium caseinate milk with the addition of both kinds of cream as compared to the 2.39 calcium caseinate milk. The calcium caseinate milk standardized with Jersey-Guernsey cream in both cases produced a deeper cream layer than that standardized with Holstein cream.

The chief reason for these shallow cream layers lies in the fact that the fat globules failed to rise because the specific gravities were abnormally low as compared to that of natural milk. That the fat globules failed to rise is shown by the percentage of fat remaining in the lower layer which is considerably higher than that in the lower layer of natural milk. The shallow cream layers at 0° C. can not be explained on the theory that the fat globules are more packed than those at 12° C. because the percentage of fat in the cream layer is much higher at 12° C. than at 0° C. It is simply a question of the failure of the fat globules to rise because the percentage of fat in the lower layer when the milk was creamed at 0°C. is much higher than that in the lower layer of the milk creamed at 12° C.

A more general discussion of the influence of lactalbumin and calcium caseinate on the creaming ability of milk will be discussed when the results of the experiments are discussed.

Further observations on the calcium caseinate milk. - - In the raw calcium caseinate milk standardized with both the Holstein and the Jersey-Guernsey cream the cream line or the line of demarkation between the cream layer and the lower layer was easily distinguished but when the calcium caseinate milk was pasteurized the cream layer seemed to blend with the lower layer. The depth of the cream layer in the case of the pasteurized calcium caseinate milk was obtained by observing the cream layer against the sun through a slit in a window curtain.

A qualitative examination of the calcium caseinate milk showed a trace of lactose and albumin, no di-calcium phosphate and on heating a thin skin of calcium caseinate formed on the surface which again formed when the first one was removed. The latter phenomena which is characteristic of all milk was the only visible change that occurred when the milk was pasteurized.

Samples of colloidal calcium caseinate solution which were left in the refrigerator (where the temperature was fairly constant at 35°F.) for two weeks showed that the colloidal calcium caseinate was gradually settling to the bottom. This suggested that the albumin in the milk may exert a protective influence on the colloidal calcium caseinate thereby keeping the caseinate in colloidal solution. This theory has already been advanced by Alexander (1919). Lactalbumin in the form of whey was added to the milk but the milk spoiled before the protective influence of the lactalbumin on the colloidal calcium caseinate could be determined.

The specific gravity of the calcium caseinate milk (without the addition of cream) was determined by the Westphal balance. For the milk representing the Holstein casein content or that containing 2.39 per cent had a specific gravity of 1.0069 while that containing 2.93 per cent casein (representing the Jersey-Guernsey casein content) had a specific gravity of 1.0096. This goes to show that the colloidal calcium caseinate in the milk has very little influence on the specific gravity of the milk but at the same time this small amount of casein has a tremendous effect upon the creaming ability of milk.

Table 19

Comparison of the Influence of Pasteurization on the Properties of Standardized Calcium Caseinate Milk.

Kind of milk	Kind of cream added	Treatment	Casein	Specific gravity of milk	P_H at 25° C.	Cream Volume at 0° C.	Cream Volume at 12°C.	% Fat in lower layer at 0° C.	% Fat in lower layer at 12°C.	% fat in cream layer at 0°C.	% fat in cream layer at 12 °C
			per cent			per cent	per cent	per cent	per cent	per cent	per cent
Calcium caseinate	Holstein cream	Raw	2.39	1.0075	6.77	3.0	4.5	2.97	2.47	20.50	25.25
	Holstein	Past	2.39	1.0075	6.71	2.0	3.75	2.97	2.40	29.25	31.73
	Jersey-Guernsey	Raw	2.39	1.0070	6.78	5.87	8.37	2.25	1.65	23.52	23.74
	Jersey-Guernsey	Past	2.39	1.0070	6.75	2.67	5.87	2.57	1.57	37.15	34.34
Calcium caseinate	Holstein	Raw	2.93	1.0076	6.78	3.50	6.0	3.02	2.37	17.02	21.12
	Holstein	Past	2.93	1.0076	6.73	2.62	5.12	2.90	2.25	25.75	26.63
	Jersey Guernsey	Raw	2.93	1.0079	6.75	11.25	10.37	1.05	.60	22.82	28.55
	Jersey Guernsey	Past	2.93	1.0079	6.72	3.5	5.25	2.40	1.52	33.82	39.14

<u>Relation between the Viscosity of the Milk and the Percentages of Fat in the Cream and Lower Layers.</u> - Although the data presented in the following pages were taken in conjunction with the data previously reported and discussed they can be presented in the light of the other experiments because they indicate to what extent the fat globules rise and how concentrated a cream layer is formed rather than to what extent the fat globules produce deep or shallow cream layers.

Influence of pumping raw mixed milk. - - With raw milk it will be observed from Tables 20 and 21 (as derived from Tables XX, XXI, and XXII in the appendix) that the higher the viscosity the lower is the percentage of fat retained in the lower layer. For example, taking the average for the experiments (regardless of the temperature at which the milk was pumped) the percentage of fat in the lower layer was 0.60 and the viscosity 5.02 cp. for the milk creamed at 0° C. as compared to 1.12 per cent fat in the lower layer and a viscosity of 3.12 cp. for the milk creamed at 9 - 10° C. This relation is shown graphically in Plate 7. From the graph it will be observed that the percentage of fat in the lower layer varies from 0.77 to 1.8 while the viscosity varies from 3.01 to 2.68 at the high creaming temperature. At the low creaming temperature the percentage of fat varies from 0.90 to 0.30 while the viscosity varies from 3.58 to 6.64. The higher the viscosity the less is the percentage of fat retained in the lower layer. This applies equally to the milk creamed at 0° C. or 9 - 10° C.

The decreased cream layers due to pumping were associated with a greater percentage of fat in the lower layer, both at 0° and 9 - 10° C.

There was no correlation between the percentage of fat in the cream layer and the viscosity. Although there was a higher percentage of fat in the cream layer when the milk was creamed at 0° C. this can not be taken as an indication that the fat globules are packed to a greater degree than in the milk creamed at 9-10° C.

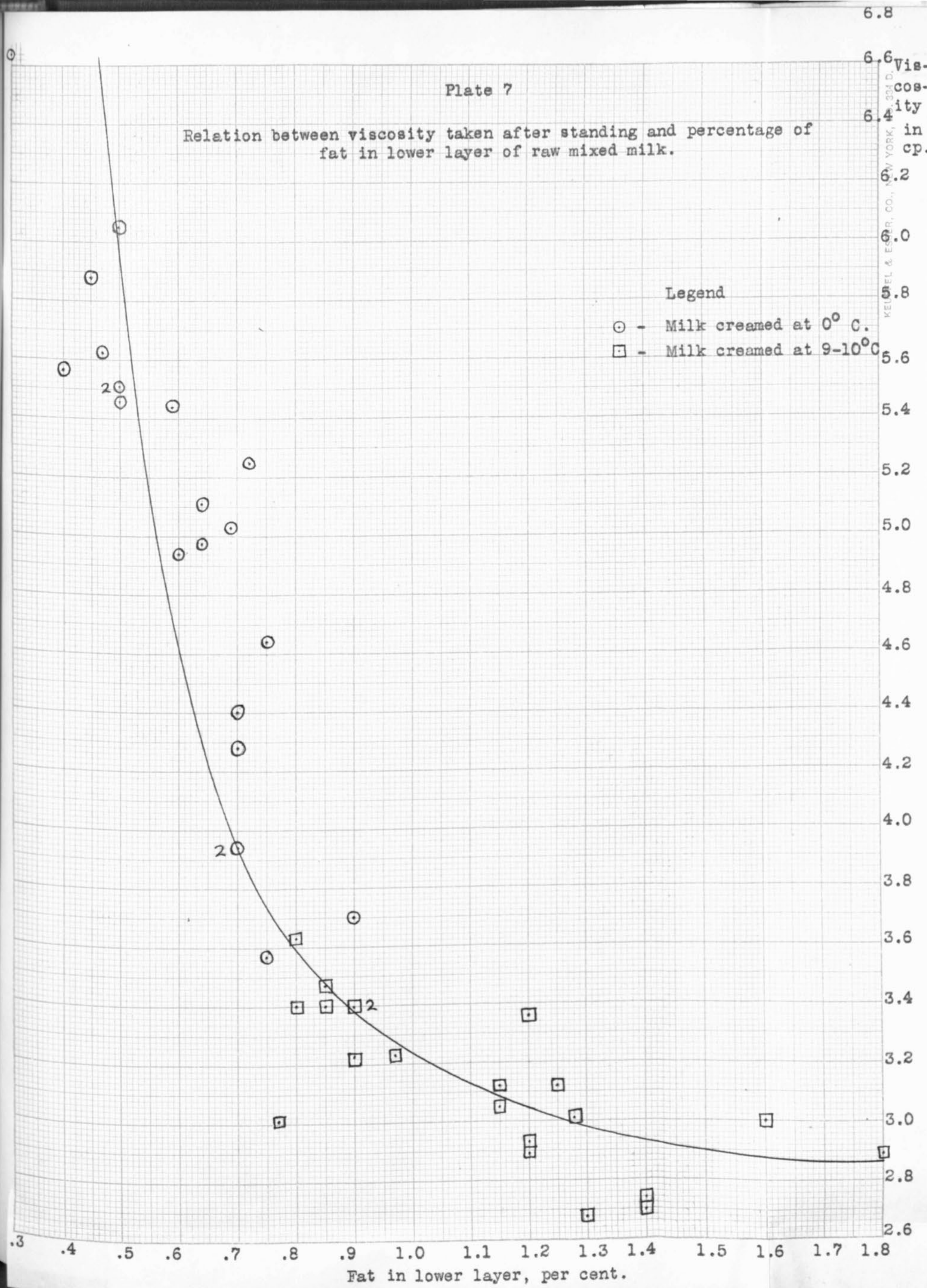
Plate 7
Relation between viscosity taken after standing and percentage of fat in lower layer of raw mixed milk.
Legend
⊙ - Milk creamed at 0° C.
⊡ - Milk creamed at 9-10°C
Viscosity in cp.
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Fat in lower layer, per cent.

because in the subsequent experiments the reverse is always true. Therefore it must be concluded that these results are exceptions to the rule.

Table 20

Influence of Pumping on the Properties of Raw Mixed Milk.

Treatment	Temperature of treatment	Properties at 0° C.			
		Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer
	0° C.	cp	per cent	per cent	per cent
Raw untreated		3.94	13.62	0.70	20.55
Pumped once at 125 R.P.M.	12.22	4.40	12.87	0.70	21.80
Pumped twice at 125 R.P.M.	12.22	4.28	13.00	0.70	21.55
Pumped once at 220 R.P.M.	12.22	3.94	13.00	0.70	21.55
Pumped twice at 220 R.P.M.	12.22	4.64	12.87	0.75	21.40
Pumped once at 300 R.P.M.	12.22	3.58	12.52	0.75	21.95
Pumped twice at 300 R.P.M.	12.22	3.70	12.45	0.90	20.87
Raw untreated		6.64	15.45	0.30	20.71
Pumped once at 125 R.P.M.	17.22	6.05	15.12	0.50	19.85
Pumped twice at 125 R.P.M.	17.22	5.88	14.87	0.45	20.50
Pumped once at 220 R.P.M.	17.22	5.51	14.75	0.50	20.35
Pumped twice at 220 R.P.M.	17.22	5.51	14.00	0.50	21.43
Pumped once at 300 R.P.M.	17.22	5.57	14.37	0.40	21.55
Pumped twice at 300 R.P.M.	17.22	5.46	13.95	0.50	21.50
Raw untreated		5.62	12.87	0.47	23.50
Pumped once at 125 R.P.M.	32.77	5.44	13.00	0.59	22.40
Pumped twice at 125 R.P.M.	32.77	5.11	12.90	0.64	22.20
Pumped once at 220 R.P.M.	32.77	5.03	12.37	0.69	21.95
Pumped twice at 220 R.P.M.	32.77	4.98	12.50	0.64	22.90
Pumped once at 300 R.P.M.	32.77	4.94	12.50	0.60	23.20
Pumped twice at 300 R.P.M.	32.77	5.23	12.12	0.72	32.90

Table 21

Influence of Pumping on the Properties of Raw Mixed Milk

Treatment	Temperature of treatment	Properties at 9 - 10° C.: Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in Cream layer
	0° C.	cp	per cent	per cent	per cent
Raw untreated		3.36	11.95	1.20	19.25
Pumped once at 125 R.P.M.	12.22	2.89	12.00	1.25	18.75
Pumped twice at 125 R.P.M.	12.22	2.68	11.55	1.30	19.05
Pumped once at 220 R.P.M.	12.22	2.73	10.70	1.40	19.65
Pumped twice at 220 R.P.M.	12.22	2.70	11.50	1.40	18.25
Pumped once at 300 R.P.M.	12.22	3.01	10.62	1.60	17.90
Pumped twice at 300 R.P.M.	12.22	2.89	9.10	1.80	18.65
Raw untreated		3.40	12.87	0.85	20.60
Pumped once at 125 R.P.M.	17.22	3.40	13.17	0.80	20.50
Pumped twice at 125 R.P.M.	17.22	3.47	12.17	0.85	21.75
Pumped once at 200 R.P.M.	17.22	3.63	12.12	0.80	22.20
Pumped twice at 200 R.P.M.	17.22	3.40	13.37	0.90	19.45
Pumped once at 300 R.P.M.	17.22	3.23	12.95	0.90	20.10
Pumped twice at 300 R.P.M.	17.22	3.40	12.50	0.90	20.60
Raw untreated		3.01	11.95	0.77	22.90
Pumped once at 125 R.P.M.	32.77	3.23	11.25	0.97	22.42
Pumped twice at 125 R.P.M.	32.77	3.05	10.25	1.15	22.70
Pumped once at 200 R.P.M.	32.77	3.01	9.50	1.28	23.40
Pumped twice at 200 R.P.M.	32.77	3.12	11.00	1.15	21.35
Pumped once at 300 R.P.M.	32.77	2.93	11.12	1.20	20.80
Pumped twice at 300 R.P.M.	32.77	3.12	10.62	1.25	21.20

Influence of the method of heating milk to the pasteurization temperature. - - The method of heating milk to the pasteurization temperature has some influence on the percentage of fat remaining in the layer as shown in Tables 22 and 23 (as derived from Table X in the appendix). When milk was heated to the pasteurization temperature with constant agitation more fat was retained in the lower layer than with milk heated with intermittent agitation whether the milk was creamed at 0° C. or 12° C., except in one case at 12°C. In this latter case the cream layer on the milk agitated intermittently was shallower and the percentage of fat in the cream layer was practically the same as on the milk agitated constantly. The deeper cream layers produced when the milk was heated to the pasteurization temperature with constant or intermittent agitation and creamed at 0° or 12° C. were associated with less fat in the lower layers than in the milk heated in 5 minutes with or without agitation and creamed at 0° or 12° C.

Less fat was retained in the lower layer in the milk heated in 30 minutes with or without agitation than that retained in the raw milk. With the milk heated in 5 minutes with intermittent agitation less fat is retained in the lower layer than in the lower layer of the raw milk, but with constant agitation the percentage of fat retained in the lower layer was considerably higher than that of the raw milk or the milk heated in 5 minutes with intermittent agitation. All this seems to indicate that heating of milk intermittently during the holding process either does not break up the fat globules as much as constant agitation or that there is less change in the physical properties of the hydrophilic colloids when the milk is not agitated as intensively during the heating process. As agitation itself does not hinder the development of a normal cream layer it seems altogether probably that the latter theory is a plausible explanation for the retention of the fat globules in the lower layer.

The variations in the percentage of fat retained in the lower layer can not be explained by similar differences in the viscosity. For example when the milk was creamed at 12° C. the percentages of fat in the lower layer varied from 1.00 to 1.90 while the viscosity remained constant at 3.10. However, the low viscosities at 12° C. were accompanied by a higher percentage of fat in the lower layer and the higher viscosities at 0° C. were accompanied by a lower percentage of fat in the cream layer. Also, it will be noted that the raw milk with the greater volume of cream contains less fat in the cream layer as compared to the higher percentage of fat in the heated milks with the smaller cream volumes. This indicates that in heated milk there is a greater packing of the fat globules than in the raw milk, both at 0° and 12° C.

Table 22

Influence of the Method of Heating to the Pasteurization Temperature on the Properties of the Milk

Kind of milk	Temperature to which milk was heated	Time of treatment	Amount of agitation	Properties at 0° C. Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer
	°C.,	minutes		cp	percent	per cent	per cent
Mixed	raw		none	5.69	16.07	0.60	18.64
Mixed	62.7	30	constant	5.67	14.62	0.50	21.00
Mixed	62.7	30	intermit-tent	5.32	15.25	0.22	21.72
Mixed	62.7	5	constant	4.85	12.50	1.00	21.00
Mixed	62.7	5	intermit-tent	4.85	14.37	0.23	22.97

Table 23

Influence of the Method of Heating to the Pasteurization Temperature on the Properties of the Milk.

Kind of Milk	Temperature to which milk was heated	Time of Treatment	Amount of agitation	Properties at 12° C. Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer
	° C.	minutes		cp	percent	per cent	per cent
Mixed	raw		none	3.22	11.87	1.30	19.82
Mixed	62.7	30	constant	3.10	11.62	1.00	21.72
Mixed	62.7	30	Intermit-tent	3.10	11.37	1.15	21.80
Mixed	62.7	5	constant	3.10	8.50	1.90	20.72
Mixed	62.7	5	Intermit-tent	3.10	10.75	1.05	23.84

Influence of pasteurizing mixed milk. - - When mixed milk is pasteurized the same general observations are to be noted as in the case of the milk heated just to the pasteurization temperature as shown by Tables 24 and 25 (derived from Tables XI, XII, XIII, and XIV in the appendix). That is, a higher viscosity is accompanied by less fat remaining in the lower layer and a lower viscosity is accompanied by a higher percentage of fat retained in the lower layer. In the pasteurized milk as in the milk heated just to the pasteurization temperature the percentages of fat in the cream layer are higher than that of raw milk. However, the variations in viscosity obtained when milk is pasteurized at different temperatures can not be correlated with variations in the percentage of fat in the cream and lower layers at the different creaming temperatures.

The lower percentages of fat in the lower layer coupled with the shallower cream layers and the higher percentage of fat in the cream layers of pasteurized milk indicate that in pasteurized milk the fat is far more concentrated than in the raw milk. However, when the milk is pasteurized at 67° C. more fat remains in the lower layer than in the lower layer of raw milk but the percentage of fat in the cream layer is slightly higher indicating that the fat in the cream layer must be packed in spite of the higher percentage of fat in the lower layer. In general the percentages of fat in the cream layers of the raw or pasteurized milk are much higher at 12° C. than at 0° C.

When milk is pasteurized at 62° C. or below and creamed at 12° C. more fat is retained in the lower layer when the milk is held at the pasteurizing temperature without agitation than when the milk is held with agitation. However, the opposite is true when milk is pasteurized at 65° C. or above. Similar differences do not occur, however, when the milk is creamed at 0° C.

Table 24

Comparison of the Influence of Pasteurization on the Properties of Mixed Milk

Kind of Milk	Treatment during holding process	Temperature of Pasteurization	Properties at 12° C.			
			Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer
		°C.	cp	per cent	per cent	per cent
Mixed	none	raw	3.12	11.60	1.12	21.59
Mixed	none	60	3.03	11.67	0.85	23.64
Mixed	agitated	60	2.96	11.80	0.79	23.75
Mixed	none	raw	2.93	11.67	1.20	20.90
Mixed	none	62	2.89	10.75	0.90	25.08
Mixed	agitated	62	2.89	11.67	0.70	24.68
Mixed	none	raw	3.10	10.50	1.50	20.54
Mixed	none	65	2.93	10.00	1.22	23.97
Mixed	agitated	65	3.01	9.50	1.35	23.98
Mixed	none	raw	2.75	9.80	1.52	21.42
Mixed	none	67	2.87	9.00	1.42	24.48
Mixed	agitated	67	2.89	8.00	1.67	24.51

Table 25

Comparison of the Influence of Pasteurization on the Properties Of Mixed Milk.

Kind of Milk	Treatment during holding process	Temperature of Pasteurization	Properties at° C.			
			Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer
		°C.	cp	per cent	per cent	per cent
Mixed	none	raw	5.45	14.75	0.34	21.73
Mixed	none	60	5.57	13.62	0.23	22.54
Mixed	agitated	60	5.32	13.62	0.23	24.23
Mixed	none	raw	5.34	16.37	0.27	19.96
Mixed	none	62	4.80	14.87	0.35	21.49
Mixed	agitated	62	5.08	13.95	0.23	23.67
Mixed	none	raw	4.73	15.37	1.00	17.26
Mixed	none	65	4.45	13.50	1.20	18.23
Mixed	agitated	65	4.75	11.62	0.70	24.78
Mixed	none	raw	5.02	15.87	0.52	19.26
Mixed	none	67	4.28	11.05	1.30	21.30
Mixed	agitated	67	4.49	9.87	1.60	20.84

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Influence of raw Holstein and Jersey-Guernsey milk alone and with interchanged creams. --- The data showing the influence of viscosity on the percentage of fat in the cream and lower layers are summarized in Tables 26 and 27 and are derived from Tables VII and VIII in the appendix.

As in the case of the raw mixed milk the data showing the influence of viscosity on the percentage of fat in the lower layer and the cream layer are taken from the pumping experiments because it has been shown that pumping does not decrease the depth of the cream layer appreciably, the data therefore, are truly indicative of the milk from the same breeds without having been pumped.

In these experiments as in the mixed milk experiments there is no correlation between the viscosity and the percentage of fat in the cream layer. However a general relation exists between the viscosity and the amount of fat in the lower layer. Taking the average for the breeds a viscosity of 5.5 cp is accompanied by 0.62 per cent fat in the lower layer when the milk was creamed at 0° C. as compared to a viscosity of 3.29 cp with 1.39 per cent fat in the lower layer when the milk was creamed at 9 - 10° C.

The fat in the cream layer is more concentrated in the milk creamed at 9 - 10° C. than at 0° C. being 22.88 and 20.42 per cent respectively. The higher viscosities are accompanied by deeper cream layers, lower percentages of fat in the cream and lower layers which indicate that the fat is less packed in the cream layers when the milk is held at the lower temperature.

When the Holstein milk alone is creamed at 0° C. the average cream layer is 11.30 per cent with a percentage of fat in the lower layer of 1.23 and a percentage of fat in the cream layer of 20.03 as compared to a cream layer of 12.62, a percentage of fat of 0.60 in the lower layer and a percentage of fat in the cream layer of 23.00 per cent when the Holstein skim is standardized with Jersey-Guernsey cream.

When the Jersey-Guernsey milk alone is creamed at 0° C. the average cream layer is 17.18 per cent with a percentage of fat in the lower layer of 0.05 and a percentage of fat in the cream layer of 19.70 as compared to a cream layer of 15.51 per cent, a percentage of fat of 0.61 in the lower layer and a percentage of fat in the cream layer of 18.66 per cent when the Jersey-Guernsey skim milk is standardized with Holstein cream.

These data show that although more fat rises in the case of milk containing large fat globules, causing a more perfect separation of the fat globules from the lower layer, the depth of the cream layer is not materially increased because the large fat globules pack together more than the small fat globules. Hence the question resolves itself back into the problem of the amount of hydrophilic colloids present in the milk. The Jersey-Guernsey skim milk used as a base contains a greater amount of solids-not-fat, hence a larger amount of hydrophilic colloids. This causes a higher viscosity and hence the fat globules rise more easily as shown by the percentage of fat in the lower layer of the two skim milk standards. This holds true also at 9 - 10° C.

Table 26

Comparison of the Influence of Pumping on the Properties of Raw Holstein and Jersey-Guernsey milk Alone and With Interchanged Creams.

Kind of Milk	Treatment	Number times pumped	Speed of pump	Temperature of milk when pumped	Properties at 0° C. Viscosity after standing 24 hrs	Cream Volume	Fat in lower layer	Fat in cream layer
			R.P.M	0°C	cp	percent	per cent	per cent
Holstein	untreated				5.32	11.25	1.30	19.55
Holstein	pumped	twice	300	32	5.29	11.67	1.10	20.55
Holstein	pumped	twice	300	8	5.15	11.00	1.30	20.00
Holstein skim with Jersey-Guernsey cream	untreated				5.38	13.00	0.60	22.30
Holstein skim with Jersey-Guernsey cream	pumped	twice	300	32	4.87	12.00	0.60	24.00
Holstein skim with Jersey-Guernsey cream	pumped	twice	300	8	5.46	12.88	0.60	22.50
Jersey-Guernsey	untreated				6.05	17.37	0.06	19.80
Jersey-Guernsey	pumped	twice	300	32	5.39	17.62	0.04	19.60
Jersey-Guernsey	pumped	twice	300	8	5.70	16.55	0.07	20.72
Jersey-Guernsey skim with Holstein cream	untreated				5.93	16.50	0.60	17.60
Jersey-Guernsey skim with Holstein cream	pumped	twice	300	32	5.63	14.83	0.60	19.55
Jersey-Guernsey skim with Holstein cream	pumped	twice	300	8	5.93	15.20	0.65	18.75

Table 27

Comparison of the Influence of Pumping on the Properties of Raw Holstein and Jersey-Guernsey Milk Alone and With Interchanged Creams.

Kind of Milk	Treat-ment.	Number times pumped	Speed of pump	Temperature of milk when pumped	Properties at 9-10° C. Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in Cream layer
			R.P.M	°C.	cp	percent	per cent	per cent
Holstein	untreated				2.89	6.80	2.00	22.05
Holstein	pumped	twice	300	32	2.83	7.00	1.75	25.00
Holstein	pumped	twice	300	8	2.89	5.70	2.17	23.83
Holstein skim with Jersey-Guernsey cream	untreated				3.13	9.25	1.38	22.90
Holstein skim with Jersey-Guernsey cream	pumped	twice	300	32	3.13	8.83	1.10	27.20
Holstein skim with Jersey-Guernsey cream	pumped	twice	300	8	3.13	8.75	1.45	23.40
Jersey-Guernsey	untreated				3.36	12.75	0.52	23.35
Jersey-Guernsey	pumped	twice	300	32	3.94	12.12	0.52	24.55
Jersey-Guernsey	pumped	twice	300	8	3.43	11.00	0.75	25.00
Jersey-Guernsey skim with Holstein cream	untreated				3.58	11.25	1.53	17.50
Jersey-Guernsey skim with Holstein cream	pumped	twice	300	32	3.36	9.25	1.68	19.70
Jersey-Guernsey skim with Holstein cream	pumped	twice	300	8	3.82	8.15	1.88	20.60

Influence of pasteurizing Holstein and Jersey-Guernsey milk alone and with interchanged creams. - - The data under discussion are presented in Tables 28 and 29 and are derived from Tables XV, XVI, XVII and XVIII in the appendix.

The data in Tables 28 and 29 show that a higher viscosity is associated with a lower percentage of fat in the lower layer and vice versa. The percentage of fat in the cream layer of pasteurized milk is higher than that of raw milk but variations in the percentage of fat in the cream and lower layer at the same temperature can not be correlated with the variations in the viscosity.

In the first experiment when the Holstein and Jersey-Guernsey milk was pasteurized at 62° and 62.8° C., respectively, the same cream layers were produced with practically the same amount of fat remaining in the lower layer and the same percentage of fat in the cream layer. In the second experiment when the Jersey-Guernsey milk alone was pasteurized at 62.2° C. practically the same depth of cream layer was secured as in the first experiment, namely, 11.37 and a percentage of fat of 1.20 in the lower layer which is practically the same as in the first experiment but a lower percentage of fat in the cream layer.

When the Jersey-Guernsey skim milk with the Holstein fat was pasteurized an effect was produced similar to that of pasteurizing skim milk and then adding the cream raw which is reported in the next section. This also occurred when Holstein milk alone and with Jersey-Guernsey cream was pasteurized at 63.0, 63.1 and 65.4 and 65.8° C. These latter results probably were due to some changes in the milk which accompany aging as it was several days old when pasteurized. When fresh mixed milk was pasteurized at 67° C. the cream layer produced was 9.87 per cent at 0° C. which is not much below that of a normal cream layer. These results go to show that the extremely large reductions in the cream layers when milk is pasteurized can not be accounted for by variations in viscosity at the particular creaming temperature, because it will be seen that the viscosities did not change much in the milk in which the reductions were extreme. Other reasons for the belief that the raw milks were not normal are the large amount of fat remaining in the lower layer in the raw milk and the fact that pasteurization increased the amount retained in the lower layer.

With these marked differences arising in the experiments it would be difficult, if not impossible, to arrive at a fair conclusion. However, it seems certain from the first experiment in which a 11.00 per cent cream layer was secured on both the pasteurized Holstein and Jersey-Guernsey milks that the influence of the effect of an increased amount of hydrophilic colloids on the creaming ability of milk probably is negligible when the milk is heated to pasteurization temperatures under market milk conditions. It should be pointed out, however, that Rahn (1922) has shown that boiled milk can be made to produce a normal cream layer, and in some cases an abnormally large cream layer, by the addition of hydrophilic colloids like gelatine, gum arabic, etc., to the milk.

Table 28

Comparison of the Influence of Pasteurization on the Properties of Holstein and Jersey-Guernsey Milk Alone and With Interchanged Creams

Kind of Milk	Treatment	Temperature of Pasteurization	Properties at 0° C. Viscosity after standing 24 hrs.	Cream Volume	Fat in lower layer	Fat in cream layer
		°C.	cp.	percent	per cent	per cent
Holstein	Raw		4.05	14.25	1.00	18.54
Holstein	Past.	62.0	3.94	11.00	1.40	20.49
Jersey-Guernsey	Raw		4.84	17.00	0.37	18.78
Jersey-Guernsey	Past.	62.8	4.62	11.00	1.30	21.30
Jersey-Guernsey	Raw		4.22	16.37	0.90	11.28
Jersey-Guernsey	Past.	62.2	4.10	11.37	1.20	16.16
Jersey-Guernsey skim with Holstein cream	Raw		4.28	14.25	1.00	9.81
Jersey-Guernsey skim with Holstein cream	Past.	62.8	4.28	2.00	3.10	29.22
Holstein	Raw		4.14	15.25	1.60	14.05
Holstein	Past.	63.0	4.03	2.75	2.95	22.94
Holstein skim with Jersey-Guernsey cream	Raw		3.70	11.75	1.70	17.02
Holstein skim with Jersey-Guernsey cream	Past.	63.1	3.54	2.00	2.90	32.90
Holstein	Raw		4.22	10.75	2.50	11.80
Holstein	Past.	65.4	3.94	1.50	3.30	16.63
Holstein skim with Jersey-Guernsey cream	Raw		4.10	6.37	2.70	15.25
Holstein skim with Jersey-Guernsey cream	Past.	65.8	4.45	1.50	3.30	16.63

Table 29

Comparison of the Influence of Pasteurization on the Properties of Holstein and Jersey-Guernsey Milk Alone and With Interchanged Creams.

Kind of Milk	Treatment	Temperature of Pasteurization	Properties at 12° C.			
			Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer
		°C.	cp	percent	per cent	per cent
Holstein	Raw		2.54	13.37	1.37	17.26
Holstein	Past.	62.0	2.43	8.50	1.87	20.99
Jersey-Guernsey	Raw		2.89	14.25	0.90	19.14
Jersey-Guernsey	Past.	62.8	2.89	7.25	2.00	22.68
Jersey-Guernsey	Raw		2.63	7.00	1.97	38.04
Jersey-Guernsey	Past.	62.2	2.59	6.37	1.87	37.27
Jersey-Guernsey skim with Holstein cream	Raw		2.66	5.12	2.45	49.78
Jersey-Guernsey skim with Holstein cream	Past.	62.8	2.47	1.50	2.97	29.76
Holstein	Raw		2.24	8.50	2.10	18.57
Holstein	Past.	63.0	2.32	2.87	2.90	23.77
Holstein skim with Jersey-Guernsey cream	Raw		2.01	5.75	2.35	22.35
Holstein skim with Jersey-Guernsey cream	Past.	63.1	2.19	2.25	2.75	36.08
Holstein	Raw		2.32	7.12	2.55	15.88
Holstein	Past.	65.4	2.19	1.37	3.05	35.77
Holstein skim with Jersey-Guernsey cream	Raw		2.43	6.00	2.60	17.60
Holstein skim with Jersey-Guernsey cream	Past.	65.8	2.89	1.50	3.20	23.20

Influence of pasteurizing skim milk and adding the cream raw. - - In this connection it is interesting to note that the pasteurization of skim milk alone at 62° C. and adding the cream raw as shown by Table 30 produced the same general effects in an even more striking manner than when the Jersey-Guernsey skim milk with the Holstein cream and the Holstein milk alone and with Jersey-Guernsey cream were pasteurized at temperatures ranging from 62.8 to 65.8° C. in the preceding experiment. For example, a cream layer of 13.75 per cent was produced on the raw whole milk whereas only a 1.00 per cent cream layer was produced on the skim milk pasteurized alone and then adding raw cream, at the pasteurization temperature, after which the milk was cooled and creamed at 0°C. It will be observed that when the milk was pasteurized in this manner and then creamed at 0° 12° C. the cream layers are practically the same and the percentage of fat remaining in the cream layers are practically identical. Cooling the milk to 25.5° C. before adding the cream favored the development of a slightly deeper cream layer and the fat in the cream layer was less concentrated as shown by the percentage of fat in the cream layer.

Table 30

Influence of Pasteurizing Skim Milk From Mixed Milk and Adding the Cream (Raw) on the Properties of the Milk.

Temperature at which skim milk was pasteurized	Temperature at which cream was added	Properties at 0°C. Cream Volume	Fat in cream layer	Fat in lower layer	Properties at 12° C. Cream Volume	Fat in cream layer	Fat in lower layer
°C.	°C.	percent	per cent	per cent	percent	per cent	per cent
Raw	25.5	13.75	23.39	0.33	11.25	23.22	1.00
62	62.0	1.00	38.15	3.15	1.50	34.69	3.02
62	25.5	1.75	17.53	3.25	2.00	21.87	3.12
67	62.0	0.50	43.30	3.30	0.95	45.21	3.10
67	25.5	0.82	39.56	3.20	1.00	38.15	3.15

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Summary of Data. - - When the properties of the raw and pasteurized milk reported in the several experiments of this section are summarized, regardless of the temperature of pasteurization, the manner of treatment or the source of the milk, a relationship exists, which is shown in Table 31.

Table 31

Summary of Properties of All Milks When Raw or Pasteurized

Number of Samples	Treatment.	Properties at 0° C.				Properties at 9-12° C.			
		Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer	Viscosity after standing 24 hours	Cream Volume	Fat in lower layer	Fat in cream layer
		cp	per cent	per cent	per cent	cp	per cent	per cent	per cent
46	raw	5.10	15.58	0.76	19.56	3.01	10.58	1.45	22.22
16	Past	4.47	9.07	1.58	22.08	2.71	7.13	1.84	26.47

The average data in Table 31 show clearly that there is a general relationship between the viscosity and the percentage of fat in the cream and lower layers and the cream volume. The viscosity of the milk decreases when pasteurized and this is accompanied by a shallower cream layer, and a higher percentage of fat in the cream and lower layers. The difference between the properties of the milk at 0° and 9 - 12° C. is apparent. For example, at the higher creaming temperature a lower viscosity is accompanied by a shallower cream layer and a higher percentage of fat in the cream and lower layers. This shows that the shallower cream layers are produced at a lower viscosity and are associated with a packing of the fat globules at the lower creaming temperature whether the milk is raw or pasteurized. However, these data should not be misconstrued to mean that variations in the depth of the cream layer can be accounted for by similar variations in the viscosity because it has already been shown that this is not true.

Table 31 supports this conclusion strongly. For example, it may be pointed out that the differences in the depth of the cream layer of the raw milk when creamed at 0° and 9 - 12° C. was presumably due to the difference in viscosity, because the difference in viscosity of 2.09 between the two temperatures is sufficient to account for the decrease of 5.00 per cent in the cream layer. On the other hand, when the milk was pasteurized the decrease in the cream layers at 0° or 9 - 12° C. can not be attributed to a decrease in the viscosity. For example, when the milk was creamed at 0° C. the viscosity decreased from 5.10 to 4.47 cp. or a decrease of 0.63 cp. with a decrease in the cream layer from 15.58 to 9.07 per cent or a decrease of 6.51 per cent. When the milk is creamed at 9 - 12° C. the viscosity decreased from 3.01 to 2.71 cp. or a decrease of 0.30 cp. with a decrease in the cream layer from 10.58 to 7.13 per cent or a decrease of 3.45 per cent.

When the viscosity and cream layer on the pasteurized milk creamed at 0° C. are compared with the data for the same milk creamed at 9 - 12° C. it is seen that a decrease in viscosity of 1.76 cp. is accompanied by a decrease in the cream layer of 1.84 per cent.

These data show clearly that while there is some correlation between the viscosity and depth of cream on pasteurized milk as compared to raw milk and even on pasteurized milk creamed at different temperatures the variations in viscosity are either not sufficient to account for the great changes in the volume of cream or are too great to account for the changes observed. It is obvious that changes in cream volume due to pasteurization are caused primarily by other factors than changes in viscosity.

General Discussion of Data

The data submitted in the study of some of the factors influencing the depth of the cream layer on raw and pasteurized milk have been discussed as the data concerning each particular phase of the subject has been presented. Therefore, this discussion is a resumé of the work in an attempt to link together some of the factors.

The preliminary experiments on raw milks from different breeds showed that the viscosity of the milk increases upon standing 24 hours at 0° C., this increase being presumably due to the increased hydration of the hydrophilic colloids such as the lactalbumin, lactoglobulin and calcium caseinate of the milk. When milk is creamed at 0° or $9 - 12^{\circ}$ C. considerable difference is exhibited in the viscosity of the milk as well as in the depth of the cream layer. The difference in viscosity between the two creaming temperatures is sufficient to account for the variations in the cream layer. However, the variations in the depth of the cream layer at the same creaming temperature can not be accounted for by changes in the viscosity. On the other hand, it is distinctly evident that with pasteurized milk the decreased viscosity due to heating can not be increased sufficiently by creaming at a low temperature to overcome the dehydration effect on the hydrophilic colloids. The changes in the viscosity in pasteurized milk are too small to account for the decrease in the depth of the cream layer when compared to raw milk and are too large to account for the small difference in the depth of the cream layer between the pasteurized milk creamed at different temperatures. Therefore, the reductions in the cream layer on pasteurized milk must involve other factors than viscosity.

Among these factors may be the changes in the properties of the hydrophilic colloids present in the milk. There is no doubt that the amount of the hydrophilic colloids in raw milk is one of the determining factors in the development of deep cream layers. This is clearly shown by the experiments on milk from different breeds. With the presence of a large amount of hydrophilic colloids in milk as indicated by the higher percentage of solids-not-fat in the milk from Jersey-Guernseys, a deeper cream layer is secured than in milk from Holsteins which contains a smaller amount of hydrophilic colloids as indicated by the lower percentage of solids-not-fat in the milk. By interchanging the creams of the two standards of milk, practically the same cream layers are produced as with the same milk containing its natural fat. Thus, it is seen that the relative size of the fat globules in the milk is only a slight factor and at times may be negligible. However, when milk from different breeds is pasteurized the influence of the amount of hydrophilic colloids present in the milk becomes negative because practically the same cream volumes are secured on milk with high or low percentages of solids-not-fat.

The assumption that pasteurization affects the hydrophilic colloids in some way is shown by the experiments on pasteurizing skim milk and then adding the cream raw. When milk is treated in this manner creaming is imperfect, due to the failure of the fat globules to rise. Thus, it is seen that the effect of pasteurization is primarily a change in the properties of the proteins in colloidal solution rather than a change in the properties of the fat globules. However, assuming that this is true does not explain why the cream volume should be practically eliminated when the skim milk alone is pasteurized, as compared to the good cream layers produced when the whole milk is pasteurized at the same temperature. If the fat acts as a protective agent for the hydrophilic colloids during the process of pasteurization at the ordinary pasteurization temperatures, this protective influence evidently is gradually overcome when whole milk is pasteurized above 62.7° C. because the cream volume decreases and the percentage of fat in the lower layer increases as the temperature of pasteurization is increased.

The two hydrophilic colloids present in milk in the largest quantities, namely, lactalbumin and calcium caseinate, seemingly have opposite effects when solutions containing these two colloids are pasteurized. When raw whey is standardized with cream a normal cream layer is produced. However, when the whey-milk is pasteurized a deeper cream layer is produced than on the raw whey-milk. As lactalbumin is the principle protein present in whey the effect of pasteurization must be upon this protein. Certainly it is neither a dehydration effect nor is the lactalbumin precipitated. If this were true then a shallow cream layer would have been produced due to the obstruction of the precipitated lactalbumin and the hindering of the rate of the rising of the fat globules by the dehydrated colloidal particles. The effect of the lactalbumin is an accelerating one in regard to the depth of the cream layer and the depth of the cream layer is increased by pasteurization.

The calcium caseinate of milk in all probability hinders the development of a cream layer in both raw and pasteurized milk which is exactly the opposite influence as that of lactalbumin. However, it should be pointed out that the difference in the specific gravity of the whey-milk and the calcium caseinate milk may account for the vast differences in results. The whey-milk showed an average specific gravity of 1.025 as compared to the very low average specific gravity of the calcium caseinate milk of 1.0073. The low specific gravity in the case of the calcium caseinate milk may account for the extremely low cream layers produced but it is evident that calcium caseinate hinders creaming especially when pasteurized because even with the very low specific gravity a further decrease in the cream volume resulted when the calcium caseinate milk was pasteurized. In all probability the colloidal calcium caseinate is dehydrated on pasteurization and to such an extent that it does not regain its initial hydrated state when the milk is placed to cream at low temperatures.

From the results of the experiments on lactalbumin and calcium caseinate it is clearly evident that one of the most important factors in decreasing the cream volume rising on pasteurized milk lies in the changes in the physical or chemical properties of calcium caseinate rather than in the lactalbumin.

There was no correlation between the hydrogen ion concentration and the depth of the cream layer between a P_H of 5.72 to 6.61. However, with whey-milk having a P_H of 6.12 a deeper cream layer was secured on both raw and pasteurized milk than on whey-milk with a P_H of 6.5 which is the P_H value of normal, fresh cow's milk. This seems to indicate that a milk with a higher hydrogen ion concentration would develop a deeper cream layer. However, it seems that in normal milk the hydrogen ion concentration must be greater than that reported in order to gain the desired effect.

The decrease in the depth of the cream layer due to pumping can not be attributed to changes in the viscosity because the reduction of cream volume is too small to be accounted for by the slight variations in viscosity. At first sight it would seem that these decreases must be accounted for by the old theory that the fat globules are broken up when the milk is agitated. However, this does not seem plausible in the light of the results showing that pumping milk containing relatively large fat globules did not cause the retention of a greater percentage of fat in the lower layer than did pumping of milk with relatively small fat globules.

The observation at the market milk plants that pumping at a low temperature decreased the cream layer more than pumping at a high temperature was confirmed by laboratory studies. Likewise, the observation that agitation during the holding process seemed to decrease the cream layer more than simply holding without agitation was confirmed in part, by laboratory studies. Holding the milk at temperatures above 144° F. with agitation decreased the cream layer more than did simply holding without agitation. However, holding the milk at a temperature of 144° F. or below, with agitation, did not decrease the cream layer to any appreciably greater extent than did simply holding without agitation. It is clear that since the action of agitation during the holding process does not decrease the cream layer to any greater extent than simply holding without agitation that the fat globules are not broken up by such treatment. Hence, it is probable that at temperatures above 144° F. the decrease in the cream volume due to agitation is not caused by a further breaking up of the fat globules but is undoubtedly due to the greater effect of heat on the hydrophilic colloids when the milk is agitated.

A greater percentage of fat remained in the lower layer of milk when the milk was creamed at 9 - 12° C. than at 0° C. This difference in the retention of the fat globules in the lower layer is correlated with the viscosity. The higher the viscosity the less fat is retained in the lower layer and the lower the viscosity the more fat is retained in the lower layer. The higher viscosity of the milk creamed at 0° C. is undoubtedly accompanied by a greater difference between the specific gravity of the milk serum and the fat globules. Due to the greater difference between the specific gravity of the fat globules and the milk serum the fat globules rise rapidly and more exhaustively, accounting for the fact that less fat remains in the lower layer of milk creamed at 0° C. The less difference between the specific gravity of the milk serum and the fat globules at 9 - 12° C. accounts for the fact that more fat is retained in the lower layer of the milk creamed at this temperature because the fat globules rise much more slowly. However, this assumption does not hold true when skim milk is pasteurized and raw cream added, because with little or no change in the specific gravity of the milk serum and the fat globules, practically the same amount of fat is retained in the lower layer of milk creamed at 0° C. or 9 - 12° C.

When milk is creamed at 9 - 12° C. the fat in the cream layer is more concentrated than at 0° C. The difference between the concentration of fat in the cream layer at the two creaming temperatures is not due to the viscosity alone. The surface tension of a solution increases as the temperature decreases. With a high surface tension the fat globules in the milk creamed at the low temperature would have a greater concentration of solid matter of the milk serum around them. Thus, the fat globules would be kept further apart by the virtue of the increased amount of solid matter around each fat globule. Hence, the cream layer would have a lower concentration of fat.

The milk creamed at 9 - 12° C. has a lower viscosity and a lower surface tension. With a low surface tension less solid matter of the milk serum is concentrated around the fat globules as compared to the effect at 0° C. Therefore the fat globules are not held as far apart which accounts for the higher concentration of fat in the cream layer.

Conclusions

1. The stage of lactation apparently has no effect on the viscosity under the experimental conditions studied.

2. Milk from Jerseys and Guernseys has a higher viscosity than milk from Holsteins and Ayrshires due to the greater percentage of solids-not-fat in the former.

3. The difference between the creaming ability of Holsteins as compared to Jersey-Guernsey milk with the same percentage of fat is due to the lower percentage of solids-not-fat in the milk of the former as compared to the higher percentage of solids-not-fat in the latter.

4. The relative size of the fat globules has a very slight effect on the depth of the cream layer and sometimes this is negligible.

5. In raw milk the higher percentage of solids-not-fat means primarily a larger amount of hydrophilic colloids and the greater the amount of hydrophilic colloids the deeper the cream layer in raw milk.

6. In raw milk the differences in the depth of the cream layer at the different creaming temperatures can be accounted for by the differences in viscosity.

7. The variations in the depth of the cream layer at the same creaming temperature of both raw and pasteurized milk can not be accounted for by the differences in the viscosity.

8. When milk containing different amounts of hydrophilic colloids, as indicated by the percentage of solids-not-fat, is pasteurized the tendency to produce deeper cream layers is negligible in the milk containing the higher percentage of solids-not-fat.

9. Pumping milk at 54 - 63° F. is more detrimental to the depth of the cream layer than pumping at 90° F.

10. Pumping of milk having relatively large fat globules does not decrease the depth of the cream layer any more than pumping milk with relatively small fat globules.

11. The creaming ability of milk pumped at 45° F. can be restored by heating the milk to 90° F.

12. There is no correlation between the viscosity and the reductions in the depth of the cream layer due to pumping.

13. The influence of the hydrogen ion concentration between a P_H of 5.72 to 6.61 does not seem to be correlated with changes in the viscosity or the depth of the cream layer.

14. Intermittent agitation during the process of heating to the pasteurization temperature decreases the cream volume less than constant agitation. Heating milk in 5 minutes to the pasteurization temperature with constant or intermittent agitation decreases the cream volume more than heating in 30 minutes with constant or intermittent agitation.

15. Agitating milk at 144° F. or below during the holding process does not materially decrease the cream volume to any greater extent than simply holding without agitation. When milk is agitated in the same manner at temperatures above 145° F. the cream volume is reduced more by agitating than by simply holding at the pasteurization temperature.

16. The effect of pasteurization is primarily upon the hydrophilic colloids rather than on the fat globules because when skim milk is pasteurized and the raw cream added practically no cream rises to the surface.

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17. Removing the gas from the pasteurized skim milk seems to favor the development of a deeper cream layer at 0° C.

18. The fat globules may have a protective effect on the hydrophilic colloids up to a temperature of 62.7° C. but above this temperature the effect gradually decreases.

19. Pasteurization of solutions containing lactalbumin accelerates the formation of a deeper cream layer. Raw solutions containing lactalbumin produced normal cream layers.

20. The colloidal calcium caseinate of milk hinders the formation of a cream layer in pasteurized milk. The cause probably lies in the dehydration of the colloidal calcium caseinate.

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Appendix

Table I

Factors Influencing the Viscosity of Raw Milk

	Ayrshire		Jersey				
Number of cow	13	7	120	113	118	102	122
Stage of lactation-days.	301	301	135	169	169	34	210
Specific gravity at 60° F.	1.0325	1.0337	1.0346	1.0343	1.0334	1.0323	1.0340
Fat, per cent	4.8	4.35	5.75	5.55	6.00	5.00	5.80
Total solids calc. per cent	13.97	13.50	15.54	15.24	15.58	14.10	15.49
Solids-not-fat calc. per cent	9.11	9.15	9.79	9.69	9.56	9.10	9.69
P_H at 25° C.	6.65	6.76	6.45	6.48	6.49	6.55	6.41
Viscosity in cp. at 25° C.	2.52	2.25	3.12	2.66	2.89	2.55	2.66
at 0° C.	5.30	5.02					5.93
Difference in viscosity between 0° and 25° C.	2.78	2.77					3.27
Viscosity in cp. at 0° after 24 hours	6.05	5.70	5.46	5.52	5.27	6.22	6.11
Change in viscosity after 24 hours at 0° C.	+0.75	+0.64					+ .18

Table II

Factors Influencing the Viscosity of Raw Milk

	Guernsey					
Number of cow	510	508	512	515	502	517
Stage of lactation - days	240	280	155	48	177	338
Specific gravity at 60° F.	1.0332	1.0360	1.0351	1.0321	1.0326	1.0332
Fat, per cent	5.1	5.2	4.5	5.2	4.2	5.5
Total solids calc. per cent	14.44	15.27	14.19	14.26	13.21	14.93
Solids-not-fat calc. per cent	9.34	10.07	9.69	9.06	9.01	9.43
P_H at 25° C.	6.52	6.55	6.39	6.49	6.50	6.26
Viscosity in cp. at 25° C.	2.42	2.83	2.66	2.42	2.26	2.20
at 0° C.		5.22	5.05	4.75	4.46	6.40
Difference in viscosity between 0° and 25° C.		2.39	2.39	2.32	2.20	4.20
Viscosity in cp. at 0° C. after 24 hours	4.98	5.70	5.75	5.11	5.11	5.93
Change in viscosity after 24 hours at 0°C.		+0.48	+0.70	+0.36	+0.65	-0.47

Table III

Factors Influencing the Viscosity of Raw Milk

	Guernsey				
Number of cow	513	500	514	516	517
Stage of lactation - days	157	6	58	31	345
Specific gravity at 60° F.	1.0352	1.0328	1.0356	1.0342	1.0327
Fat, per cent	4.4	4.9	4.3	3.4	4.8
Total solids calc. per cent	14.11	14.10	14.09	12.65	13.96
Solids-not-fat calc. per cent	9.71	9.20	9.79	9.25	9.16
PH at 25° C.	6.47	6.38	6.44	6.44	6.40
Viscosity in cp. at 25° C.	2.26	2.42	2.42	2.07	2.17
at 0° C.	5.25	5.54	4.46	5.27	5.46
Difference in viscosity between 0° and 25° C.	2.99	3.11	2.03	3.19	3.29
Viscosity in cp. at 0° C. after 24 hours	5.97	5.46	4.98	5.42	5.40
Change in viscosity after 24 hours at 0°C	+0.72	-0.08	+0.52	+0.15	-0.12

Table IV

Factors Influencing the Viscosity of Raw Milk

	Holstein					
Number of cow	306	310	305	300	309	314
Stage of lactation - days	105	74	201	104	751	194
Specific gravity at 60° F.	1.0318	1.0308	1.0322	1.0325	1.0322	1.0310
Fat, per cent	3.9	3.0	3.9	2.38	3.8	3.0
Total solids Calc. per cent	12.64	11.30	12.74	11.01	12.62	11.36
Solids-not fat Calc. per cent.	8.74	8.30	8.84	8.63	8.82	8.36
PH at 25° C.	6.39	6.43	6.59	6.57	6.52	6.44
Viscosity in cp. at 25° C.	2.07	1.97	2.07	1.67	2.42	1.73
at 0° C.		3.36	4.63	3.58	4.75	4.17
Difference in viscosity between 0° and 25° C.		1.39	2.55	1.90	2.32	2.44
Viscosity in cp. at 0° C. after 24 hours	4.05	4.05	3.64	4.77	5.05	4.05
Change in viscosity after 24 hours at 0° C.		+0.69	−0.99	+1.19	+0.30	−−0.12

Table V

Factors Influencing the Viscosity of Raw Milk

	Holstein					
Number of cow	336	337	330	334	338	332
Stage of lactation days	371	53	60	47	50	175
Specific gravity at 60° F.	1.0349	1.0331	1.0333	1.0333	1.0340	1.0336
Fat, per cent	4.0	3.2	4.0	2.6	4.3	3.3
Total solids Calc. per cent	13.55	12.13	13.14	11.46	13.68	12.37
Solids-not-fat Calc. per cent	9.55	8.93	9.14	8.86	9.38	9.07
PH at 25° C.	6.26	6.38	6.47	6.49	6.39	6.38
Viscosity in cp. at 25° C.	1.97	1.87	1.78	1.73	2.20	1.81
at 0° C.	3.87	4.17	5.11	4.82	4.40	5.05
Difference in viscosity between 0° and 25° C.	1.90	2.29	3.33	3.09	2.20	3.24
Viscosity in cp. at 0° C. after 24 hours	4.63	5.06	5.28	4.82	5.06	5.30
Change in viscosity after 24 hours at 0° C.	+0.75	+0.89	+0.17	-0.0	+0.66	+0.25

Table VI

Factors Influencing the Viscosity of Raw Milk

	Holstein						
Number of Cow	314	336	339	333	320	336	305
Stage of lactation days	187	378	25	185	208	385	221
Specific gravity at 60° F.	1.0300	1.0334	1.0331	1.0313	1.0319	1.0344	1.0327
Fat, per cent	2.7	3.4	2.7	3.2	3.2	3.4	3.8
Total solids Calc. per cent	10.74	12.44	11.55	11.68	11.83	12.70	12.75
Solids-not-fat Calc. per cent	8.04	9.04	8.85	8.48	7.63	9.30	8.95
PH at 25° C.	6.51	6.38	6.45	6.38	6.44	6.38	6.53
Viscosity in cp. at 25° C.	1.78	2.07	1.87	1.96	1.97	1.50	1.73
at 0° C.	5.57	4.98	4.75	5.28	4.63	4.17	5.03
Difference in viscosity between 0° and 25° C.	3.79	2.90	3.87	3.32	2.66	2.67	3.30
Viscosity in cp. at 0° C. after 24 hours	4.11	4.33	4.87	5.38	4.98	4.01	4.69
Change in viscosity after 24 hours at 0° C.	-1.46	-0.65	+0.12	+0.10	+0.35	-0.16	-0.34

Table VII

Comparison of the Influence of Pumping on the Properties of Raw Holstein Milk and Holstein Skim Milk Plus Jersey-Guernsey Cream

	Holstein Milk			Holstein Skim Milk Plus Jersey-Guernsey Cream		
Treatment	untreated	pumped	pumped	untreated	pumped	pumped
Number of times pumped at 300 R.P.M.		twice	twice		twice	twice
Temperature of treatment, °F.		90	48		90	48
Viscosity at 0°., at once, cp.	4.73	5.46	5.10	5.79	5.03	4.75
Viscosity at 0°., after standing 24 hours, cp.	5.32	5.29	5.15	5.38	4.87	5.46
Viscosity at 9-10°C., at once, Cp.	2.89	3.01	3.32	3.13	2.89	3.13
Viscosity at 9-10° C., after standing 24 hours, cp.	2.89	2.83	2.89	3.13	3.13	3.13
Cream volume, at 0°C., per cent	11.25	11.67	11.00	13.00	12.00	12.88
Cream volume, at 9-10°C., per cent	6.80	7.00	5.70	9.25	8.83	8.75
P_H at 25° C.	6.54	6.54	6.54	6.44	6.44	6.44
Specific gravity at 60° F.	1.0315	1.0315	1.0315	1.0316	1.0316	1.0316
Solids-not-fat, (calc.) percent	8.59	8.59	8.59	8.61	8.61	8.61
Fat in lower layer, at 0°C., per cent	1.30	1.10	1.30	0.60	0.60	0.60
Fat in lower layer, at 9-10°C., per cent	2.00	1.75	2.17	1.38	1.10	1.45
Fat in cream layer, at 0° C., per cent	19.55	20.55	20.00	22.30	24.20	22.50
Fat in cream layer, at 9-10°C., per cent	22.05	25.00	23.33	22.90	27.20	23.40

Table VIII

Comparison of the Influence of Pumping on the Properties of Raw Jersey-Guernsey Milk and Jersey-Guernsey Skim Milk Plus Holstein Cream

	Jersey-Guernsey Milk			Jersey-Guernsey Skim Milk Plus Holstein Cream		
Treatment	untreated	pumped	pumped	untreated	pumped	pumped
Number of times pumped at 300 R.P.M.		twice	twice		twice	twice
Temperature of treatment, 0° F.		90	48		90	48
Viscosity at 0°C., at once, cp.	5.93	4.87	6.17	6.09	5.79	7.12
Viscosity at 0°C., after standing 24 hours, cp.	6.05	5.39	5.70	5.93	5.63	5.93
Viscosity at 9-10° C., at once, cp	3.58	3.58	3.48	3.40	3.63	3.77
Viscosity at 9-10° C., after standing 24 hours, cp.	3.36	3.94	3.43	3.58	3.36	3.82
Cream volume, at 0°C., per cent	17.37	17.62	16.55	16.50	14.83	15.20
Cream volume, at 9-10°C., per cent	12.75	12.12	11.00	11.25	9.25	8.15
P_H at 25° C.	6.60	6.60	6.60	6.47	6.47	6.47
Specific gravity at 60° F.	1.0345	1.0345	1.0345	1.0343	1.0343	1.0343
Solids-not-fat, (Calc.)., per-cent	9.35	9.35	9.35	9.30	9.30	9.30
Fat in lower layer, at 0° C., per cent	0.06	0.04	0.07	0.60	0.60	0.65
Fat in lower layer at 9-10° C., per cent	0.52	0.52	0.75	1.53	1.68	1.88
Fat in cream layer, at 0° C., per cent	19.80	19.60	20.72	17.60	19.55	18.75
Fat in cream layer at 9-10° C., per cent	23.35	24.55	25.00	17.50	19.70	20.60

Table IX

Comparison of the Influence of Skim Milk and the Inter-changing of the Cream of Holstein and Jersey-Guernsey Milk on the Properties of Raw Holstein and Jersey-Guernsey Milk

	Jersey-Guernsey			Holstein		
	Whole Milk	Skim Milk	Skim milk plus Holstein cream	Whole	Skim	Skim milk plus Jersey-Guernsey Cream
Fat, per cent	3.50	0.02	3.50	3.50	0.02	3.50
Viscosity at 0°C., at once, cp.	6.17	6.17	5.65	5.00	4.80	5.65
Viscosity at 0°C., after standing 24 hours, cp.	6.41	6.96	6.19	5.24	5.83	5.87
Viscosity at 12°C., at once, cp.	3.25	3.58	3.28	2.78	2.82	3.01
Viscosity at 12°C., after standing 24 hours, cp.	3.25	3.77	3.47	2.93	3.01	3.07
P_H at 25° C.	6.49		6.39	6.45		6.53
Specific gravity at 60° F.	1.0351	1.0374	1.0344	1.0318	1.0351	1.0331
Solids-not-fat (calc.) per cent	9.61		9.44	8.79		9.11
Fat in lower layer at 0° C., per cent	0.40		0.50	1.30		0.64
Fat in lower layer at 12° C., per cent	0.60		1.42	2.30		1.37
Cream volume at 0° C., per-cent	16.75		16.70	12.40		12.80
Cream volume at 12° C., per cent	14.50		10.90	7.50		6.40
Fat in cream layer at 0° C., per cent	18.90		18.46	19.04		24.87
Fat in cream layer at 12° C., per cent	20.60		20.46	18.30		34.57

Table X

Comparison of the Influence of the Method of Heating on the Properties of Mixed Milk.

	Mixed Milk				
Treatment	raw untreated	Heated	Heated	Heated	Heated
Temperature to which milk was heated, 0° F.		145	145	145	145
Time required for heating, minutes		30	30	5	5
Amount of agitation during heating process		con-stant	inter-mittent	con-stant	inter-mittent
Viscosity at 0°C., at once, cp	6.14	6.52	5.58	5.38	5.44
Viscosity at 0°C., after standing 24 hours, cp.	5.69	5.67	5.32	4.85	4.85
Viscosity at 12° C., at once, cp	3.01	2.98	2.89	3.01	3.05
Viscosity at 12° C., after standing 24 hours, cp	3.22	3.10	3.10	3.10	3.10
P_H at 25° C.					
Specific gravity at 60° F.	1.0348	1.0348	1.0348	1.0348	1.0348
Solids-not-fat (calc.), per cent	9.54	9.54	9.54	9.54	9.54
Fat in lower layer at 0° C., per cent	0.60	0.50	0.22	1.00	0.23
Fat in lower layer at 12°C., per cent	1.30	1.00	1.15	1.90	1.05
Cream volume at 0° C., per cent	16.07	14.62	15.25	12.5	14.37
Cream volume at 12°C., per cent	11.87	11.62	11.37	8.5	10.75
Fat in cream layer at 0° C., per cent	18.64	21.00	21.72	21.00	22.97
Fat in cream layer at 12° C., per cent	19.82	22.50	21.80	20.72	23.84

Table XI

Comparison of the Influence of Pasteurization With and Without Agitation During the "Holding Process" on the Properties of Mixed Milk

	Mixed Milk		
Temperature of Pasteurization, °F.	raw	140	140
Treatment during "holding process"	untreated	no agitation	agitated
Viscosity at 0° C., at once, cp	5.11	5.17	5.45
Viscosity at 0° C., after standing 24 hours, cp	5.45	5.57	5.32
Viscosity at 12° C., at once, cp	2.89	2.87	2.77
Viscosity at 12° C., after standing 24 hours, cp	3.12	3.03	2.96
Cream volume at 0° C., per cent	14.75	13.62	13.62
Cream volume at 12° C., per cent	11.60	11.67	11.80
P_H at 25° C.	6.49	6.49	6.54
Specific gravity at 60° F.	1.0335	1.0335	1.0335
Solids-not-fat (calc.), per cent	9.21	9.21	9.21
Fat in lower layer at 0° C., per cent	0.34	0.23	0.23
Fat in lower layer at 12° C., per cent	1.12	0.85	0.79
Fat in cream layer at 0° C., per cent	21.73	22.54	24.23
Fat in cream layer at 12° C., per cent	21.59	23.64	23.75

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Table XII

Comparison of the Influence of Pasteurization With and Without Agitation During the "Holding Process" on the Properties of Mixed Milk

	Mixed Milk		
Temperature of Pasteurization, °F.	raw	144	144
Treatment during "holding process".	untreated	no agitation	agitated
Viscosity at 0° C., at once, cp	5.64	5.06	5.01
Viscosity at 0° C., after standing 24 hours, cp	5.34	4.80	5.08
Viscosity at 12° C., at once, cp	2.77	2.77	2.75
Viscosity at 12° C., after standing 24 hours, cp	2.93	2.89	2.89
Cream volume, at 0° C., per cent	16.37	14.87	13.95
Cream layer at 12° C., per cent	11.67	10.75	11.67
P_H at 25° C.	6.34	6.27	6.33
Specific gravity at 60° F.	1.0333	1.0333	1.0333
Solids-not-fat (calc.), per cent	9.16	9.16	9.16
Fat in lower layer, at 0° C., per cent	0.27	0.35	0.23
Fat in lower layer, at 12° C., per cent	1.20	0.90	0.70
Fat in cream layer, at 0° C., per cent	19.96	21.49	23.67
Fat in cream layer, at 12° C., per cent	20.90	25.08	24.68

Table XIII

Comparison of the Influence of Pasteurization With and Without Agitation During the "Holding Process" on the Properties of Mixed Milk

	Mixed Milk		
Temperature of Pasteurization, °F.	raw	149	149
Treatment during "holding process"	untreated	no agitation	agitated
Viscosity at 0° C., at once, cp	4.12	4.12	4.40
Viscosity at 0° C., after standing 24 hours, cp	4.73	4.45	4.75
Viscosity at 12° C., at once, cp	3.24	2.66	2.59
Viscosity at 12° C., after standing 24 hours, cp	3.10	2.93	3.01
Cream volume, at 0° C., per cent	15.37	13.50	11.62
Cream volume, at 12° C., per cent	10.50	10.00	9.50
P_H at 25° C.	6.60	6.61	6.61
Specific gravity at 60° F.	1.0334	1.0334	1.0334
Solids-not-fat (calc.), per cent	9.19	9.19	9.19
Fat in lower layer, at 0° C., per cent	1.00	1.20	0.70
Fat in lower layer, at 12°C., per cent	1.50	1.22	1.35
Fat in cream layer at 0° C., per cent	17.26	18.23	24.78
Fat in cream layer at 12° C., per cent	20.54	23.97	23.98

Table XIV

Comparison of the Influence of Pasteurization With and Without Agitation During the "Holding Process" on the Properties of Mixed Milk

	Mixed Milk		
Temperature of pasteurization, 0° F.	raw	152	152
Treatment during "holding process"	untreated	no agitation	agitated
Viscosity at 0° C., at once, cp	4.82	4.14	4.40
Viscosity at 0° C., after standing 24 hours, cp	5.02	4.28	4.49
Viscosity, at 12° C., at once, cp	2.66	2.66	2.59
Viscosity, at 12° C., after standing 24 hours cp	2.75	2.87	2.89
Cream volume, at 0° C., per cent	15.87	11.05	9.87
Cream volume, at 12° C., per cent	9.80	9.00	8.00
P_H at 25° C.	6.57	6.59	6.59
Specific gravity at 60° F.	1.0329	1.0329	1.0329
Solids-not-fat, (calc.), per cent	9.06	9.06	9.06
Fat in lower layer, at 0° C., per cent	0.52	1.30	1.60
Fat in lower layer, at 12° C., per cent	1.52	1.42	1.67
Fat in cream layer, at 0° C., per cent	19.26	21.20	20.84
Fat in cream layer, at 12° C., per cent	21.42	24.48	24.51

Table XV

Comparison of the Influence of Pasteurization on the Properties of Holstein and Jersey-Guernsey Milk

	Holstein		Jersey-Guernsey	
Treatment	Raw	Past.	Raw	Past.
Temperature of Past., ° C.		62.8		62.8
Viscosity at 0° C., at once, cp		3.92	4.56	4.40
Viscosity at 0° C., after standing 24 hours, cp	4.05	3.94	4.84	4.62
Viscosity at 12° C., at once, cp		2.24	2.66	2.59
Viscosity at 12° C., after standing 24 hours, cp	2.54	2.43	2.89	2.89
P_H at 25° C				
Specific gravity at 60° F.	1.0314	1.0314	1.0345	1.0345
Solids-not-fat (calc.), per cent	8.71	8.71	9.47	9.47
Fat in lower layer at 0° C., per cent	1.00	1.40	0.37	1.30
Fat in lower layer at 12° C., per cent	1.37	1.87	0.90	2.00
Cream volume at 0° C., per cent	14.25	11.00	17.00	11.00
Cream volume at 12° C., per cent	13.37	8.50	14.25	7.25
Fat in cream layer at 0° C., per cent	18.54	20.49	18.78	21.30
Fat in cream layer at 12° C., per cent	17.26	20.99	19.14	22.68

Table XVI

Comparison of the Influence of Pasteurization on the Properties of Jersey-Guernsey Milk and Jersey-Guernsey Skim Milk Plus Holstein Cream.

	Jersey-Guernsey		Jersey-Guernsey skim milk plus Holstein cream	
Treatment	Raw	Past.	Raw	Past.
Temperature of Past., °C.		62.2		62.8
Viscosity at 0° C., at once, cp	4.22	3.75	3.82	3.82
Viscosity at 0° C., after standing 24 hours, cp	4.22	4.10	4.28	4.28
Viscosity at 12° C., at once, cp	2.32	2.17	2.08	2.19
Viscosity at 12° C., after standing 24 hours, cp	2.63	2.59	2.66	2.47
P_H at 25° C.	6.50	6.56	6.26	6.41
Specific gravity at 60° F.	1.0358	1.0358	1.0322	1.0322
Solids-not-fat (calc.), per cent	9.81	9.81	9.34	9.34
Fat in lower layer at 0° C., per cent	0.90	1.20	1.00	3.10
Fat in lower layer at 12°C., per cent	1.97	1.87	2.45	2.97
Cream volume at 0° C., per cent	16.37	11.37	14.25	2.00
Cream volume at 12° C., per cent	7.00	6.37	5.12	1.50
Fat in cream layer at 0° C., per cent	11.28	16.16	9.81	29.22
Fat in cream layer at 12° C., per cent	38.04	37.27	49.78	29.76

Table XVII

Comparison of the Influence of Pasteurization on the Properties of Holstein Milk and Holstein Skim Milk Plus Jersey-Guernsey Cream.

	Holstein		Holstein Skim Milk plus Jersey-Guernsey Cream	
Treatment	Raw	Past.	Raw	Past.
Temperature of Past. ° C.		63.0		63.1
Viscosity at 0° C., at once, cp	4.10	3.70	3.58	3.45
Viscosity at 0° C., after standing 24 hours, cp	4.14	4.03	3.70	3.54
Viscosity at 12° C., at once, cp	2.32	2.19	2.08	2.13
Viscosity at 12° C., after standing 24 hours, cp	2.24	2.32	2.01	2.19
pH at 25° C.	6.42	6.42	6.48	6.54
Specific gravity at 60° F.	1.0334	1.0334	1.0326	1.0326
Solids-not-fat (calc.), per cent	9.19	9.19	8.99	8.99
Fat in lower layer at 0° C., per cent	1.60	2.95	1.70	2.90
Fat in lower layer at 12° C., per cent	2.10	2.90	2.35	2.75
Cream volume at 0° C., per cent	15.25	2.75	11.75	2.00
Cream volume at 12° C., per cent	8.50	2.87	5.75	2.25
Fat in cream layer at 0° C., per cent	14.05	22.94	17.02	32.90
Fat in cream layer at 12° C., per cent	18.57	23.77	22.35	36.08

Table XVIII

Comparison of the Influence of Pasteurization on the Properties of Holstein Milk and Holstein Skim Milk Plus Jersey-Guernsey Cream.

	Holstein		Holstein Skim Milk plus Jersey-Guernsey cream	
Treatment	Raw	Past.	Raw	Past.
Temperature of Pasteurization, ° C.		65.4		65.8
Viscosity at 0° C., at once, cp	3.98	3.63	3.82	4.62
Viscosity at 0° C., after standing 24 hours, cp	4.22	3.94	4.10	4.45
Viscosity at 12° C., at once, cp	2.32	2.17	2.24	2.59
Viscosity at 12° C., after standing 24 hours, cp	2.32	2.19	2.43	2.89
P_H at 25° C.	6.42	6.49	5.72	6.05
Specific gravity at 60° F.	1.0314	1.0314	1.0331	1.0331
Solids-not-fat (calc.), per cent	8.69	8.69	9.11	9.11
Fat in lower layer at 0° C., per cent	2.50	3.30	2.70	3.30
Fat in lower layer at 12° C., per cent	2.55	3.05	2.60	3.20
Cream volume at 0° C., per cent	10.75	1.50	6.37	1.50
Cream volume at 12° C., per cent	7.12	1.37	6.00	1.50
Fat in cream layer at 0° C., per cent	11.80	16.63	15.25	16.63
Fat in cream layer at 12° C., per cent	15.88	35.77	17.60	23.20

Table XIX

Comparison of the Influence of Pumping at Different Speeds on the Properties of Raw Mixed Milk

	Raw Mixed Milk						
Treatment	untreated	pumped	pumped	pumped	pumped	pumped	pumped
Temperature of treatment, °F		54	54	54	54	54	54
Number of times pumped at 125 R.P.M.	none	once	twice	twice	twice	twice	twice
Number of times pumped at 220 R.P.M.	none			once	twice	twice	twice
Number of times pumped at 300 R.P.M.	none					once	twice
Total number of times pumped	0	1	2	3	4	5	6
Viscosity at 0° C., at once, cp	3.63	3.75	3.59	3.86	3.88	3.59	3.86
Viscosity at 0° C., after standing 24 hours, cp	4.17	4.49	4.40	4.77	4.22	3.52	4.01
Viscosity at 12° C., at once cp	2.66	2.73	2.73	2.89	2.73	2.82	2.66
Viscosity at 12° C., after standing 24 hours, cp	2.77	2.77	2.77	2.19	2.49	2.66	2.87
Cream volume at 0°C., per cent	14.00	14.00	14.00	13.00	13.00	13.00	13.00
Cream volume at 9-10° C., per cent	11.75	12.00	11.50	10.00	11.00	10.75	10.00
P_H at 25° C.	6.49	6.49	6.49	6.49	6.49	6.49	6.49
Specific gravity at 60° F.	1.0337	1.0337	1.0337	1.0337	1.0337	1.0337	1.0337
Solids-not-fat (calc.), per cent	9.14	9.14	9.14	9.14	9.14	9.14	9.14

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Table XX

Comparison of the Influence of Pumping at Different Speeds on the Properties of Raw Mixed Milk

	Raw Mixed Milk						
Treatment	untreated	pumped	pumped	pumped	pumped	pumped	pumped
Temperature of treatment, °F		54	54	54	54	54	54
Number of times pumped at 125 R.P.M	none	once	twice				
Number of times pumped at 220 R.P.M	none			once	twice		
Number of times pumped at 300 R.P.M	none					once	twice
Viscosity at 0° C., at once, cp	4.24	4.98	4.98	5.20	4.68	5.15	4.98
Viscosity at 0° C., after standing 24 hours, cp	3.94	4.40	4.28	3.94	4.64	3.58	3.70
Viscosity at 9-10° C., at once, cp	3.12	2.70	3.01	2.66	2.84	2.70	2.89
Viscosity at 9-10° C., after standing 24 hours, cp	3.36	2.89	2.68	2.73	2.70	3.01	2.89
Cream volume at 0° C., per cent	13.62	12.87	13.00	13.00	12.87	12.52	12.45
Cream volume at 9-10° C., per cent	11.95	12.0	11.55	10.70	11.50	10.62	9.10
P_H at 25° C.	6.54	6.54	6.54	6.54	6.54	6.54	6.54
Specific gravity at 60° F.	1.0338	1.0338	1.0338	1.0338	1.0338	1.0338	1.0338
Solids-not-fat (calc.) per cent	9.16	9.16	9.16	9.16	9.16	9.16	9.16
Fat in lower layer at 0° C., per cent	0.70	0.70	0.70	0.70	0.75	0.75	0.90
Fat in lower layer at 9-10° C., percent	1.20	1.25	1.30	1.40	1.40	1.60	1.80
Fat in cream layer at 0° ., per cent	20.55	21.80	21.55	21.55	21.40	21.95	20.87
Fat in cream layer at 9-10° C., per cent	19.25	18.75	19.05	19.65	18.25	17.90	18.65

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Table XXI

Comparison of the Influence of Pumping at Different Speeds on the Properties of Raw Mixed Milk

	Raw Mixed Milk						
Treatment	untreated	pumped	pumped	pumped	pumped	pumped	pumped
Temperature of treatment, °F.		63	63	63	63	63	63
Number of times pumped at 125 R.P.M.	none	once	twice				
Number of times pumped at 220 R.P.M.	none			once	twice		
Number of times pumped at 300 R.P.M.	none					once	twice
Viscosity at 0° C., at once, cp	5.08	5.51	5.55	5.32	5.27	5.46	5.57
Viscosity at 0° C., after standing 24 hours, cp	6.64	6.05	5.88	5.51	5.51	5.57	5.46
Viscosity at 9-10° C., at once, cp	3.31	3.35	3.33	3.31	3.23	3.19	3.12
Viscosity at 9-10° C., after standing 24 hours, cp	3.40	3.40	3.47	3.63	3.40	3.23	3.40
Cream volume at 0°C., percent	15.45	15.12	14.87	14.75	14.00	14.37	13.95
Cream volume at 9-10° C., per cent	12.87	13.17	12.17	12.12	13.37	12.95	12.50
PH at 25° C.	6.49	6.49	6.49	6.49	6.49	6.49	6.49
Specific gravity at 60° F.	1.0354	1.0354	1.0354	1.0354	1.0354	1.0354	1.0354
Solids-not-fat (calc.), per cent	9.57	9.57	9.57	9.57	9.57	9.57	9.57
Fat in lower layer at 0° C., per cent	0.30	0.50	0.45	0.50	0.50	0.40	0.50
Fat in lower layer at 9-10° C., per cent	0.85	0.80	0.85	0.80	0.90	0.90	0.90
Fat in cream layer at 0° C., per cent	20.71	19.85	20.50	20.35	21.43	21.55	21.50
Fat in cream layer at 9-10° C., per cent	20.60	20.50	21.75	22.20	19.45	20.10	20.60

Table XXII

Comparison of the Influence of Pumping at Different Speeds on the Properties of Raw Mixed Milk

	Raw Mixed Milk						
Treatment	untreated	pumped	pumped	pumped	pumped	pumped	pumped
Temperature of treatment, °F.		91	91	91	91	91	91
Number of times pumped at 125 R.P.M.	none	once	twice				
Number of times pumped at 220 R.P.M.	none			once	twice		
Number of times pumped at 300 R.P.M.	none					once	twice
Viscosity at 0° C., at once, cp	5.42	5.46	5.42	5.23	5.11	5.11	5.08
Viscosity at 0° C., after standing 24 hours, cp	5.62	5.44	5.11	5.03	4.98	4.94	5.23
Viscosity at 9-10° C., at once cp.	3.28	3.19	3.01	2.77	2.89	2.77	2.89
Viscosity at 9-10° C., after standing 24 hours, cp	3.01	3.23	3.05	3.01	3.12	2.93	3.12
Cream volume at 0° C., per cent	12.87	13.00	12.90	12.37	12.50	12.50	12.12
Cream volume at 9-10° C., per cent	11.95	11.25	10.25	9.50	11.00	11.12	10.62
P_H at 25° C.	6.60	6.60	6.60	6.60	6.60	6.60	6.60
Specific gravity at 60° F.	1.0336	1.0336	1.0336	1.0336	1.0336	1.0336	1.0336
Solids-not-fat (calc.), per cent	9.11	9.11	9.11	9.11	9.11	9.11	9.11
Fat in lower layer at 0° C., per cent	0.47	0.59	0.64	0.69	0.64	0.60	0.72
Fat in lower layer at 9-10° C. per cent	0.77	0.97	1.15	1.28	1.15	1.20	1.25
Fat in cream layer at 0° C., per cent	23.50	22.40	22.20	21.95	22.90	23.20	32.90
Fat in cream layer at 9-10° C. per cent	22.90	22.42	22.70	23.40	21.35	20.80	21.20