THE EFFECT OF VISCOLIZATION ON SOME OF THE PHYSICAL PROPERTIES OF MILK

THESIS FOR THE DEGREE OF M. S.

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Thesis

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

By

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1932

THESIS

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INTRODUCTION

For years the public has judged the quality of milk chiefly by the cream layer at the top of the milk bottle, reasoning perhaps that the deeper the cream layer on the milk the richer was the milk. Such a deduction by the layman is perfectly logical, especially when one realizes that the amount of cream which rises on a bottle of milk is the only standard by which the consumer may judge the richness, or fat content, of the milk. Unfortunately, this basis of measurement is not a reliable indication of the amount of butterfat present in the milk.

A bottle of milk showing a deep cream layer is not necessarily richer in fat than milk in which the cream layer is less pronounced. This fact was universally accepted by members of the dairy industry at the time of the adoption of the Babcock test to determine the fat content of milk and of cream.

Since the beginning of the market milk industry firms distributing milk and manufacturers of dairy equipment have concentrated their efforts upon the production of milk having a deep cream layer. Special dairy equipment has been devised in order to avoid adversely affecting the cream layer. Even the milk bottle has been so constructed as to make the cream layer appear as deep as possible. Much research has been conducted to determine the temperature that would destroy pathogenic bacteria and yet not reduce the cream layer.

The milk distributor has catered to this inaccurate method of judging milk quality on the assumption that "the consumer is always right", which assumption is only justified from a dollar and cents point of view.

Instances have been cited in connection with children's homes, state institutions, restaurants, and even private homes in which the cream had been poured from the milk and the remaining serum had been given to the children. This is in opposition to the doctrine broadcast by our health authorities who have been recommending to everyone that a quart of whole milk is needed by every growing child as well as every adult. It is here that homogenization, or viscolization, of milk finds the greatest argument in its favor. Furthermore, the introduction of the single service container has minimized the importance of the cream line on milk. 14

Viscolized or homogenized milk has been and is being processed with two different aims in view which are antagonistic to each other. One group went to the trouble of homogenizing cream and mixing it with milk of a low fat content to increase the volume of cream rising on the bottled milk. The use of this so called "Viscolized" milk promotes the common practice of using the top of the bottle of milk for coffee or cereal, thereby forcing the less fortunate members of the family to use the remaining portion which is little better than skim milk. This process defeats the purpose of viscolization and renders the word a misnomer. The other group endorses the full meaning of the word homogenization, which renders the entire milk homogeneous and on which a cream layer does not form. 15

Viscolization, or homogenization, of milk may be defined as the passing of milk through exceedingly small openings at high pressure, as a result of which the fat globules are so finely divided that they are not affected 6 by the force of gravity. Thus the fat remains evenly distributed throughout the milk.

In view of the fact that considerable attention is being given to homogenization of milk, and that the effects of the process upon the physical and chemical properties of milk are not so generally understood, a study of viscolization, or homogenization, of milk as affecting these properties seemed desirable.

REVIEW OF LITERATURE

Extent of Viscolization

Although the principle of viscolization is not new to the dairy industry the process has not been used extensively in this country in connection with market milk. However, in some countries the process has been accepted commercially. Jones (3) states that homogenization has been extensively used in the preparation of sterilized milk in Europe. This product is simply milk homogenized, bottled and then sterilized at high temperature. According to Jones (3), Hudson (30) and Hollingsworth (4), Canada is the pioneer in the application of the homogenization principle to the market milk trade. The first successful commercial introduction of homogenized milk took place at Ottawa, Ontario, Canada in 1927. At the present time, the homogenization of milk in Canada is mainly a product of Ontario, Quebec, and British Columbia, with a scattering of individual dealers in the other provinces.

In the United States the homogenizer is used chiefly in the preparation of sweet cream, ice cream, and condensed milk. However, in some specific instance market milk, chocolate milk, commercial sour cream and milk used in manufacturing various kinds of cheese has also been homogenized.

Theory of Viscolization

The homogenizer and the viscolizer, although somewhat different in construction, operate upon the same principle. They are essentially high pressure pumps which are capable of pumping under a pressure of 5,000

pounds per square inch and are so constructed that the liquid is forced through a small opening known as the homogenizing valve. The pressure at which the liquid is homogenized is regulated by the closure of this valve. These machines are usually constructed in sets of three cylinders, each having a suction and a discharge valve. The discharge from the three cylinders is into a common manifold which leads to the homogenizing head. The valves are usually of the pocket type and may be ground using a common valve grinding compound. The homogenizing head consists of a hardened metal seat, against which a block of hardened metal, or composition material is held by a spring. The pressure is regulated by the tension of the spring on the homogenization block. August Gaulin of France according to Turnbow and Raffetto (1) is given credit for this invention.

Sommer (2) states that there are several views concerning the manner in which this fine dispersion of fat is accomplished by the homogenization process. According to one view, the dispersion results from the shattering effect produced when the liquid impinges against the side walls of the homogenizing valve. With a clearance of 0.0001 inch in a homogenizing valve, it has been estimated that the liquid is traveling at a velocity of 3,000 to 6,000 feet per second as it emerges through the valve. As the liquid emerges into space already filled, the velocity of the stream must be retarded before striking against the side wall, but the fact that the metal wears away in the homogenizing head, is proof that there is an impact of the liquid against the side walls.

Another theory is that the dispersion results from the shearing of the fat globules as they pass through the liquid in the homogenizing head. This is due to the liquids traveling at different velocities. The clear-

ance in the homogenizing valve may also be smaller than some of the fat globules and these would certainly be sheared in passing through. In the valve clearance, the liquid in contact with the metal would be retarded while the liquid in the center of the clearance would be traveling at a high velocity. In like manner there must be a great difference in the velocities of the liquid mixture as it leaves the homogenizing valve.

The dispersion of the fat globules may also result from the explosive action caused by the compression of the liquid followed by a sudden release of pressure. Since the compressibility of butterfat is very low this explosive effect would be slight.

Effect of Viscolization on the Creaming of Milk

Viscolization, or homogenization, as used in the dairy industry consists of forcing milk or cream through small openings under high pressure. Butterberg (42) in 1903 was perhaps the first to report that when milk is homogenized, the fat does not separate. His method consisted of heating milk to 85° C. and forcing it, under 250 pounds pressure, through a tube of one millimeter in diameter and then between closely applied plates of agate and metal. Bishop and Murphy (43) further state that the fat of homogenized milk could not be separated by centrifugal separation nor could homogenized cream be churned. Cream from homogenized milk testing 3.5 per cent was found to test only 7.5 per cent fat while the skim milk tested 3.2 per cent.

Later Hammer (5) reported that when milk is homogenized no cream layer is found. He attributed this loss of creaming to the breaking up of the fat globules, which have less tendency to rise than the original

fat globules. Martin and Combs (6) viscolized a sample of milk at 2,000 pounds pressure and compared its creaming ability with a check sample. The volume of cream rising on the check sample was 10 per cent while that on the viscolized sample was two per cent.

Troy and Sharp (7) observed that the fat is not clumped in homogenized milk. Doan (8) noted that the degree of clumping increased with the concentration of the fat in the mixture. This lead him to conclude that the ratio of the amount of plasma colloids to the amount of fat in the mixture is the limiting factor in the fat clumping phenomenon. These results agree with Hening (9) who states that mixtures containing 5 to 10 per cent of fat clump but little while mixtures containing higher percentages of fat clump markedly on homogenization.

Mortensen (10) found that by homogenizing cream the fat is brought together in large clusters. Evenson and Ferris (18), Dahle and Martin (26), Sherwood and Smallfield (19), and Reid and Mosely (32) have called attention to the fact that homogenization of cream, or ice cream, not only causes a subdivision of the fat, but also causes a clumping of the fat globules. Reid (33) states that the clumping effect of ice cream is not influenced by changes in pressure of homogenization, while Doan (8) is of the opinion that clumping of cream increases as the pressure increases. Webb and Holm (27) also recognized the factor of fat clumping in their study of cream feathering. They suggested that the phenomenon may be due to the change of potential of the fat globules.

Palmer and Anderson (28) have shown that heating the milk plasma destroys creaming. This agrees with Troy and Sharp (7) who state that creaming ability is dependent upon the ability of the fat to clump. They have

further shown that heating the milk retards or destroys clumping. Likewise Doan (8) found that heating the plasma also reduced the fat clumping when milk containing 12 to 13 per cent fat was homogenized. Hening (29) has also shown that a temperature of 180° F. for 10 minutes diminished the size and number of fat clumps of homogenized ice cream mix.

According to Doan (12) if fluid milk or cream containing eight per cent or more of fat is homogenized at a pressure of 2,000 to 3,000 pounds, a peculiar structure of the fat is created. The globules are greatly reduced in size and tend to clump together in such a fashion as to occupy the greatest possible space. He also concluded (12) (8) that such a milk or cream will not separate a cream layer regardless of whether the fat is clumped or not. However, if diluted with skim or whole milk, creaming takes place, the amount of creaming being greater as the fat clumping becomes more pronounced, although samples containing no clumps form no cream layer on dilution with milk.

"Viscolized" Milk

The term "viscolized" milk usually refers to that milk to which some viscolized cream has been added and which yields a definite cream layer.

Martin and Combs (6) were the first to give definite data which show the effect on the volume of cream rising on milk made from homogenized cream and skim milk. Later Doan (11) (12) and Troy and Sharp (7) have given similar data.

Doan (11) reports that homogenization of a part of the milk decreased the creaming ability. Later Doan (12) homogenized 20 per cent cream at 110° F. under a pressure of 2,000 pounds and standardized it to four per cent butterfat with skim milk. He also standardized a four per cent milk

using the same skim milk and unhomogenized cream. The volume of risen cream on the unhomogenized sample was 12 per cent while that on the homogenized sample was 71.2 per cent. His results indicate that the greater the amount of cream viscolized and returned to the milk the greater the cream layer, and also the richer the cream viscolized the larger the cream volume, although the cream volume does not correlate directly with the fat viscolized. This lead him to conclude that the factor exerting the greatest influence on the volume of cream rising is not the amount of fat homogenized but the amount of cream in which a given amount of fat is contained. Doan interpreted this enormous increase in creaming ability to the looseness of packing of the fat clumps in the homogenized sample as compared to that of the normal sample. Microscopic examination of the homogenized milk showed the fat to be finely divided but gathered together in clumps containing hundreds of small globules, with no normal globules present, while the globules of the unhomogenized sample were large, mostly spherical, and individual in most cases, although a few clumps were present.

To determine if the so called "viscolized" milk could be heated without deleterious effects, Doan (12) pasteurized the milk spoken of above at 145° F. for 30 minutes. The volume of cream on the homogenized sample was 40 per cent in this case, while that on the unhomogenized sample was 10.8 per cent. Microscopic examination of the homogenized sample showed smaller clumps along with a greater proportion of individual globules. This would explain the decrease in volume of cream layer. The volume of creaming, however, was still four times that of the normal milk. From this he concluded that pasteurization can be practiced without destroying the ability of homogenization to increase the cream layer.

Detection of the so called "Viscolized" Milk

Milk exhibiting a larger cream layer than normal, considering the fat content, may be suspected of being viscolized. This according to Doan (12) can be determined by a simple microscopic examination. By this method the sample of milk is mixed well and a small portion is transferred to a drop of water previously placed on a cover glass. The water and sample are not mixed. The cover glass is then inverted over a depression slide and examined under a microscope. Normal milk will contain round globules mostly individual and fairly uniform in size. Any irregular dark patches indicate "viscolized" milk. "Viscolized" milk may also contain normal fat globules. This depends upon whether only a portion of the fat was homogenized in the form of cream. Along with the "visco-clumps" a comparatively large number of small globules help in the identification. Care must be taken to mix the milk well before the slide is made or too much fat may appear in the microscopic field. In this case the globules and clumps may appear too close together to distinguish the characteristics of the sample. Doan claims to be able to distinguish as little as one-half of one per cent of homogenized cream when added to milk by this method, even though this small amount had practically no effect upon the cream volume.

Theory of Viscosity

Miscroscopical examination of the fat globules before and after homogenization, showed that their average size had been greatly reduced. According to Sommer (2) the increased viscosity produced by a given amount of fat is increased as the fat is divided into smaller globules. This is in ac-

cord with Bingham's (45) discussion of emulsions who stated that a decrease in the particle size of the dispersed phase also decreased the fluidity. Hatschek (54) was of the opinion that this increased viscosity was due to an adsorption film of the liquid phase around the particles, the thickness of which was independent of the degree of dispersion.

Associates of Rogers (34) stated that by the process of homogenization, the fat globules are subdivided and dispersed throughout the medium. These globules are stabilized by a protein membrane formed at the fat liquid interface which prevents their coalescence.

Bateman and Sharp (14) are of the opinion that since the thickness of the adsorption film varied slightly, if at all, with the particle size, and the amount of adsorption depends upon the surface, more of the skim milk phase will be adsorbed in the case of whole milk. This resulted in an increased viscosity because of a decrease in the free liquid. Increased viscosity during aging is undoubtedly due to the altering of the proteins.

Effect of Viscolization on Viscosity

Numerous studies of the viscosity of whole milk and cream have been carried out. The methods used by the different investigators have varied greatly. This makes it difficult to compare the work of one experimenter with that of another.

Viscosity according to Turnbow and Raffetto (1) may be defined as the resistance offered by a liquid to shearing, stirring or flow through a capillary tube.

Buglia (13), and Bateman and Sharp (14) found that homogenization increased the viscosity of whole milk while it had no effect on skim milk. Wiegner (15) obtained similar results for that of whole milk. He attributed

this increase to the increased adsorption of the protein especially casein. Kobler (16) reported that viscosity of milk is due to both the fat and the protein content, it is diminished by skimming and dilution with water. The viscosity is also lessened by shaking, but returns to normal in about 10 to 12 hours. Taylor (17) concluded that the viscosity of milk is not proportional to the total solids but is a function of the fat and solids not fat. Milk heated to 60° C. decreased in viscosity, but increased in viscosity when heated to 70° C. He attributed this later increase to coagulation.

Evenson and Ferris (18) reported that homogenization at 3,500 pounds pressure increases the viscosity of milk as well as cream. Pressures of 1,200 pounds increased the viscosity of cream, but affected the milk only slightly. They also found that pasteurization at 62° to 65° C. decreased the viscosity, but heating to 75° to 80° C. increased the viscosity.

Mortensen (10) noted that cream decreased in viscosity by pasteurization, but homogenization increased the viscosity. Babcock (20) found that homogenization is very detrimental to the whipping properties of cream and this effect is increased as the homogenization pressure increases. Homogenization and pasteurization together practically destroy the whipping properties of cream.

Sherwood and Smallfield (19) indicated that the increase in viscosity of cream during aging can be attributed to the greater grouping of the fat globules. Agitation caused a reduction of the viscosity with a corresponding decrease in fat clumping. They also believed that the increase in viscosity immediately after homogenization was due to the taking up, or fixing, of more of the milk serum on the increased surface of the fat globules.

Babcock and Russell (35) found that pasteurization broke up the clusters of fat globules present in raw normal milk, and they attributed the decrease in viscosity produced to the breaking up of the fat clusters. Wall (36) also pasteurized milk and cream and noted a decrease in viscosity. Pasteurization of skim milk decreased in viscosity slightly while pasteurization of whey increased the viscosity. Weinlig (37) heated milk to 60° to 65° C. and found that it decreased the viscosity when cooled back to the original temperature, but heating the milk to 80° C. had the opposite effect when the milk was cooled. He attributed the decrease in viscosity to a change in the casein, and the increase at higher temperature to evaporation of water along with changes in the albumin.

According to Bateman and Sharp (14) pasteurization of skim milk at 62° C. for 30 minutes caused a slight decrease in viscosity when determined at 25° C. The viscosity of skim milk also progressively increased with age. This increase in viscosity could not be brought back to that of the fresh sample by repeatedly running it through a capillary tube. They also reported that agitation may cause a decrease in the viscosity of milk containing clumps of fat globules, due to the breaking up of the clumps. However, mechanical agitation produced no change in the viscosity of fresh skim milk or homogenized milk.

Whitaker, Sherman, and Sharp (38) found that as the temperature is raised from 5° to 60° C., the viscosity of skim milk decreases faster than that of water; from 60° to 70° C. the viscosity of both decrease at the same rate; and above 70° C. the viscosity of skim milk decreases more slowly than does the viscosity of water. Pasteurization of skim milk for 30 minutes between 40° and 72° C. caused a decrease in viscosity, while pasteuriza-

tion at higher temperature caused an increase. Whey decreased in viscosity when pasteurized below 60° C., increased in viscosity from 60° to 100° C. and decreased in viscosity from 100° to 120° C.

Dahlberg and Hening (25) stated that the viscosity of unhomogenized cream increased with aging and with increased percentage of fat, but both effects were variable. They also found that pasteurization slightly reduced the viscosity of milk and greatly reduced the viscosity of cream. Pasteurization largely inhibited the effect of aging.

Doan and Minster (39) found that the use of a two stage homogenizer or double homogenization decreased the viscosity and fat clumping of milk as compared with the use of a single stage homogenizer. Dahle and Barnhart (40) reported that homogenizing of ice cream mix at 170 to 180° F. resulted in a lower viscosity and greatly reduced fat clumping. Reid (33) and Reid and Garrison (41) stated that when the pressure on the first valve of the homogenizer is increased there is a resulting increase in the viscosity of the mix. However, when the pressure is increased on the second valve of the homogenizer, the viscosity is not always decreased, but may also be increased.

Babcock (44) in a recent article stated that homogenization of cream increased its viscosity. This increased viscosity is in direct relation to the homogenization pressure. However, the increase in viscosity due to homogenization at any definite pressure depended upon the temperature at which the cream is homogenized. Rehomogenization of cream lowers the viscosity. Babcock also reported that the viscosity of cream increases as the per cent of solids not fat increases.

Theory of Surface Tension

Surface tension may be defined as the resistance of a liquid to rupture. According to Sommer (2), surface tension arises from the force of attraction between closely adjacent molecules. This force of attraction is toward the center at all times. However, the molecules within the liquid have these forces balanced by other molecules which completely surround it. But with molecules at the surface only the lower half of this sphere of forces are balanced by similar forces. For this reason the molecules of the surface are pulled inward by the molecules of the liquid. The unbalanced forces may be thought to bend over to the surface. This results in a state of stress at the surface which is known as surface tension.

Getman (55) stated that some liquids like water wet the walls of a glass capillary tube, whereas others, like mercury, do not. In the first case the surface of the liquid is concave, while in the second case it is convex. The surface area in each case tended toward a minimum.

Surface Tension

Kolber (16) in 1908 was one of the first to study the surface tension of milk. According to his studies, factors which altered the viscosity also changed the surface tension.

Burri and Nussbaumer (46) discovered that the surface tension of milk decreased on aging. However, in milk where the temperature does not go lower than 20° C., the surface tension fell but slightly, but cooling to 10° or lower produced a marked depression. The decreased surface tension due to cooling was permanent in character and could not be restored by heating the milk to body temperature.

Bauer (47) confirmed the results of Burri and Nussbaumer, but stated that warming the milk at 50° C. almost restored the surface tension to its original value. He attributed this decrease in surface tension to the solidification of the fat. On the other hand Qualiariello (48) stated that the lowering of the surface tension by cooling to 10° C. or lower can not be undone by warming. He thought the glycerides of the higher fatty acids become solid at lower temperatures and liberated mixed lower glycerides which are slightly soluble in water, thus lowering the surface tension. Homogenized milk, he stated, has always a lower surface tension than normal milk, and is not affected by low temperatures.

Dahlberg and Hening (25) found that the surface tension of milk and cream decreased with an increased fat content. It also usually decreased with aging. Pasteurization as a rule increased the surface tension and aging would not reduce it to normal.

Behrendt (49) stated that the fat has no essential influence upon the surface tension of milk. He found that milk with a reduced protein content has a considerably higher surface tension than normal milk.

Doan and Minster (69) found that the surface tension of milk was irregularly affected for both single and double stage homogenization, but when the fat content was more than four per cent, single stage homogenization increased the surface tension, whereas in skim milk it was lowered. They (50) also stated that homogenization lowers the surface tension of skim milk, except where the skim milk has been heated to a temperature of 120° F., in which case there appears to be an increase. Homogenization of milk containing fat always increased the surface tension. If the viscosity

is increased greatly the effect is pronounced. Rehomogenization of the milk destroys the viscosity, which lowers the surface tension.

Reid (33), who worked with ice cream mixes, found that the surface tension is increased as the pressure of homogenization is increased.

Theory of Foaming

A foam consists of a gas phase, which is usually air, dispersed in a liquid. The gas phase, according to the Associates of Rogers (34), is in the form of bubbles of microscopic size. Thus an air phase of enormous surface area is produced which is covered by film of micronic, or submicronic thickness. To produce these films, the surface tension of the liquid phase must be sufficiently reduced so that the active agents may spread into a thin film. However, Hillyer (51) has shown that a low surface tension alone is not all that is required to produce a stable foam. The film must be sufficiently elastic so as to prevent coalescense of the air bubbles.

Associates of Rogers (34) stated that the tendency of milk to foam when agitated is evidence that a surface tension depressant is present, which is this case is a protein. Rahn (52) believes the accumulation of an albuminous substance which passes into the walls of the foam cells, reduces the surface tension causing the formation of a foam. If left undisturbed, the foam falls leaving a thin wrinkled layer on the surface. This material is composed of a solid substance which is similar to that of albuminous material, in that it appears irreversible. When cream is whipped it forms a network of solidified albuminous substance intermingled with solid fat having the form of foam. This foam is prevented from falling

by the fat. The chemical nature of this foaming substance is not known. It is different from that of albumin and is not casein.

Otswald and Steiner (53) are of the opinion that there is no relationship between surface tension and foaming. Adsorption on the surface, such as fatty acids on water, or small colloidal particles on the surface of a liquid, is necessary to form a membrane before foam forms.

Foaming of Milk

A thick stable foam is desirable in the whipping of cream or in the manufacture of ice cream. In the operation of such machines as the separator, clarifier, or the filling of bottles, vats, cans, and so forth, the formation of foam presents a serious problem.

Sanmann and Ruehe (23) heated raw whole milk and skim milk to 145° F. and homogenized it at several different pressures. These were cooled promptly in ice water and stored over night at 40° F. The foaming ability was then determined on both the check and the homogenized samples. Their data indicated that homogenization increased the foaming of whole milk at both 40° and 80° F. but decreased the foaming at 140° F. Skim milk showed a slight increased ability in all cases. They also found that with individual cows there was no relationship between the fat and total solids content and its foaming ability. However, when the influence of individual characteristics of the milk was standardized the fat generally decreased the foaming ability while the solids not fat generally increased the foaming ability. Leete (24) also using mixed herd milk, reported that no definite statement could be made regarding the effect of butterfat without considering temperature.

Sanmann and Ruehe (23) studied the effect of temperature from 35° to 180° F., using pasteurized skim milk, pasteurized whole milk, and 20 per cent cream. They found the greatest amount of foam was produced at the lowest temperature. With increased temperature, the volume of foam decreased to a minimum at 70° to 80° F. for whole milk, 80° F. for skim milk, and 90° F. for 20 per cent cream. Further increase in temperature resulted in an increase of foaming, to a second maximum of 110° F. for skim and whole milk and 120° to 130° F. for 20 per cent cream. At low temperature skim milk foamed most, whole milk next, and 20 per cent cream least. Pasteurization of whole or skim milk at 140° F. for 30 minutes had no effect upon the foaming of milk. Heating to 180° F. for 30 minutes caused a slight but regular decrease in foaming ability.

Leete (24) found that skim milk and milk containing between three and five per cent fat had a minimum foaming at from 20° to 30° C. Lower temperatures produced large amounts of light airy foam with large bubbles, while at higher temperatures, 30° to 80° C., the foaming also increased but the air bubbles were small. With cream, containing 18 per cent fat, the minimum amount of foaming occurred at 40° C. and increased to a maximum at 80° C. A slight decrease in foaming occurred at 90° C. At lower temperatures, 40° to 20° C., the foaming increased, then gradually decreased from 20° to 5° C. Leete also stated that immediate measurements of the foam on raw milk containing from three to five per cent fat showed more foam than on pasteurized milk under the same condition. While measurements made one minute later showed the pasteurized milk to have the greater foaming. One minute measurements were the same for both raw and pasteurized samples held 24, 48 and 72 hours. Immediate measurements of the foam on raw skim milk were greater than those on pasteurized milk while

the reverse was true at the end of one minute.

Dahlberg and Hening (25) stated that a 50 cc. sample of pasteurized skim milk whipped to a volume of 230 cc. at 4.4° C., while the same amount of raw skim milk whipped to a volume of 196 cc. at the same temperature. Skim milk also whipped to a much greater volume than milk containing 10 per cent fat.

According to the Associates of Rogers (34) the tendency of milk to foam is at a minimum between the temperatures of 20° and 30° C. Below this range foaming ability increased with decreased temperature, while above this temperature foaming ability also increased rapidly. Pasteurization reduced slightly the foaming ability. As the fat content of the milk increased the temperature of minimum foaming shifted to a higher temperature.

According to Leete (24) aging at a temperature of 10° C. had but little effect on the foaming ability of either milk or cream. Skim milk showed a slight variation at 5° and 10° C. At these temperatures the immediate measurements showed a gradual increase in amount of foam after aging 24 and 48 hours, which was followed by a decided falling off after aging 72 hours. In this case the amount of foam was less than on the fresh milk, however, no such condition was found at the one minute measurement.

Sammann and Ruehe (23) found that the temperature at which milk is held is significant in determining the effect of age on the foaming ability of milk. Measurements made after the milk had been held for three or four hours at 98° F. were almost identical with those of the fresh milk. Freshly drawn milk and milk held at 98° F. had approximately the same foaming ability at both 80° F. and 140° F. while in previously cooled milk the

foaming ability of the whole milk was much less at 80° F. than at 140° F. Milk held at 40° F. for three or four hours showed a slight decrease in foaming ability at 40° F., and a great decrease at 80° F. All milk showed the same foaming ability when measurements were made at 140° F. These authors believed that the solidification and clumping of the fat globules when milk is cooled, influenced the foaming ability of the milk.

Stability of Foams.

Leete (24) believed that temperature is the major factor in foam stability. Low temperatures did not as a rule produce stable foams, whereas high temperatures produced quite resistant foams. Temperatures that produced the least amount of foam also produced the least stable foams. As the temperature increased above that of minimum foam production, the stability of the foam increased. For milk the stability of the foam was approximately the same at temperatures of 50° to 90° C., while cream showed about the same amount of stability from 60° to 90° C. At temperatures of 5° to 10° C., skim milk produced a slightly stable foam, however, milk containing three to five per cent of butterfat produced practically no foam. Age had practically no effect upon foaming stability.

The butterfat content also exerts an influence on foam stability. Dahlberg and Hening (25) found that milk with 10 per cent of butterfat gives a fairly stable foam while the foam from skim milk lacked permanency. This agrees with the Associates of Rogers (34) who stated that large increases of fat content not only increases the foaming but also stabilizes the foam.

Effect of Viscolization on the Specific Gravity

Weigner (15) is of the opinion that there is no measurable change in the density of milk upon homogenization. Weinlig (37) states that definite influence on the specific gravity of milk could not be ascribed to pasteurization. Rahn (61) concluded that any decrease in the specific gravity of milk which occurs after passing through a separator, pasteurizer, pump, or cooler, was due to the incorporation of air during the process. For this reason several hours is necessary for the specific gravity to return to normal.

Fat Test of Viscolized Milk

Butterberg (42) reported that the Adams test gave a much lower fat test on homogenized milk than the Gottlieb method. Henseval (56) stated that some difficulty was experienced in applying the Gerber method to homogenized milk. Six samples of homogenized milk showed an average of 3.36 per cent by the Gerber method, 3.51 per cent by the Soxhlet method, and 3.65 per cent by the Gottlieb method. Likewise, Burr (57) concluded that the Rose-Gottlieb method was more accurate in testing for fat in homogenized milk than the Adams or Gerber method. Burr and Weise (58) in a later report stated that from 0.1 to 10 per cent of the fat remained in homogenized milk tested by the Gerber method over that tested by the Rose-Gottlieb process.

Hudson (30) and Hollingsworth (4) stated that dealers have come to realize that a 3.6 per cent pasteurized milk will not yield a 3.6 per cent homogenized milk by the Babcock test. The reason given for this discrepancy is due to the fact that the fat globules are so finely divided that the smaller ones cannot be raised with the fat column in the Babcock Test

bottle. Doan and Swope (59) disagreed with the majority of investigators and stated that homogenization of whole milk or cream, even at high pressures, exerted but little influence on the Babcock test.

Stability of Protein toward Alcohol

Homogenization, according to Doan (62), strikingly changes the protein stability of milk where fat is present. He further shows that as the fat content increases, the stability of protein toward alcohol decreases, and this increase is much more rapid than that in unhomogenized samples. If no fat were present, homogenization produces no appreciable change in the alcohol number. Doan also examined the milk at the alcohol flocculation point under the microscope and found the floccules indistinguishable from fat clumps. He also found that samples containing 16 per cent fat gave a flocculated appearance when diluted with water alone. This suggests that the stability of the proteins may be dependent upon fat clumping.

Webb and Holm (27) who studied the protein stability by the resistance of the sample to heat, found that increasing the fat content of homogenized cream decreased the protein stability as did also higher pressures of homogenization. Doan (62) agreed that the same relationship exists as determined by the alcohol test.

When the milk was heated before homogenization, Doan (62) reported that the proteins were rendered more stable. In other words, heating causes the protein to become more stable, thus reducing the effect of homogenization. This is in agreement with the results obtained by Webb and Holm (27) on cream. It has also been shown by Doan (8) and Hening (29) that heating the plasma inhibits the fat clumping. This agrees with Doan's (62) suggestion that fat clumping may influence the protein stability. Doan and Minster (50) concluded that high temperature of preheating will not eliminate fat clumping in any of the mixtures containing over seven per cent fat, if the mixture is subsequently homogenized at low temperatures. This, they stated, indicates that the precipitation of calcium ions is probably not as important a factor as has been thought.

Auzinger (64) concluded that the alcohol reaction with milk is not dependent upon the amount of acid present, but is probably caused by the transfer of calcium ions in its reaction to the protein substance. Later Sommer and Binney (66) demonstrated that the addition of calcium salts decreases the protein stability of milk protein in the alcohol test, while sodium citrate and disodium phosphate increases the stability.

Since the total area of the fat surface is increased greatly by homogenization, Sommer (2) quoted Tracy and Ruehe (65) as suggesting that the decreased stability of milk protein as the result of homogenization may be due to the increased adsorption of phosphates and citrates at the fat-serum interface. This leaves less of these salts in the serum proper. Sommer (2) concluded that this explanation is in harmony with the observation that the presence of fat appears to be essential for the destabilizing effect of homogenization.

Size of Fat Blobules

The main result of homogenization is the breaking up of the fat into many small fat globules. According to Butterberg (42), the fat globules in ordinary milk vary in size from 1.6 to 10 microns, while those in homogenized milk vary in size from 0.8 to 2.8 microns. Weigner (15) in his studies found that the fat in normal milk averaged 2.9 microns and in homogenized milk 0.27 microns.

Baldwin (60) observed that the degree of dispersion generally increased as the pressure increased. He found that the majority of the fat globules in homogenized milk ranged between one and two microns in diameter, whereas the majority of normal fat globules range in diameter from five to six microns.

According to the Associates of Rogers (34) Rahn found that the greater part of the fat in homogenized whole milk was dispersed into globules of less than two microns in diameter. They also state that homogenization as carried out rendered the fat in a dispersed form more finely divided than the fat remaining in skim milk.

Sommer (2) pointed out that the bulk of the fat in milk and cream exists in globules of from six to eight microns and that properly homogenized ice cream mixes contain most of the fat in globules of between one and two microns in diameter. A globule of six microns in diameter upon homogenization yields 216 globules of one micron, while a globule of eight microns diameter yields 512 globules of the same size. This decidedly changes the properties of the ice cream mix.

Acidity of Viscolized Milk

Schoops (68) and Istaz and Van Svest (67) concluded that homogenization does not increase the acidity nor noticeably alter the chemical composition. However, Doan (62) gives data to show that the pH of raw milk is lowered whenever fat is present. This occurs regardless of whether the initial pH has been altered prior to homogenization. Alcohol tests were also made but this lowering of the pH accounted for only a small part of the protein stability.

Weinlig (37) and Rupp (31) found that pasteurization decreased slightly the titratable acidity of milk. This they attributed to the loss of gases during the heating process.

Dorner and Widmer (70) found that the titratable acidity of raw milk increased as the pressure of homogenization increased, although the acidity did not develop at the same rate in all samples. Aging the raw homogenized milk showed a continued increase for 24 hours. Increasing the acidity markedly before processing prevented changes in acidity due to homogenization. However, the increase in titratable acidity found after homogenization of raw milk was not due to the action of bacteria.

Flavor of Viscolized Milk

Doan (69) is of the opinion that homogenization may be carried out with comparable results on either raw or pasteurized milk. He cites one instance where the dairy short course students at the Pennsylvania State College gave a preference for milk homogenized at 100° F. over the same raw milk before homogenization. However, Dorner and Widmer (70) found that homogenization caused raw milk and raw cream to become distinctly rancid within a few hours. The development of rancidity increased as the homogenization pressure increased. They attributed this rancidity to a lipase. Lipase was detected in all samples examined although the activity in different samples varied greatly. In unhomogenized samples the lipase acts so slowly that it cannot be detected, but since a greater fat surface is exposed in homogenized milk rancidity develops much more rapidly. This lipase was very sensitive to heat, milk held at 55° C. for 20 minutes completely destroyed its activity.

Considerable disagreement may be found in the literature as to whether the enzyme lipase is present in normal raw milk. However, Nair (63) states that a true lipase is a normal constituent of raw cow's milk. This is indicated by an increase in titratable acidity of high butterfat cream preserved by sucrose and by rancid odors development. Pasteurization inactivates lipolytic enzymes.

Curd Tension of Viscolized Milk

The study of soft-curd milk has received considerable attention during the last few years because of its beneficial effects as an infant food. However, this study of the effect of viscolization on the curd tension of milk may be considered only as a preliminary report. Therefore, a complete review of literature will not be given.

Washburn and Jones (22) found that the curd formed from homogenized milk did not become hard and tough as in the case of untreated milk. Homogenized milk coagulated as promptly as did the control samples. However, its curd was so flocculent that it took five hours to precipitate it as compared to 20 minutes for normal milk.

Hill (71) boiled milk and secured a curd which was only 31 per cent as hard as that of the original milk. However, pasteurization of the milk at 143° F. for 30 minutes had little effect on the hardness of the curd formed by its coagulation with pepsin. Hill (72) also stated that removal of fat renders the curd harder, while the addition of cream to the skim milk restored its normal curd tension.

Espe and Dye (73) concluded that doubling the curd tension of milk increased the length of digestion period from 30 to 65 per cent. Boiling the milk lowered the curd tension markedly. However, acidifying the milk before coagulation with rennin raised the curd tension.

PURPOSE OF EXPERIMENT

The purpose of this experiment was to observe and to study the effect of viscolization at different pressures, upon the following properties, using both raw milk preheated to 32.2° C. (90° F.) and pasteurized milk heated to 62.8° C. (145° F.) and held for 30 minutes:

1. Creaming ability of the viscolized and unviscolized samples at 24 and 48 hours.
2. Viscosity of the viscolized and unviscolized milk at 20° C., both while fresh and after aging for 24 hours.
3. Surface tension of the viscolized and unviscolized samples immediately after processing and after aging for 24 hours.
4. Foaming ability of the viscolized and unviscolized samples at 4° to 5° C. immediately after cooling.
5. Titratable acidity, while fresh and after aging for 24 hours, as affected by viscolization.
6. Butterfat content of the viscolized and unviscolized milk as determined by the Babcock test.
7. Specific gravity at 15° C. both of the viscolized and unviscolized milk.
8. Protein stability toward 95 per cent alcohol of the viscolized and of the unviscolized samples.
9. Size of fat globules both in the check and in the viscolized samples.
10. Curd tension of the viscolized and of the unviscolized samples.
11. Flavor of the viscolized and of the unviscolized samples.

PLAN OF EXPERIMENTAL WORK

Source of Milk Supply

The milk supply used in this experiment was secured from two herds which delivered milk to the College Creamery. These herds were selected because each delivered daily approximately the amount of milk needed in the experiment. The first six experiments were carried out using milk from the herd number one, which consisted of four Holsteins, three Guernseys, two Jerseys, and one Brown Swiss cow. Because of a shortage of milk supply from this herd at that time, the rest of the experiments were carried out using milk from the second herd, which consisted entirely of Holsteins. All of the milk was delivered at a temperature of less than 65° F.

Experimental Methods

The milk, as soon as delivered to the College Creamery, was taken to the experimental laboratory and placed in a 50 gallon Cherry-Burrell coil type vat pasteurizer. It was immediately heated to 90° F. and a portion viscolized at 500, 1500, and 2500 pounds pressure. About two gallons of the milk was run through the viscolizer at the desired pressure before taking samples to insure the proper processing at each pressure. The remaining milk in the vat, unless otherwise stated, was quickly heated to 145° F. and held for 30 minutes. This milk was then viscolized at the pasteurizing temperature using the same procedure as in the raw milk. The viscolizer used was a Union Steam Pump Company viscolizer of 200 gallon capacity, containing "Duo-Visco" valves.

Viscolized and check samples of the milk were taken in gallon ice cream cans. These were immediately emptied in pint bottles and cooled in

ice water. Samples for creaming ability were placed in 100 cc. graduated cylinders. These were also cooled in ice water. Unless used immediately all samples were stored in an electric refrigerator held at a temperature of 35° to 40° F.

Description of Tests Made

The creaming ability was determined by observing the cc. of cream appearing on 100 cc. graduated cylinders both at 24 and 48 hour periods. These observations were recorded as per cent.

To insure that the samples were well mixed, all samples were poured from one bottle to another twice before any tests were made.

Viscosity determinations were made by means of the Improved MacMichael Viscosimeter. In all determinations, gauge wires, number 34, were used. These were standardized against distilled water at 20° C. by the following method: one hundred cc. of distilled water was placed in the dash pot and the pointer adjusted to the zero mark on the dial. The machine was then allowed to run until the reading on the dial remained constant. The reading was made in degrees M. deflection of the dial. This equaled one centipoise. Therefore, the degrees M reading of the milk divided by the degrees reading of the distilled water equals the number of centipoise viscosity of the milk. In each viscosity determination 100 cc. of the milk sample were used. The milk was first tempered to 20° C. and placed in the cup on the turntable. After making the reading to the closest one-half degree M., the temperature of the milk was taken. The trial was repeated if the temperature varied more than one-half of one degree Centigrade. Before removing the sample of milk the movable index arm was checked to see if it was directly over the zero mark on the disc.

The surface tension of the milk was determined by the Du Noüy Tensiometer on the same sample as the viscosity determination. This machine measures the force in dynes required to pull a platinum ring four cm. in circumference, free from the surface of the liquid. Before each sample was examined for surface tension the platinum wire was rinsed in distilled water and burned in a Bunsen flame. Each sample of milk was placed in a different petri dish which was previously boiled in cleaning solution. All readings were made at 20° C. plus or minus one-half of one degree. In all cases the readings used checked within one-tenth of one dyne.

The foaming ability of the samples of milk was determined immediately after cooling by a method similar to that suggested by Sanmann and Ruehe (23). The method used was to place 200 cc. of the sample in a graduated 500 cc. tall form beaker, and whip it for one minute in an electric stirring machine such as is used at soda fountains in the preparation of malted milks. After one minute stirring, the agitator was withdrawn. Readings of the total volume of sample and foam were made 15 seconds after agitation. The volume of foam was calculated as the per cent of the original volume.

Acidity tests were made by titrating with N/10 sodium hydroxide immediately after processing and again after aging for 24 hours. In order to increase the accuracy of the test 17.6 cc. samples were used for titrating and the results were recorded in per cent of lactic acid. Because of the rise in acidity observed in the raw viscolized samples, a few trials were run to determine if preheating to 145° F. and if pasteurizing after viscolization would show the same results.

A Westphal balance was used to secure the specific gravity of the milk. All determinations were carried out at 15° C.

Protein stability was determined by diluting two cc. of the sample of milk with the least amount of 95 per cent ethyl alcohol required to produce a noticeable trace of flocculation.

The size of the fat globules were measured by means of an eyepiece micrometer. The milk used for this work was diluted with a one per cent solution of gelatin at the rate of one part of milk to 30 parts of gelatin solution. This prevented Browning movement. One loopful of the diluted milk was placed upon a slide and examined under a dry oil immersion lens of the microscope. The average size of the fat globules was reported in microns.

After most of the experimental work of this problem had been completed several trials were carried out to determine the effect of viscolization on the flavor of milk. Therefore, separate lots of milk were viscolized and held in order to study the flavor development due to viscolization. In one case the milk was viscolized as previously stated. In another trial raw whole milk, skim milk and milk standardized to the same per cent fat were used in the same manner. These latter samples were all from the same original source. Milk from the different patrons of the College Creamery was also viscolized at 2500 pounds pressure. All the samples were judged for flavor within two hours after viscolization and again after several hours, or until distinct off flavors appeared. The check samples were also held for several days to determine if the same off flavors due to age developed.

The curd tension of the milk was determined as suggested by Hill (72), using an American Curd-O-Meter. In each trial 100 cc. of milk was placed in the coagulation cylinder and heated to 95° F. Ten cc. of the coagulant, consisting of a mixture of three parts of 0.6 per cent solution of one to 3,000 dry scale pepsin to one part of calcium chloride solution containing 378 grams of dry granular calcium chloride per liter, were added to each 100 cc. of milk. After standing for 10 minutes the knife of the Curd-O-Meter was gently pushed through the coagulated milk. The reading was recorded directly in grams.

RESULTS

Creaming of Viscolized Milk

That viscolization destroys the creaming ability of milk has been known for several years. However, the effect of varying pressures of viscolization on the creaming ability of milk is not so generally understood. Table I shows the creaming after 24 hours of both raw and pasteurized milk viscolized at 500, 1500, and 2500 pounds pressure. Pressure as low as 500 pounds was not efficient in completely destroying the cream layer. The average of 12 trials shows the cream layer of raw unviscolized milk was 15.5 per cent while that viscolized at 90° F. under 500 pounds pressure was 1.83 per cent. Likewise, the milk pasteurized at 145° F. for 30 minutes before processing at that temperature reduced the cream layer from 12.42 per cent in the raw milk to 0.63 per cent when viscolized at 500 pounds pressure. This shows greater creaming of the milk viscolized at the lower temperature. However, the creaming ability of the sample viscolized at 500 pounds pressure varied from zero to six per cent in the raw milk and from zero to two per cent in the pasteurized milk. In no case was there enough creaming to measure in the samples viscolized at the higher pressures regardless of the temperature used.

Table II indicates that the cream layer of milk viscolized at low pressure continues to increase even after 24 hours while that of the unviscolized samples decreases. The average of the 12 trials shows that the raw unviscolized milk decreased 1.08 per cent in cream volume while the samples viscolized at 500 pounds pressure increased 0.62 per cent in cream volume. In like manner the pasteurized unviscolized milk decreased 0.33 per cent in cream volume and the pasteurized milk viscolized at 500 pounds pressure

Table I. Effect of Viscolization on the Per Cent of Cream Rising on Raw and Pasteurized Milk Held 24 Hours after Processing.

	Raw (90° F.)				Pasteurized (145° F.)			
Lot	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
1	14	3	trace	-	12	2	trace	-
2	16	1	-	-	14	2	-	-
3	17	trace	-	-	16	trace	-	-
4	16	2	-	-	13	1	-	-
5	17	-	-	-	10	-	-	-
6	15	5	-	-	11	trace	-	-
7	15	-	-	-	12	trace	-	-
8	14	6	-	-	13	trace	-	-
9	16	-	-	-	13	-	-	-
10	15	1	-	-	14	trace	-	-
11	15	2	-	-	11	1	-	-
12	16	2	-	-	10	1.5	-	-
Ave.	15.5	1.83	-	-	12.42	0.63	-	-

Table II. Effect of Viscolization on the Per Cent of Cream Rising on Raw and Pasteurized Milk Held 48 Hours after Processing.

	Raw (90° F.)				Pasteurized (145° F.)			
Lot	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
1	14	3	trace	-	12	2	trace	-
2	15	1	-	-	14	2	-	-
3	15	trace	-	-	14	2	-	-
4	14	3	1	-	12	2	1	-
5	15	1	trace	-	10	1	-	-
6	13	7	-	-	11	trace	-	-
7	14	1	-	-	12	1.5	-	-
8	13	7	-	-	12	1	-	-
9	15	1	-	-	12	1	-	-
10	14	1.5	-	-	14	1	-	-
11	15	2	-	-	11	1	-	-
12	16	2	-	-	11	2	-	-
Ave.	14.42	2.45	0.08	-	12.09	1.37	0.08	-

increased 0.74 per cent in cream volume. At the 48 hour interval only one sample showed enough creaming to measure when viscolized at 1500 pounds pressure. In no case was any creaming shown at 2500 pounds pressure.

Viscosity of Viscolized Milk

The viscosity of raw milk may be either increased or decreased by viscolization as shown in Table III. The general trend, however, is an increase in viscosity due to viscolization. Seven of 11 trials show that the viscosity of raw milk is increased by viscolization, five of which indicate that the viscosity increases as the pressure increases. On the other hand, two trials showed a decreased viscosity by viscolization and two samples were affected irregularly. The average of the 11 samples indicates that the viscosity of raw milk is increased by viscolization in proportion to the pressure used.

The average results after aging raw milk for 24 hours show an increase in viscosity due to viscolization. However, as shown in Table IV, the viscosity of any one sample may increase, decrease or remain the same as compared to the determination made 24 hours previously.

Immediate measurements of viscosity on the milk pasteurized prior to viscolization show a decrease in every case. The results are shown in Table III. Five samples were lowered in viscosity as the pressure increased. In the remaining samples, as the pressure increased, the viscosity was irregularly affected, but was always lower than that of the unviscolized milk. The average of the 11 trials shows the pasteurized unviscolized milk to have a viscosity of 2.142 centipoises; that viscolized at 500 pounds pressure 2.957 centipoises; 1500 pounds pressure 1.869 centipoises, and 2500 pounds pressure 1.814 centipoises.

Table III. Effect of Viscolization on the Viscosity of Raw and Pasteurized Milk Immediately after Processing. The Viscosity Is Expressed in Centipoise at 20° C.

Lot No.	Raw (90° F.) Pounds Pressure of Viscolization 0	500	1500	2500	Pasteurized (145°F.) Pounds Pressure of Viscolization 0	500	1500	2500
1	1.58	1.73	1.88	2.15	2.18	1.85	1.82	1.85
2	2.12	2.09	2.24	2.24	2.06	2.03	1.87	1.81
4	2.18	2.21	2.33	2.51	2.27	2.18	2.00	1.64
5	2.24	2.18	2.12	2.33	2.24	1.82	1.79	1.82
6	2.12	2.00	2.09	2.06	2.00	1.79	1.79	1.67
7	2.13	2.26	2.26	2.23	1.97	1.90	1.83	1.70
8	2.30	2.20	2.13	2.00	2.37	1.80	1.77	1.77
9	2.27	2.30	2.37	2.43	2.27	2.03	1.90	2.00
10	2.33	2.40	2.57	2.57	2.20	2.17	1.93	1.87
11	2.17	2.33	2.40	2.47	2.23	2.13	2.13	2.13
12	2.23	2.26	2.26	2.47	1.83	1.80	1.73	1.70
Ave.	2.152	2.178	2.241	2.315	2.142	1.954	1.869	1.814

Table IV. Effect of Viscolization on the Viscosity of Raw and Pasteurized Milk Held 24 Hours after Processing. The Viscosity Is Expressed in Centipoise at 20° C.

Lot No.	Raw (90° F.) Pounds Pressure of Viscolization 0	500	1500	2500	Pasteurized (145° F.) Pounds Pressure of Viscolization 0	500	1500	2500
1	2.18	2.12	2.18	2.24	2.15	1.76	1.67	1.67
2	2.24	2.30	2.36	2.48	2.30	2.15	2.06	2.09
4	2.09	2.15	2.27	2.42	1.97	1.97	2.03	1.97
5	2.12	2.21	2.27	2.30	2.12	2.06	2.00	2.03
6	2.15	2.15	2.30	2.30	2.00	1.90	1.85	2.03
7	2.07	2.33	2.26	2.23	1.67	1.97	1.93	2.00
8	2.20	2.17	2.30	2.27	2.27	2.00	1.97	1.90
9	2.33	2.27	2.33	2.37	2.33	1.90	2.00	2.07
10	2.30	2.47	2.57	2.60	2.37	2.30	2.23	2.20
11	2.20	2.27	2.50	2.43	2.20	2.13	2.13	2.13
12	2.26	2.16	2.36	2.27	2.33	2.20	2.20	2.07
Ave.	2.194	2.236	2.346	2.355	2.155	2.031	2.012	2.014

Aging all of the samples for 24 hours after viscolization increased the average viscosity although individual samples were affected irregularly. Eight of the 11 samples still showed a decreased viscosity due to viscolization of the pasteurized milk; one showed an increase in viscosity; and two were affected irregularly.

Surface Tension of Viscolized Milk

Results of surface tension study indicate that the surface tension of unpasteurized milk is always lowered by viscolization. However, the decrease in surface tension does not lower as the pressure increases. Table V shows that the surface tension was lowest at 1500 pounds pressure in nine of 12 times. The 2500 pound pressure samples showed the lowest surface tension only twice, while the 500 pound pressure of viscolization was also lowest twice, one of which was the same as that at 1500 pounds pressure. The average of 12 trials shows the surface tension of the unviscolized raw milk to be 43.62 dynes; that viscolized at 500 pounds pressure to be 39.61 dynes; that viscolized at 1500 pounds pressure 38.47 dynes; and that viscolized at 2500 pounds pressure 39.16 dynes.

Table V also shows that the surface tension of pasteurized milk was as a rule increased slightly by viscolization. However, in two trials the surface tension of the milk viscolized at 500 pounds pressure appeared one-tenth of a dyne lower than that of the unviscolized milk. In only one trial was the surface tension at 1500 pounds pressure slightly lower than that at 500 pounds pressure. At 2500 pounds pressure the surface tension was always the same or higher than that of the other samples. The average of the 12 trials shows the surface tension of the pasteurized milk to be

Table V. Effect of Viscolization on the Surface Tension of Raw and Pasteurized Milk Immediately after Processing. The Surface Tension is Expressed in Dynes at 20° C.

	Raw (90° F.)				Pasteurized (145° F.)			
Lot	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
1	46.1	41.6	39.1	39.7	45.9	46.9	46.6	47.0
2	44.3	41.2	39.4	39.3	46.4	46.5	46.5	46.5
3	44.8	42.0	41.4	40.4	45.1	46.3	46.4	46.8
4	44.1	39.7	38.5	39.6	42.6	43.5	43.6	43.8
5	42.0	37.0	37.8	39.5	43.2	43.5	43.9	44.1
6	42.8	39.5	37.5	37.6	43.8	43.7	44.3	44.9
7	42.5	38.0	38.0	39.2	44.0	44.6	44.9	45.1
8	43.2	39.5	38.7	39.7	44.4	44.5	44.8	45.0
9	44.4	40.3	38.9	39.7	44.0	44.8	45.2	45.7
10	43.1	39.5	39.1	39.5	45.2	45.1	45.8	46.0
11	43.6	38.5	37.3	37.9	44.7	44.9	45.5	45.5
12	42.5	38.5	36.0	37.8	45.0	45.3	45.8	46.3
Ave.	43.62	39.61	38.47	39.16	44.53	44.97	45.27	45.55

Table VI. Effect of Viscolization on the Surface Tension of Raw and Pasteurized Milk Held 24 Hours after Processing. The Surface Tension Is Expressed In Dynes at 20° C.

	Raw (90° F.)				Pasteurized (145° F.)			
Lot	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
1	45.6	43.0	37.3	37.3	46.5	46.4	46.6	46.7
2	44.3	40.5	34.5	35.8	44.9	44.5	45.5	45.5
3	45.5	38.8	39.0	38.3	44.5	45.3	45.8	46.3
4	42.5	37.2	35.0	35.8	43.2	43.0	43.1	43.9
5	43.5	34.9	34.8	35.5	43.3	43.2	43.5	44.5
6	42.5	37.5	33.5	35.0	43.8	43.3	44.4	44.8
7	42.5	37.7	35.0	35.3	43.8	44.3	44.5	44.7
8	44.2	39.2	37.5	37.0	44.6	45.4	45.5	45.7
9	44.2	40.0	37.0	37.0	44.8	45.2	45.5	45.9
10	42.8	38.3	34.0	36.5	44.0	44.2	45.4	45.6
11	43.2	37.3	33.0	35.5	44.5	44.6	45.0	45.5
12	41.9	37.5	35.0	34.3	44.8	44.9	45.9	45.9
Ave.	43.56	38.51	35.47	36.11	44.39	44.54	45.06	45.42

44.54 dynes; that viscolized at 500 pounds pressure 44.97 dynes; at 1500 pounds pressure 45.27; and at 2500 pounds pressure 45.55 dynes.

Aging the milk for 24 hours appeared to cause a slight decrease in the surface tension of the pasteurized milk and a more marked decrease in the raw milk, as shown in Table VI. However, the aged pasteurized and viscolized milk was irregularly affected, but the average of the 12 samples shows a slight decrease. The raw viscolized milk indicates slightly different results. In this case the milk viscolized at 1500 and 2500 pounds pressure was always lower in surface tension. Raw milk and viscolized milk at 500 pounds pressure were both irregularly affected but the average shows a slight decrease.

Foaming of Viscolized Milk

The foaming of milk is of considerable importance in the preparation of market milk. In this study foaming was determined only at low temperatures such as might be used in the bottling of milk. The results of this study as shown in Table VII indicate that foaming ability, as carried out, is reduced by the viscolization of raw milk while pasteurization has the opposite effect. Pasteurization alone appeared to affect the foaming ability irregularly. The viscolization of raw milk always lowered the foaming ability, however, the pressure at which the minimum foaming occurred is not necessarily the highest one used. In only four out of 12 trials did the foaming decrease directly as the pressure increased. In two trials the foaming at 1500 and 2500 pounds pressures was the same. However, in six of the 12 trials 1500 pounds pressure gave the lowest foaming. Viscolization of raw milk at 500 pounds pressure always gave the same or a higher foaming ability than at 1500 pounds. This relationship did not

Table VII. Effect of Viscolization on the Foaming of Raw and Pasteurized Milk Immediately after Processing. The Foaming Ability Is Expressed in Per Cent at 4° to 5° C.

	Raw (90° F.)				Pasteurized (145° F.)			
Lot	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
1	122.5	112.5	60.0	50.0	130.0	157.5	162.5	162.5
2	145.0	95.0	82.5	82.5	127.5	150.0	157.5	162.5
3	120.0	75.0	70.0	67.5	110.0	112.5	137.5	140.0
4	130.0	75.0	75.0	77.5	125.0	145.0	150.0	160.0
5	140.0	87.5	82.5	92.5	145.0	142.5	160.0	162.5
6	130.0	107.5	77.5	75.0	120.0	140.0	162.5	162.5
7	140.0	115.0	87.5	100.0	140.0	155.0	157.5	157.5
8	137.5	115.0	105.0	105.0	137.5	150.0	152.5	150.0
9	135.0	105.0	100.0	92.5	142.5	142.5	152.5	160.0
10	137.5	85.0	72.5	75.0	125.0	137.5	150.0	157.5
11	122.5	55.0	47.5	67.5	127.5	152.5	150.0	160.0
12	112.5	60.0	47.5	67.5	87.5	92.5	112.5	127.5
Ave.	131.0	90.6	75.3	79.4	126.5	139.8	150.4	155.2

hold when comparing foaming at 500 and 2500 pounds pressure. In this latter case four of the 12 samples showed a greater foaming at the higher pressure. The average of 12 trials shows the foaming of unviscolized raw milk to be 131 per cent; that viscolized at 500 pounds pressure 90.6 per cent; that at 1500 pounds pressure 75.5 per cent; and that at 2500 pounds pressure 79.4 per cent.

As the pressure of viscolization increased the foaming ability of pasteurized milk either increased or remained the same, except in one case at 500 pounds pressure when the foaming was slightly less than that of the check pasteurized sample. However, the average shows a gradual increase in foaming from 126.5 per cent in the pasteurized unviscolized sample to 155.2 per cent when viscolized at 2500 pounds pressure.

While the foaming ability of raw viscolized milk was always less than that of the pasteurized viscolized milk, its foam appeared more stable. The air cells were also much larger in the raw viscolized milk and had a rather frothy appearance which broke down slowly. The air cells in the pasteurized viscolized milk were very small and appeared to break down rather rapidly.

Stability of Protein

Viscolization of whole milk not only disperses the fat, but in every case it also lowered the stability of the protein toward alcohol. Table VIII shows that the proteins of viscolized milk were less stable to 95 per cent alcohol than that of the original milk. However, milk pasteurized before viscolization is considerably more stable to alcohol than that of raw milk.

Table VIII. Effect of Viscolization on the Protein Stability of Raw and Pasteurized Milk Immediately after Processing. The Protein Stability Is Expressed in cc. of 95 Per Cent Alcohol to Coagulate Two cc. of Milk.

	Raw (90° F.)				Pasteurized (145° F.)			
Lot	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
4	2.1	1.3	1.0	0.9	3.6	2.9	1.7	1.6
5	3.3	1.2	1.1	1.1	3.6	3.5	3.2	2.8
6	3.4	1.9	1.0	1.0	3.4	3.2	3.2	3.1
7	3.3	2.2	1.1	0.9	3.3	3.1	2.9	2.6
8	1.2	1.0	0.8	0.8	3.4	2.7	2.5	2.5
9	1.6	0.7	0.7	0.7	3.5	2.5	2.3	2.2
10	3.5	1.9	0.9	0.8	3.5	3.2	2.7	2.0
11	1.7	1.0	0.8	0.5	3.5	3.0	3.0	3.0
Ave.	2.5	1.4	0.92	0.84	3.46	3.01	2.69	2.47

Table VIII also indicates that as the pressure of viscolization increases the destabilizing effect becomes more pronounced, but this effect is far less marked in the pasteurized milk. In other words, only one-third as much alcohol was required to produce a visible coagulation of the milk protein in raw milk viscolized at 2500 pounds pressure as in the pasteurized milk viscolized at the same pressure.

Titratable Acidity

The titratable acidity is increased in every case by the viscolization of raw milk. However, if the milk is pasteurized before viscolization no such raise in acidity is apparent. This is shown conclusively by Table IX. According to this table, the titratable acidity of raw milk always increases or remains the same as the pressure increases. The average of 12 trials shows the raw unviscolized samples to contain 0.175 per cent acidity; milk viscolized at 500 pounds pressure 0.193 per cent acidity; 1500 pounds pressure 0.201 per cent acidity; and 2500 pounds pressure 0.208 per cent acidity. These results might be interpreted to show that the titratable acidity of viscolized raw milk is less rapid as the pressure increases.

Results after aging for 24 hours show the same trend as that stated above. Table X shows no marked change in titratable acidity if the milk had been pasteurized previous to viscolization. However, the titratable acidity of the raw viscolized milk continued to increase to a greater extent than that of the raw unviscolized milk. It appears from Tables IX and X that the average titratable acidity of the fresh milk increased 0.008 per cent; that viscolized at 500 pounds pressure 0.012 per cent; 1500 pounds pressure 0.036 per cent; and 2500 pounds pressure 0.037 per cent.

Table IX. Effect of Viscolization on the Titratable Acidity of Raw and Pasteurized Milk Immediately after Processing. The Titratable Acidity Is Expressed in Per Cent Lactic Acid.

Lot	Raw (90° F.) Pounds Pressure of Viscolization				Pasteurized (145° F.) Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
1	.190	.195	.230	.230	.180	.180	.180	.180
2	.175	.185	.185	.200	.165	.170	.170	.170
3	.160	.190	.190	.200	.160	.160	.160	.160
4	.195	.220	.230	.240	.190	.190	.190	.190
5	.160	.175	.195	.195	.155	.155	.155	.160
6	.175	.195	.210	.220	.170	.170	.170	.170
7	.175	.190	.195	.200	.165	.165	.165	.165
8	.175	.195	.200	.200	.170	.170	.170	.170
9	.175	.185	.185	.190	.160	.160	.160	.160
10	.180	.200	.210	.215	.175	.175	.175	.175
11	.175	.195	.195	.205	.175	.175	.175	.175
12	.170	.185	.190	.195	.170	.170	.170	.170
Ave.	.175	.193	.201	.208	.170	.170	.170	.170

Table X. Effect of Viscolization on the Titratable Acidity of Raw and Pasteurized Milk Held 24 Hours after Processing. The Titratable Acidity Is Expressed in Per Cent of Lactic Acid.

Lot	Raw (90° F.) Pounds Pressure of Viscolization				Pasteurized (145° F.) Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
3	.165	.190	.210	.220	.160	.160	.160	.160
4	.205	.235	.260	.270	.195	.195	.195	.195
5	.160	.180	.200	.215	.155	.155	.160	.165
6	.190	.210	.235	.235	.170	.170	.170	.170
7	.180	.195	.235	.240	.175	.175	.175	.175
8	.180	.205	.240	.245	.175	.175	.175	.175
9	.190	.205	.220	.225	.175	.175	.175	.175
10	.180	.215	.265	.265	.175	.175	.175	.175
11	.185	.215	.270	.270	.175	.175	.175	.175
12	.180	.200	.235	.255	.170	.170	.170	.170
Ave.	.182	.205	.237	.245	.173	.173	.173	.173

Since only 0.008 per cent of the acidity as shown in the unviscolized sample could be attributed to bacterial origin, viscolization must have been responsible for the marked increase at the higher pressures.

Preheating the milk to 145° F. before viscolization apparently prohibited the increase in acidity caused by viscolization. Results of two trials as shown in Table XI show this very clearly.

Pasteurization of the raw milk after viscolization at 90° F. apparently did not prevent the titratable acidity increase. However, as shown by Table XI the acidity after aging 24 hours showed no increase in one case and only a slight increase in another.

Because of the rise in titratable acidity always noted in viscolized whole milk, several samples of skim milk were also viscolized. No change in acidity was observed as shown in Table XI. This would indicate that the rise in titratable acidity due to viscolization must be associated with the butterfat content of the milk.

Babcock Test of Viscolized Milk

It appears from this study that viscolization has little, if any, effect on the Babcock test of whole milk. If the size of the fat globule directly influenced the Babcock fat test, it would be expected that the butterfat content as shown by the Babcock test would be lowered as the pressure increased. The results in Table XII show that no such condition exists. In no case does the results at different pressures vary more than two-tenths per cent and then only in the results of the first four experiments. Considerable difficulty was experienced at this time in securing

Table XI. Effect of Viscolization on the Titratable Acidity of Milk Preheated to 145° F. and of Raw Milk Pasteurized after Processing. The Titratable Acidity Is Expressed in Per Cent Lactic Acid.

Lot No.	Treatment	Immediately after Processing: Pounds Pressure of Viscolization 0	500	1500	2500	24 Hours after Processing: Pounds Pressure of Viscolization 0	500	1500	2500
10	Pasteurized after processing	.175	.200	.210	.215	.175	.200	.215	.220
11	Pasteurized after processing	.180	.195	.200	.200	.180	.195	.200	.200
11	Preheated 145° F.	.175	.175	.175	.175	.175	.175	.175	.175
12	Preheated 145° F.	.170	.170	.170	.170	.170	.170	.170	.170
12	Raw Skim Milk preheated 90° F.	.160	.160	.160	.160	.160	.160	.160	.160
13	Raw Skim Milk preheated 90° F.	.180	.180	.180	.180	.180	.180	.180	.180

Table XII. Effect of Viscolization on the Percentage of Fat as Determined by the Babcock Fat Test.

Lot No.	Raw (90° F.) Pounds Pressure of Viscolization 0	500	1500	2500	Pasteurized (145° F.) Pounds Pressure of Viscolization 0	500	1500	2500
1	3.30	3.25	3.20	3.30	3.30	3.30	3.25	3.30
2	4.00	3.85	3.85	3.80	4.00	3.90	3.90	3.90
3	4.20	4.10	4.10	4.15	4.20	4.20	4.15	4.10
4	4.00	4.00	4.05	3.95	4.05	4.10	3.9	4.10
5	3.85	3.85	3.90	3.85	3.85	3.85	3.90	3.90
6	3.25	3.20	3.15	3.20	3.25	3.20	3.20	3.15
7	3.50	3.50	3.45	3.45	3.50	3.45	3.45	3.45
8	3.25	3.30	3.30	3.25	3.25	3.30	3.35	3.25
9	3.60	3.60	3.55	3.60	3.60	3.60	3.60	3.60
10	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.75
11	3.60	3.65	3.60	3.60	3.65	3.60	3.60	3.60
12	3.85	3.80	3.80	3.85	3.80	3.80	3.85	3.80
Ave.	3.67	3.65	3.64	3.64	3.67	3.67	3.65	3.66

clear tests, due to the use of too strong acid. After standardizing the sulphuric acid to a specific gravity of 1.82 to 1.83, no difficulty was experienced.

Specific Gravity of Viscolized Milk

The results of this experiment indicate very clearly that viscolization has no effect upon the specific gravity of milk. Slight variation as shown in Table XIII might be explained as due to slight differences in temperature or to the incorporation of small amounts of air during the mixing process.

Size of Fat Globules

The principal physical effect of viscolization of whole milk is the breaking up of the fat into many small globules. Results in Table XIV show the globules to be broken down from an average of 3.88 microns in whole unviscolized milk to an average diameter of less than 1.5 microns in the milk viscolized at 2500 pounds pressure. It appears that the degree of dispersion depends not only upon the pressure used but also upon the temperature of viscolization. The fat globules in the milk viscolized at 90° F. were not as finely dispersed as those viscolized at higher temperatures even though the pressure of viscolization remained the same.

Although the average diameter of the globules was greatly reduced, the size of the individual globules varied greatly. The average for the largest fat globules in the whole milk was found to be 13.57 microns while the largest for the milk viscolized at 2500 pounds was found to be between 3.5 and four microns in diameter.

Table XIII. Effect of Viscolization on the Specific Gravity of Raw and Pasteurized Milk as Determined at 15° C.

	Raw (90° F.)				Pasteurized (145° F.)			
Lot	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
1	1.0316	1.0316	1.0316	1.0316	1.0318	1.0315	1.0313	1.0316
2	1.0316	1.0314	1.0315	1.0315	1.0316	1.0316	1.0316	1.0315
3	1.0313	1.0314	1.0310	1.0311	1.0313	1.0310	1.0313	1.0313
4	1.0324	1.0325	1.0325	1.0325	1.0330	1.0330	1.0330	1.0330
5	1.0308	1.0308	1.0309	1.0309	1.0310	1.0310	1.0310	1.0313
6	1.0310	1.0310	1.0310	1.0310	1.0310	1.0310	1.0310	1.0310
7	1.0313	1.0313	1.0313	1.0311	1.0313	1.0313	1.0313	1.0311
8	1.0320	1.0317	1.0320	1.0317	1.0320	1.0320	1.0317	1.0317
9	1.0315	1.0315	1.0315	1.0315	1.0315	1.0315	1.0315	1.0315
10	1.0320	1.0320	1.0320	1.0320	1.0320	1.0320	1.0320	1.0320
11	1.0318	1.0318	1.0318	1.0318	1.0318	1.0318	1.0318	1.0318
12	1.0319	1.0319	1.0318	1.0319	1.0319	1.0318	1.0319	1.0319
Ave.	1.0316	1.0316	1.0316	1.0316	1.0316	1.0316	1.0316	1.0316

Table XIV. Effect of Viscolization on the Size of the Fat Globules of Raw and Pasteurized Milk. The Size of the Fat Globules Is Expressed in Microns.

Lot	Raw (90° F.)				Pasteurized (145° F.)			
	Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	0	500	1500	2500	0	500	1500	2500
4	3.93	2.85	2.14	1.45	3.93	2.50	1.78	1.43
5	3.93	2.85	2.14	1.45	3.93	2.85	1.78	1.43
6	3.64	2.85	2.14	1.49	3.64	2.35	1.78	1.43
7	3.57	2.50	1.78	1.42	3.57	2.14	1.78	1.43
8	3.57	2.50	1.78	1.42	3.57	2.14	1.96	1.25
9	3.57	2.68	2.14	1.42	3.57	2.68	2.14	1.25
12	5.00	3.03	2.50	1.56	5.00	2.85	2.14	1.42
Ave.	3.89	2.51	2.09	1.46	3.89	2.50	1.91	1.38

Flavor of Viscolized Milk

Since most of the experimental work in this study was carried out on raw and pasteurized milk before and immediately after viscolization and of viscolized pasteurized milk in storage, any off flavors due to viscolization were not observed until later, when an off flavor in stored raw viscolized milk was called to our attention. Special work was, therefore, carried out on this phase of the subject. Results in Table XV show conclusively that viscolization of raw milk at 2500 pounds always developed a rancid flavor within two hours after viscolization. In some samples the rancidity developed much more rapidly than in others. However, at the end of six hours most of the viscolized milk was unfit for human consumption. The unviscolized check samples held at low temperature for five days developed a rancid flavor only in four of 27 trials.

Results of two samples of raw milk viscolized at different pressures indicate that the rancidity develops in proportion to the pressure used. However, at the end of 24 hours all of the raw viscolized samples were unfit for human consumption.

Viscolization of separated milk re-standardized to the original fat content indicates that the rancidity develops at the same rate as that of the same milk viscolized without separation. This is shown in Table XVI. Pasteurization of the milk at 145° F. for 30 minutes before viscolization prevents the development of rancid flavors. The results in Table XVI also show that viscolized skim milk does not develop rancidity. From this we might conclude that fat must be present before a rancid off flavor due to viscolization develops. Viscolization appears to have little, if any, effect upon the natural flavor of the pasteurized milk.

Table XVI. Effect of Viscolization at 2500 Pounds Pressure on the Flavor of Raw Milk

Herd No.	Raw Milk 2 hours	Raw Milk 5 days	Viscolized Milk 2 hours	Viscolized Milk 6 hours
13	-	-	**	***
51	-	*	**	***
24	-	* *	*	**
16	-	-	**	***
3	-	*	**	***
22	-	-	*	***
23	-	-	**	***
16	-	-	**	***
21	-	-	**	***
17	-	-	**	***
26	-	-	**	***
62	-	-	**	***
61	-	-	**	***
25	-	*	**	***
10	-	-	*	**
7	-	-	**	***
12	-	-	**	***
2	-	-	*	**
6	-	-	**	**
15	-	-	**	***
3	-	-	**	***
4	-	-	*	**
11	-	-	**	***
5	-	-	**	***
59	-	-	**	***
60	-	-	**	***
36	-	-	*	**

- no off flavor

* approximately 19 score on flavor

** approximately 13 score on flavor

*** approximately 0 score on flavor

Table XVI. Effect of Viscolization on the Flavor of Raw Whole Milk, Raw Skim Milk, Preheated Whole Milk, Pasteurized Whole Milk, and Raw Milk Standardized from Raw Cream and Raw Skim Milk.

Lot	Temperature of	2 hours				6 hours				24 hours			
		Pounds Pressure of Viscolization				Pounds Pressure of Viscolization				Pounds Pressure of Viscolization			
No.	Viscolization	0	500	1500	2500	0	500	1500	2500	0	500	1500	2500
12	Raw 90° F.	-	-	*	*	-	*	**	***	-	***	***	***
13	Raw 90° F.	-	-	*	*	-	*	**	**	-	***	***	***
12	Skim Milk 90° F.	-	-	-	-	-	-	-	-	-	-	-	-
13	Skim Milk 90° F.	-	-	-	-	-	-	-	-	-	-	-	-
12	Past. 145° F.	-	-	-	-	-	-	-	-	-	-	-	-
13	Preheated 145°F.	-	-	-	-	-	-	-	?	-	-	?	*
13	Standardized Raw Milk	-	-	*	*	-	*	**	**	-	***	***	***

- \- no off flavor
- * approximately 19 score milk
- ** approximately 13 score milk
- *** approximately 0 score milk

Curd Tension of Viscolized Milk

Although the study of the curd tension of viscolized milk was originally planned for the experiment, equipment was not available until most of the experimental work had been completed. Therefore, the data obtained are not sufficient to show definite conclusions. The results in Table XVII indicate that the curd tension of both raw and pasteurized milk is lowered in proportion to the pressure of viscolization. However, viscolization of the skim milk showed no change in curd tension.

The results in Table XVIII show the curd tension of raw unviscolized and viscolized milk from herds of different patrons who deliver milk to the College Creamery. All the milk was processed at 90° F. using 2500 pounds pressure. The average of 11 trials indicates that the curd tension was reduced approximately 40 per cent by viscolization at 2500 pounds pressure. Individual samples varied greatly, one sample showed no reduction while another showed a reduction of 62 per cent. However, it is interesting to note that the sample which showed no reduction was slightly sour, which may have had some effect upon the change in the curd tension.

Table XVII. Effect of Viscolization at Different Pressures on the Curd Tension of Raw, Pasteurized and Skim Milk.**

Temperature of Viscolization	Pounds Pressure of Viscolization				
	0	500	1500	2500	3500
Raw 90^{o} F.	37	27	23	12.5	7
Pasteurized 145^{o}F.		30	24		8
Skim 90^{o} F.	38	44	39	39	

** Readings expressed in grams.

Table XVIII. Effect of Viscolization at 2500 Pounds Pressure on the Curd Tension of Raw Milk from Different Herds.**

Herd No.	Unviscolized	Viscolized
13	50	26
51	51	16
24	50	50*
16	48	35
3	55	37
22	36	17
21	52	40
17	41	16
25	39	32
26	28	8
61	35	17
Ave.	45	26.7

* Sample sour to taste.

** Readings expressed in grams.

DISCUSSION

Viscolized milk does not form a cream layer providing the pressure of viscolization is 1500 pounds or higher. However, this applies only to the viscolizer used. Other machines of slightly different construction or perhaps machines of the same construction might be expected to give considerable different results. In milk viscolized at 1500 pounds pressure the globules were broken down to an average of about two microns in diameter while those at 500 pounds pressure were about 2.5 to 2.75 microns in diameter. From this it might be concluded that the pressure of viscolization must be sufficiently high to reduce the globules to an average diameter of two microns or smaller.

The reason viscolized milk does not cream is not clearly understood. Numerous instances are cited in the literature stating that the fat in viscolized milk is not clumped. In studying the size of the fat globules some clumping was observed. However, these clumps were small and few in number, each consisting of not more than 10 or 15 small globules. It is also known that no cream layer forms on viscolized cream although clumps of fat are always present. This would indicate that the small number of fat clumps would have no effect on creaming. The slight creaming on milk viscolized at 500 pounds is in all probabilities due to the rise of the larger fat globules, while in the milk viscolized at higher pressures the globules are so finely divided that they fail to rise by the force of gravity. The fact that the milk viscolized at the lower pressure continues to increase in creaming even after 24 hours indicates that these larger single fat globules, which rise very slowly, may account for this increase.

The consumer has in the past judged the richness of the milk by the volume of cream at the top of the milk bottle. Because of the absence of a cream layer on viscolized milk, many consumers have asserted that the fat standards were not observed by the dealers. Health laboratories in a few cases have found the fat in viscolized milk below the legal standards as shown by the Babcock fat test. The dealers have claimed that the fat globules are so finely divided that all the fat cannot be raised in the fat column of the Babcock test bottles. The results of this study indicate that the Babcock fat test is a reliable index to the fat content of viscolized milk. This study also shows that the average size of the fat globules viscolized at high pressures are between one and two microns in diameter. According to the Associates of Rogers (34) 32.8 per cent of the fat globules in normal milk are of less than two microns in diameter. While these small globules amount to less than two per cent of the total fat content, it follows that the majority of these small fat globules must be included in the fat column of the Babcock test or this test would vary considerably from that of the ether extract tests.

The average viscosity of raw viscolized milk appears to be increased by viscolization as the pressure increased although individual samples were irregularly affected. Pasteurization of the milk before viscolization lowered the viscosity in every case. The average shows a decrease as the pressure increases, but individual samples were also irregularly affected, although always lower than the pasteurized unviscolized samples. The increase in viscosity of raw milk may be accounted for by greater adsorption of the milk serum on the greatly increased fat surface. However, the low-

ering of the viscosity of viscolized pasteurized milk is rather difficult to explain, but it might be accounted for by the dehydrating effect of pasteurization on the milk protein. The average of the 11 samples shows a slight increase in viscosity of viscolized raw and pasteurized milk after aging for 24 hours. However, individual samples were affected irregularly. This increase in viscosity during aging may be due to either increased adsorption or hydration of the protein.

The titratable acidity of raw milk is always increased by viscolization, but pasteurized milk shows no such change. Preheating the milk to 145° F. before viscolization prohibited all acidity changes. Pasteurization of the raw milk after viscolization did not eliminate the acidity changes, although the titratable acidity of this milk during aging did not increase as it did in the viscolized raw milk. Viscolization of the raw skim milk did not increase the titratable acidity.

As the acidity increased a rancid flavor also appeared after a few hours in all the viscolized raw milk examined. However, no rancidity developed in viscolized raw skim milk or milk pasteurized before viscolization. Preheating the milk to 145° F. before viscolization retarded the rancidity development greatly.

Dorner and Widner (70) attributed the increase in titratable acidity and rancidity to a lipase. This agrees with the results of Nair (63) who determined the presence of lipase in milk by an increase of titratable acidity of a high butterfat cream preserved with sucrose. Pasteurization of the milk destroys the lipase enzyme. Therefore, it appears as though the lipase releases the fatty acids of the butterfat thereby not only increasing the titratable acidity but also causing a very rancid flavor to appear in the milk.

Viscolization of raw milk always lowered the surface tension, while milk pasteurized before viscolization, in general, increased the surface tension slightly. Aging the samples decreased the average surface tension in both pasteurized and unpasteurized samples. However, individual samples were irregularly affected with the exception of the raw milk viscolized at 1500 and 2500 pounds pressure. These were always lowered.

The lowering of the surface tension of viscolized raw milk and increasing of the surface tension on milk pasteurized prior to viscolization is difficult to explain. However, it appears that the release of fatty acids by the enzyme lipase would lower the surface tension in viscolized milk but this does not account for the fact that nine of the 12 trials show the lowest surface tension at 1500 pounds pressure. Increase of the surface tension of milk pasteurized before viscolization might be accounted for by the increased adsorption of the milk serum on the greatly increased fat surface, along with a dehydration of the protein. This would leave more free water which would increase the surface tension.

The foaming ability of the raw milk was always lowered by viscolization. Pasteurization of the milk before viscolization appeared to increase the foaming ability. In like manner viscolization decreased the surface tension of raw milk and increased the surface tension of pasteurized milk. However, the highest pressures used did not necessarily give the lowest foaming ability or lowest surface tension with raw milk. The average of 12 trials shows the lowest surface tension and lowest foaming to be at 1500 pounds pressure, although both were somewhat irregularly affected. The average for the pasteurized milk shows a gradual increase of both surface tension and foaming as the pressure increased.

The larger air cells in the raw viscolized milk may be accounted for by the lower surface tension of the film surrounding the air pockets. In like manner the lower surface tension does not permit the withdrawal of the film surrounding the air cell. This gives greater stability. In the milk pasteurized before viscolization the air cells are much smaller due to the higher surface tension, which tends to give the greatest curvature possible to the surrounding film. This greater stress on the film hastens the coalescence of the air cells by the withdrawal of the film. For this reason the foam falls rapidly.

As was expected, viscolization has no effect on the specific gravity of whole milk. Slight variations in the specific gravity may be accounted for by the incorporation of air or by minute changes in temperature.

The proteins of milk were always rendered less stable to 95 per cent alcohol by viscolization. As the pressure of viscolization increases the viscolized milk becomes as a rule less stable but its effect is far less marked in milk pasteurized prior to viscolization. Since the total area of the fat phase is increased greatly by viscolization, it is logical to conclude that more of the milk serum would be adsorbed upon the fat phase. It is well known that the addition of calcium salts decrease protein stability, whereas citrates and phosphates increase the stability. This is in accord with the suggestion of Tracy and Ruehe (65) who stated that the destabilizing effect of homogenization may be due to the adsorption of citrates and phosphates at the fat-serum interface. This leaves less of these salts in the serum proper. However, the increase in acidity due to viscolization of the raw milk may also change the relationship between the calcium salts and the citrates and phosphates. This may, in part, account

for the decreased stability of the raw viscolized milk. Since no acidity change occurred in the pasteurized milk, greater stability of the protein would be expected.

CONCLUSIONS

1. Pressure of viscolization must be at least 1500 pounds to prevent creaming.

2. The average size of the fat globules must be less than two microns in diameter to prevent creaming.

3. The Babcock test appears to be as reliable for determining the fat content of viscolized milk as of unviscolized milk.

4. The viscosity of raw milk viscolized at 90° F. appears to be increased as the pressure is increased.

5. Pasteurization of milk before viscolization at 145° F. always decreased the viscosity but not always in proportion to the pressure used.

6. Aging of viscolized milk appears to increase the viscosity.

7. Viscolization of milk at 90° F. always lowers the surface tension, while pasteurizing of milk before viscolizing at 145° F. appears to increase the surface tension.

8. There appears to be an inverse relationship between viscosity and surface tension.

9. Viscolization of raw milk at 90° F. always lowers the foaming ability, while pasteurization before viscolization at 145° F. appears to increase the foaming ability.

10. There seems to be a direct relationship between surface tension and foaming ability.

11. The titratable acidity of raw milk is always raised by viscolization. Pasteurizing the milk before viscolization shows no such change. The titratable acidity of raw milk is increased only if fat is present.

12. Viscolization of raw milk always causes a rancid flavor to appear within a few hours. This appears to be caused by a lipase.

13. The specific gravity of milk is not affected by viscolization.

14. The proteins of milk are always rendered less stable to alcohol by viscolization. As the pressure of viscolization increases the proteins as a rule become less stable but this effect is far less marked in the pasteurized milk.

15. The curd tension of both raw and pasteurized milk appears to be decreased in proportion to the viscolization pressure, if fat is present.

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