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THE EFFECT OF HOMOGENIZATION ON
CERTAIN CHARACTERISTICS OF MILK

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INTRODUCTION

During the past few years homogenized milk and cream have received considerable attention from research workers. The work of Hill (7, 8, 9),¹ Espe and Dye (5), and others on soft-curd milk and its relation to digestibility, together with the work of Washburn and Jones (18), Washburn (16, 17), and others showing the possibility of producing soft-curd milk with the homogenizer, is bringing homogenized milk to the attention of milk dealers as well as research workers. In addition to its soft-curd properties homogenized milk has other advantages. For example, Kelly (13) has shown that serving homogenized milk to school children insures that they are not deprived of a proportion of the butterfat which they are supposed to receive. That homogenized milk has commercial possibilities has already been demonstrated in sections of Canada, where some dealers homogenize the greater proportion of their market milk. The milk consumers of the United States have associated cream line with quality for so long that undoubtedly it will be many years before the practice of homogenizing market milk becomes general. It can be safely predicted, however, that the practice will gradually be extended.

¹ Italic numbers in parentheses refer to Literature Cited, p. 11.

Before entering the field of distributing homogenized milk there are several questions which the milk dealer will desire answered. The most important of these concern its palatability and appearance as compared with pasteurized milk.

PALATABILITY OF HOMOGENIZED MILK

Doan (1) states that several years ago 33 members of the winter dairy short course at Pennsylvania State College were asked to give their preference between two samples of milk. One sample was normal raw milk, and the other was prepared by homogenizing the same milk at 100° F. (38° C.). Of the 33 persons, 28 chose the homogenized milk, from which he concluded it would seem that homogenized milk is more palatable to most people than normal milk. A similar conclusion is reported by Irwin (12), who found that the consumption of milk increased notably in several of the State institutions in Pennsylvania when homogenized milk was substituted for normal milk. For example, at the Mount Alto Sanatorium for young people the per capita consumption rose from 1½ quarts to 2 quarts. Hudon (11) also states that the homogenization of milk has undoubtedly increased the per capita consumption of milk and milk products in the localities where it has been featured.

The results of experiments in the Bureau of Dairy Industry were not so decisively in favor of homogenization. In one experiment, pasteurized milk containing an average of 4.1 percent butterfat was homogenized under closely controlled conditions at 2,500 pounds pressure, at the pasteurizing temperature, 142° F. (61° C.), and compared with the same pasteurized milk which had not been homogenized. A total of 470 opinions were obtained on 470 samples of each of the milks. The following results were obtained: 178 opinions, or 37.9 percent, were in favor of the unhomogenized milk; 172 opinions, or 36.6 percent, were in favor of the homogenized milk; and 120 opinions, or 25.5 percent, showed no choice between the two samples. In other words, with milk of good flavor, properly homogenized, 62.1 percent of the opinions showed no prejudice against homogenized milk, and the preferences for homogenized milk and unhomogenized milk were practically equal.

HOMOGENIZATION AS A SOURCE OF ABNORMAL FLAVORS

IN RAW MILK

Dorner and Widmer (4) reported that homogenization caused raw milk and raw cream to become distinctly rancid after a few hours. The development of rancidity increased as the size of the fat globules diminished. This rancidity was caused by a lipase. Halloran and Trout (6) state that the titratable acidity of raw milk was always raised by viscolization. Along with the increase in acidity a rancid flavor always developed. Pasteurization of the milk before viscolization prevented both the rise in acidity and the development of rancid flavor. These changes appeared to be caused by a lipase. Therefore they concluded that raw milk cannot be viscolized for commercial purposes. Doan (2) used the increase in titratable acidity, together with pH and surface-tension data, in determining

critical preheating temperature for inhibiting rancidity in homogenized milk.

Experimental work in this Bureau indicates that there is an optimum homogenizing temperature for the development of a rancid flavor in raw homogenized milk. This temperature ranges from 30° to 40° C. (86° to 104° F.). Raw milk homogenized within this temperature range, although cooled and stored at a low temperature, became rancid within 18 hours after homogenization. Milk homogenized at temperatures ranging from 4.5° to 10° C. (40° to 50° F.), although remaining of good flavor for this length of time, developed an abnormal flavor upon further aging. Milk homogenized at 15° and 55° C. (59° and 131° F.) developed a slight rancid flavor; that homogenized at 20°, 25°, and 45° C. (68°, 77°, and 113° F.) had developed the rancid flavor at the end of 18 hours, but to a lesser degree than the milk homogenized within the optimum temperature range. The milk homogenized at 60° C. (140° F.) remained of normal flavor.

Further evidence that there is an optimum temperature for the development of a rancid flavor is shown by the time required for the flavor to develop in the milk after homogenization at different temperatures. In table 1, the plus (+) marks indicate the relative development of rancidity in milk homogenized at 3,000 pounds pressure, at different intervals of time after being homogenized.

TABLE 1.—Development of rancidity¹ in milk homogenized at 3,000 pounds pressure, at different intervals of time after homogenization

Homogenizing temperature		Relative rancidity of homogenized milk—					
		At 2 hours		At 3 hours		At 4 hours	
		Cooled	Uncooled	Cooled	Uncooled	Cooled	Uncooled
°C.	° F.						
20	68	—	+	+	++	++	++++
30	86	+	++	++	++++	++++	++++
40	104	+	++	++	++++	++++	++++
50	122	+	—	—	—	—	+

¹ Minus marks indicate no rancidity and plus marks indicate the relative development of rancidity.

The rancid flavor not only appeared sooner but was more intense when the milk was homogenized at 30° or 40° C. than at 20° or 50°.

As shown in table 1, cooling and storing the homogenized milk at a low temperature apparently retarded the development of the rancid flavor. However, the cooled samples showed the same degree of rancidity as the uncooled samples within 10 minutes after warming.

Varying the homogenizing pressure did not affect the development of the rancid flavor. However, if complete homogenization was not obtained, thereby permitting a partial separation of the cream, a greater length of time was required for the rancid flavor to develop and the flavor was less intense.

This work shows that homogenization cannot be applied to raw milk for commercial purposes. It also indicates that in handling raw milk care must be used not to subject it to any process or agita-

tion which might have an homogenizing effect, especially at temperatures within the optimum temperature range for causing a rancid flavor.

IN PASTEURIZED MILK

Pasteurized milk was homogenized through the same temperature range as was used in the experiments with raw milk. Upon aging, the pasteurized milk that had been homogenized at a temperature within the optimum range (30° to 40° C.) for the development of rancid flavor, developed what is best described as a slight oxidized flavor. The milk homogenized at temperatures outside the optimum range did not always develop a flavor which could be identified. At the lower temperatures, however, it frequently developed a slightly bitter flavor. The pasteurized milk homogenized at 60° C. (140° F.) remained of good flavor upon aging.

When milk was pasteurized immediately after being homogenized, no abnormal flavors due to homogenization developed upon aging, regardless of the homogenizing temperature. Likewise, when milk was pasteurized and then immediately homogenized at the pasteurizing temperature, no abnormal flavors developed upon aging.

In the preparation of homogenized milk for market purposes the milk may be either pasteurized and then immediately homogenized at or above the temperature at which it was pasteurized, or else pasteurized immediately after homogenization. From a sanitary standpoint, the better practice would be to place the homogenizer between the preheater and the pasteurizer, because the milk would come into contact with one less piece of apparatus after pasteurization. If this method is followed, care must be taken to prevent delay in the pasteurizing process. It is advisable to homogenize the milk at or above the pasteurizing temperature, regardless of whether the process of homogenization is performed before or after pasteurization, because the higher temperature of homogenization insures against abnormal flavors, and because at the lower temperatures difficulty is encountered in obtaining complete homogenization.

SEDIMENT IN HOMOGENIZED MILK

One of the objections to homogenized milk is that when the milk stands after bottling, a ring of sediment frequently forms on the bottom of the bottle. Trout and Halloran (14) state that this sediment appears to be very fine dirt, probably in a mixture with some milk solids; Doan and Minster (3) concur with Trout and Halloran by stating that the sediment is undoubtedly fine dirt, which is aggregated and caused to settle out by the action of the homogenizer. While the sediment has the general appearance of separator or clarifier slime, Trout and Halloran (15) state that—

Although the deposit from homogenized milk compared with clarifier slime in respect to the percentage of water and total solids, the percentage of fat was from two to three times higher than that in clarifier slime, while the solids-not-fat were considerably lower.

The writer was unable to identify the real character of the sediment in homogenized milk by microscopic examination. However, when slides of this sediment were prepared and stained by the Breed method, it was found to consist largely of leucocytes and epithelial cells (fig. 1).

MILK CONTAINING APPROXIMATELY 1,000,000 CELLS PER CUBIC CENTIMETER

To determine whether homogenization of milk permits the cells therein to settle out, cell counts of milk from different points in the bottle were made with both homogenized and unhomogenized milk at intervals over a period of 4 days. The samples were obtained by drawing 10 cc of milk from the top, middle, and bottom of each bottle with a 10-cc pipette. Table 2 shows the average cell counts at different depths in bottled homogenized and unhomogenized milk.

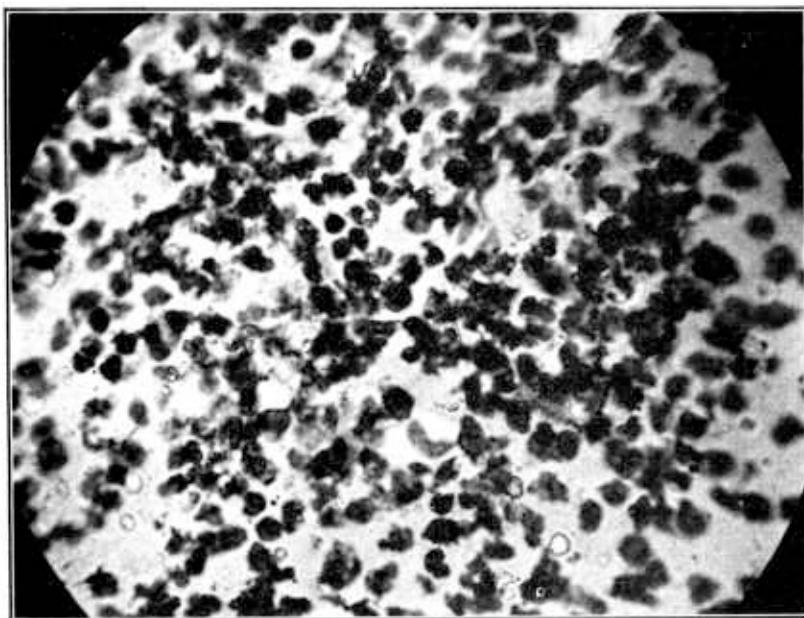


FIGURE 1.—Microscopic field showing leucocytes in the sediment from homogenized milk. (Microscopic factor 550,000.)

TABLE 2.—Average cell counts of pasteurized unhomogenized and homogenized milk at different points in the bottle

Character of milk and storage interval	Average cell count per cubic centimeter—		
	At top of bottle	At middle of bottle	At bottom of bottle
Pasteurized unhomogenized milk:			
At 3 hours.....	6,563,300	128,300	128,300
At 24 hours.....	8,818,300	119,200	91,700
At 48 hours.....	8,963,300	55,000	55,200
At 72 hours.....	9,725,800	64,200	42,500
At 96 hours.....	9,863,300	64,200	49,500
Pasteurized milk homogenized at 3,000 pounds pressure:			
At 3 hours.....	650,800	971,700	1,127,500
At 24 hours.....	467,500	800,800	2,640,000
At 48 hours.....	256,700	534,200	3,657,500
At 72 hours.....	155,800	485,800	5,105,800
At 96 hours.....	150,000	340,000	6,178,300

Table 2 shows that in unhomogenized milk the cells, to a large extent, are carried up with the fat globules and remain in the cream layer (figs. 2 and 3). In homogenized milk there is no rising of fat globules, so that the cells, which apparently have a higher specific gravity than milk, are released from the influence of rising fat globules and settle to the bottom of the bottle (figs. 3 and 4). The cells collecting on the bottom of the bottle appear as sediment in the milk.

There was no correlation between the homogenizing pressure and the formation of sediment. There was usually pronounced sediment at the end of 24 hours and the quantity was apparently the same, regardless of the homogenizing pressure. However, if the pressure was not sufficient to obtain complete homogenization, the sediment

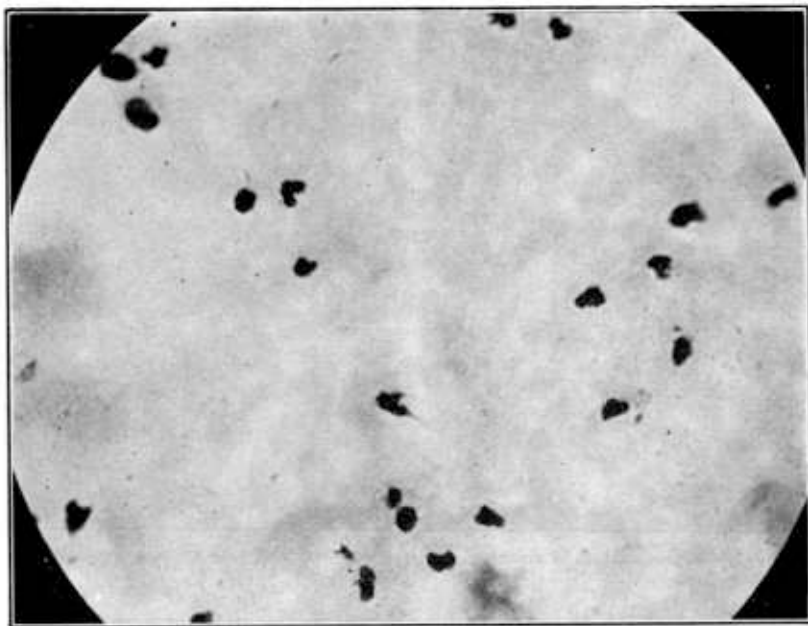


FIGURE 2.—Microscopic field showing leucocytes in the top or cream layer of unhomogenized milk. (Microscopic factor 550,000.)

in the bottled milk was less pronounced. This was due to the formation of a thin cream layer which contained a comparatively large number of cells.

MILK CONTAINING LESS THAN 100,000 CELLS PER CUBIC CENTIMETER

In order to substantiate the fact that the sediment in homogenized milk consists largely of leucocytes and epithelial cells, an experiment was conducted with milk having a low cell count, in the same manner as the preceding experiment. This milk was obtained by selecting cows giving milk with cell counts below 100,000 per cubic centimeter. The average cell count of the mixed milk used in this experiment was slightly below 90,000 per cubic centimeter. The milk was produced and handled in the same manner as the milk

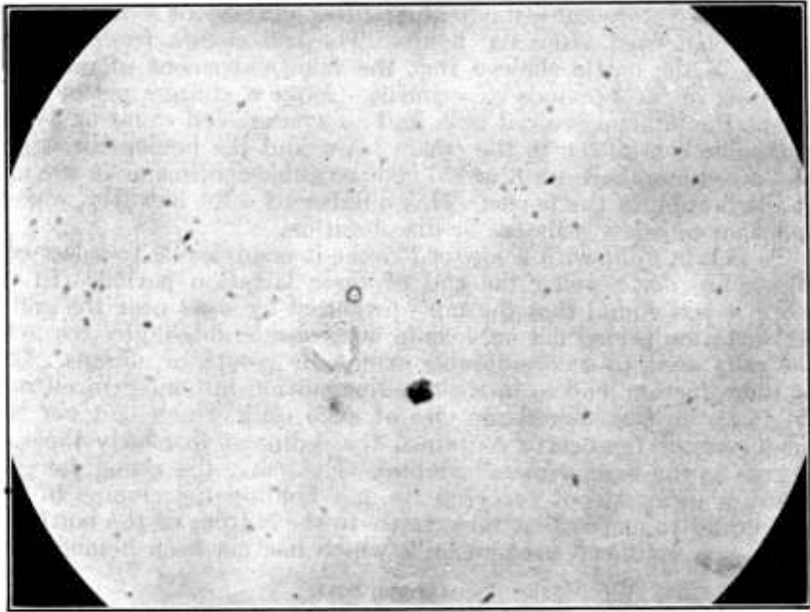


FIGURE 3.—Typical microscopic field from the middle of the hottles of both homogenized and unhomogenized milk; also the bottom of unhomogenized and the top of homogenized milk. Many fields contain no leucocytes. (Microscopic factor 550,000.)

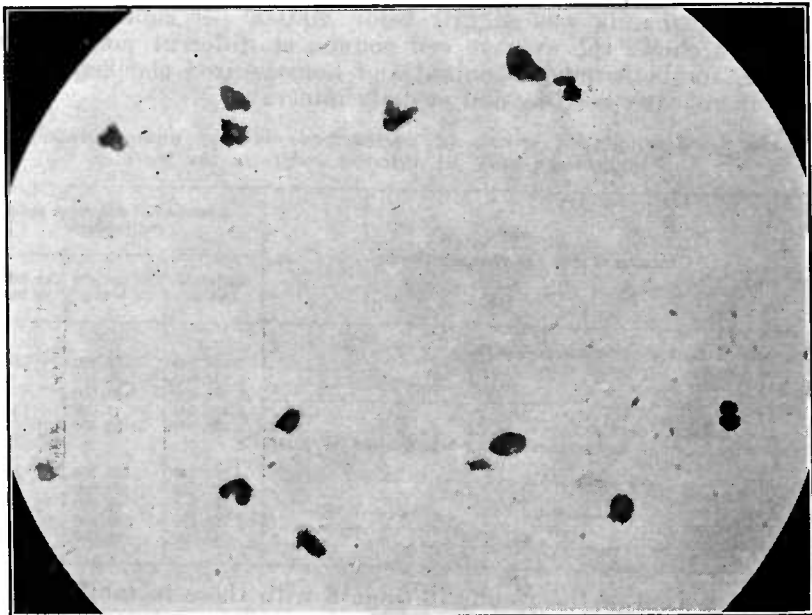


FIGURE 4.—Microscopic field showing leucocytes in the bottom of homogenized milk. (Microscopic factor 550,000.)

used in the previous experiment. When this milk was homogenized, bottled, and stored at a low temperature, no trace of sediment could be detected even after 120 hours. The cell counts from different points in the bottle showed that the same movement of cells took place as in the previous experiment. After a storage period of 96 hours, the unhomogenized milk had an average cell count of 348,300 per cubic centimeter in the cream layer and the homogenized milk had an average cell count of 337,500 per cubic centimeter in the milk at the bottom of the bottle. This number of cells, however, was not sufficient to cause sediment or discoloration.

To obtain milk with a low cell count it is advisable to select cows which are not nearing the end of their lactation period. In this work it was found that the milk produced by cows near the end of the lactation period not only contained considerable udder tissue but the cells were, to a considerable extent, in groups or clumps. Both of these factors tend to increase sedimentation in homogenized milk. In fact, the pasteurized samples of such milk which had not been homogenized frequently contained the sediment to nearly the same degree as the homogenized samples. Evidently the rising fat globules are incapable of carrying up and holding the clumps of cells and udder tissue, so that these settle to the bottom of the bottle and appear as sediment, even in milk which has not been homogenized.

CLARIFIED MILK

Inasmuch as the sediment in homogenized milk is formed mostly of cells, clarification of the milk should help to prevent its formation. Milk with a comparatively high cell count (above 1,500,000 per cubic centimeter) was clarified, otherwise the experiment was conducted in the same manner as described previously. The average cell count of the clarified milk was slightly below 200,000 per cubic centimeter. Table 3 shows the average cell counts, at different points in the bottle, for both unhomogenized and homogenized clarified milk, a few hours after bottling and at daily intervals.

TABLE 3.—Average cell counts of pasteurized clarified unhomogenized and homogenized milk, at different points in the bottle

Character of milk and storage interval	Average cell count per cubic centimeter—		
	At top of bottle	At middle of bottle	At bottom of bottle
Pasteurized clarified unhomogenized milk:			
At 3 hours.....	1, 410, 800	76, 600	137, 500
At 24 hours.....	1, 837, 000	49, 500	38, 000
At 48 hours.....	2, 068, 000	38, 500	44, 000
At 72 hours.....	2, 222, 000	44, 000	33, 000
At 96 hours.....	2, 568, 100	38, 500	38, 500
Pasteurized clarified homogenized milk, homogenized at 3,000 pounds pressure:			
At 3 hours.....	211, 750	201, 700	366, 700
At 24 hours.....	77, 000	121, 000	610, 500
At 48 hours.....	60, 500	88, 000	628, 500
At 72 hours.....	38, 500	99, 000	737, 000
At 96 hours.....	44, 000	88, 000	924, 000

Comparison of the results in table 3 with those in table 2 shows that in general the same movement of cells takes place in clarified milk as was found in the unclarified milk. Nevertheless, from a

practical standpoint, clarification prevents the formation of sediment in homogenized milk. However, a careful examination frequently disclosed a slight discoloration in the bottom of the bottle of clarified homogenized milk after it had stood for over 48 hours. When the aged milk was poured from the bottle without mixing, that clinging to the bottom of the bottle was also frequently of a grayish tint. This adhesion of cells on the bottom of the bottle probably accounts for the fact that the bottom portion of the homogenized milk had a lower cell count than the cream layer of the unhomogenized milk.

EFFECT OF HOMOGENIZATION ON THE BABCOCK TEST

In the experiments described herein the Babcock test was used in making butterfat determinations on the milk before and after homogenization. Halloran and Trout (6) state that viscolization appears to have no effect on either the Babcock test or the specific gravity of milk. The writer found that in every case the homogenized milk showed a slightly lower fat test than the same milk before being homogenized. The difference ranged from 0.05 to 0.15 percent, with an average of 0.1 percent. This is in agreement with Hollingsworth (19), who states:

Dealers have come to realize that a 3.6 percent butterfat pasteurized milk will not yield a 3.6 percent butterfat homogenized milk; that is, by actual Babcock fat test. The reason for the discrepancy is based on the fact that the fat globules are so finely divided that some of them, the more minute ones, cannot be raised with the fat column in the Babcock fat test bottle by the combined action of sulphuric acid and centrifugal force. Again, one must remember that under usual conditions, with ordinary milk, as much as one-tenth of 1 percent fat remains unseparated in the neck of the Babcock bottle. With homogenized milk this amount may be increased to as much as two- or three-tenths of 1 percent.

SPECIFIC GRAVITY OF HOMOGENIZED MILK

Williams and Leighton (19) have shown that the volume of an ice-cream mix may be increased by the incorporation of air during homogenization. The writer found that rarely was there sufficient air incorporated in milk by homogenization to affect its lactometer reading. However, by using a Westphal balance it was found that homogenization did incorporate sufficient air in milk to affect its specific gravity slightly. Table 4 shows the average decrease in specific gravity due to homogenization.

TABLE 4.—Average decrease in specific gravity of milk due to homogenization

Hours after homogenization (number)	Average decrease in specific gravity of—	
	Milk homogenized at 1,000 pounds	Milk homogenized at 3,000 pounds
1	0.00076	0.00085
24	.00042	.00045
48	.00031	.00041
72	.00023	.00038

Homogenization at 3,000 pounds pressure incorporated slightly more air in milk than homogenization at 1,000 pounds pressure. Apparently the air is not permanently incorporated, as the difference in the specific gravity of the homogenized and the unhomogenized milk became less upon aging, although it was stored in capped bottles.

The average difference in specific gravity of the milk before and after homogenization at 3,000 pounds, as shown by table 4, ranged from 0.00085 at 1 hour to 0.00038 at 72 hours. The greatest difference in specific gravity found in any one sample after homogenization at 3,000 pounds pressure was 0.0011 at 1 hour and 24 hours, 0.0007 at 48 hours, and 0.0006 at 72 hours. The average and extreme ranges, taken together, indicate that homogenization does not affect the specific gravity of milk to the extent of changing materially the percentage of total solids as calculated from the specific gravity.

SUMMARY AND CONCLUSIONS

Pasteurized homogenized milk is as palatable to the average consumer as is pasteurized milk.

Homogenization causes the development of rancidity in raw milk to such an extent that the process cannot be applied to raw milk for commercial purposes.

The optimum temperature of homogenization for the development of rancidity in raw milk ranges from 30° to 40° C. (86° to 104° F.).

In handling raw milk care should be taken not to subject it to any process or agitation which might have an homogenizing effect, especially at temperatures within the optimum temperature range for the development of rancidity.

In the preparation of homogenized milk for market purposes the milk should be homogenized immediately after being pasteurized, or pasteurized immediately after being homogenized.

Homogenization should be done at or above the pasteurizing temperature.

The sediment frequently found in homogenized milk consists largely of leucocytes and epithelial cells. In unhomogenized milk the cells are carried up with the rising fat globules and held in the cream layer. In homogenized milk these cells settle to the bottom.

To prevent sedimentation in homogenized milk the milk should be clarified before it is homogenized.

The Babcock test for butterfat does not give as high a fat reading for homogenized milk as it does for the same milk before homogenization.

Although the specific gravity of milk is lowered slightly by homogenization, this does not occur to such an extent that it affects materially the percentage of total solids as calculated from the specific gravity.

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