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The Effect of Different Pasteurization Temperatures on Several of the Physical Properties of Milk

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The Effect of Different Pasteurization Temperatures on Several of the Physical Properties of Milk

Wm. H. E. Reid

Abstract.—Increasing the temperature at which milk is pasteurized decreases the length of the cream column. The viscosity, specific gravity, and surface tension of the milk were not materially affected by the application of different pasteurizaton temperatures. As the temperature was increased the gravitation of the butterfat globules was retarded. Greater distortion of globules, when photographed, was apparent at the higher temperatures.

The object of this study was to determine the effect of different pasteurization temperatures on several of the physical properties of milk. The variation in length of the cream line of milk, specific gravity, viscosity, and surface tension was thought to be caused by the application of different pasteurization temperatures.

Pasteurization of milk has come to be generally recognized as the most important safeguard of the healthfulness of the milk supplies of the country.

The principle underlying the method of pasteurization has been recognized for several decades; however, the actual application of this principle has undergone numerous changes. These changes have reflected themselves, at times, on one or more of the physical properties of milk.

It is a known fact that there are factors which affect the creaming ability of milk. Inability to properly control the pasteurization causes a variation in ability of butterfat in milk to gravitate. Pasteurization, it is thought, also affects other properties of the milk.

The literature furnishes no researches treating specifically on this problem.

PROCEDURE

The milk used in this investigation was obtained from the University herd, and is representative of the four leading dairy breeds. The usual procedure of pasteurization of milk in the market milk department was followed except that different temperatures were used. The milk was weighed and then poured into the pasteurizing vat and a composite sample taken for a butterfat analysis. Before heating the milk to the desired temperature three gallons of the milk was removed from the pasteurizer to be used in studying the different properties of the raw milk. Subsequent to the pasteurization exposure, four gallons of the milk was cooled immediately to 40°F. (4.44°C.) to be used in making the different determinations.

Microphotographs were made of the raw and the pasteurized milk, immediately after the pasteurization process was completed. Two standardized sample bottles were filled with raw milk and two with pasteurized milk, one of each to be used in determining the specific gravity, surface tension, and viscosity. The remaining samples were held at 40°F. (4.44°C.) for 18 hours and the same determinations again made. A half-pint milk bottle was filled with raw milk previously colored with india ink, and another bottle filled with pasteurized milk similarly treated. These samples were held at 40°F. (4.44°C.) for 24 hours in an inverted position, and samples of skim milk obtained for use in making microscopic photographs. Microphotographs were made of the unpasteurized skim milk, cream, pasteurized skim milk, and pasteurized cream after aging for 24 hours at 40°F. (4.44°C.).

As a means of studying the effect of different pasteurization temperatures on the length of the cream line, ten calibrated-ML graduates were filled with raw milk previously colored with india ink. The pasteurized milk was treated and an equal number of graduates filled. The filled graduates were held for 24 hours at 40°F. (4.44°C.), photographed, and the length of the cream layer of each graduate measured. The object of using india ink was to facilitate reading the length of cream layer and in photographing the samples. Without the use of ink in the milk pasteurized at 150°F. (65.55°C.) the cream line was very indistinct.

After photographs were made of the graduates, and the cream layer read, microphotographs were made of the cream and skim milk.

The Improved McMichael Viscometer was used in determining the viscosity of all samples at a temperature of 68°F. (20°C.). The DuNouy apparatus was used in determining the surface tension, maintaining a constant temperature of 68°F. (20°C.), while the Westphal balance was used in determining the specific gravity of the samples at a constant temperature of 60°F. (15.55°C.).

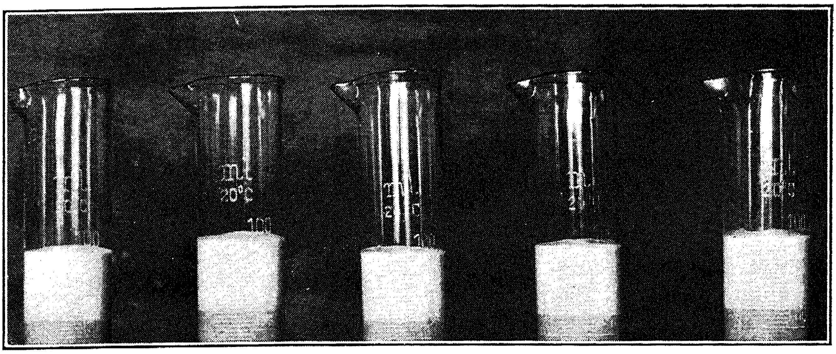
Figureo 1, 2, 3, and 4. (See opposite page)

Figure 1.—Raw Milk, Butterfat Content 3.60 Per Cent, Gravitation Period 24 Hours at 40°F. (4.44°C.).

Figure 2.—Milk Pasteurized at 140°F. (60°C.), Butterfat Content 3.60 Per Cent, Gravitation Period 24 Hours at 40°F. (4.44°C.).

Figure 3.—Milk Pasteurized at 145°F. (62.78°C.), Butterfat Content 3.60 Per Cent, Gravitation Period 24 Hours at 40°F. (4.44°C.).

Figure 4.—Milk Pasteurized at 155°F. (68.33°C.), Butterfat Content 3.60 Per Cent, Gravitation Period 24 Hours at 40°F. (4.44°C.).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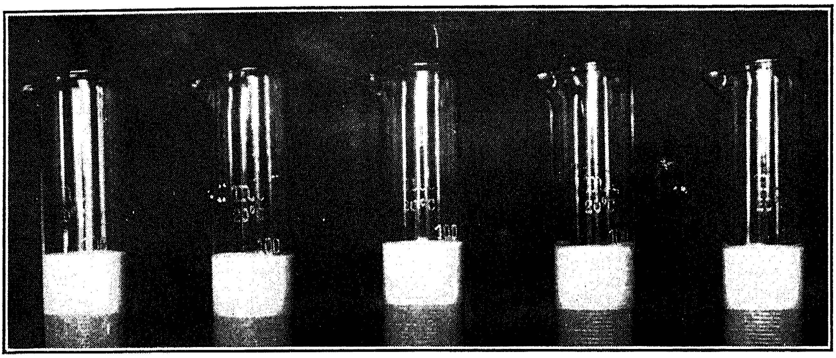
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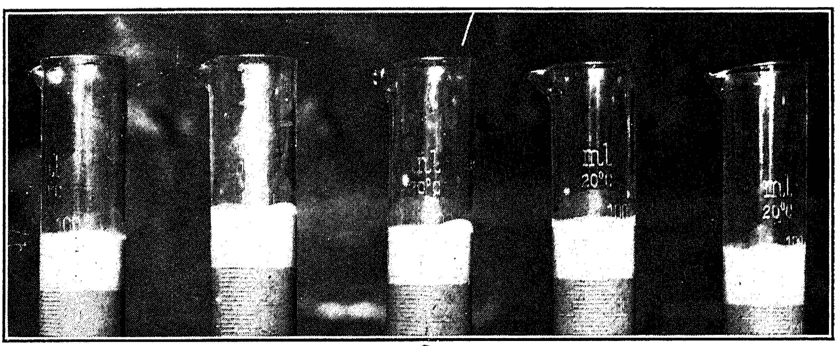
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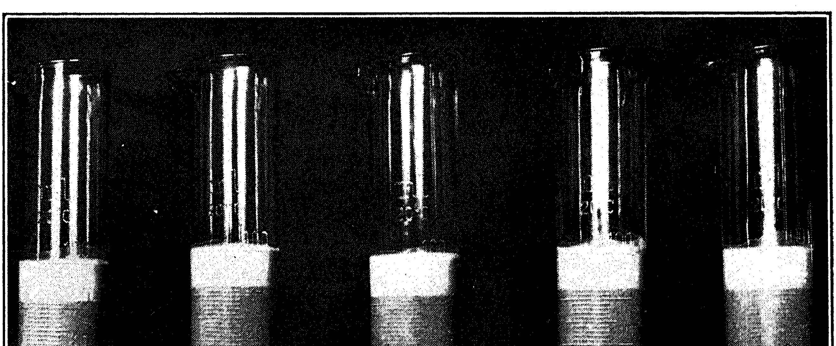

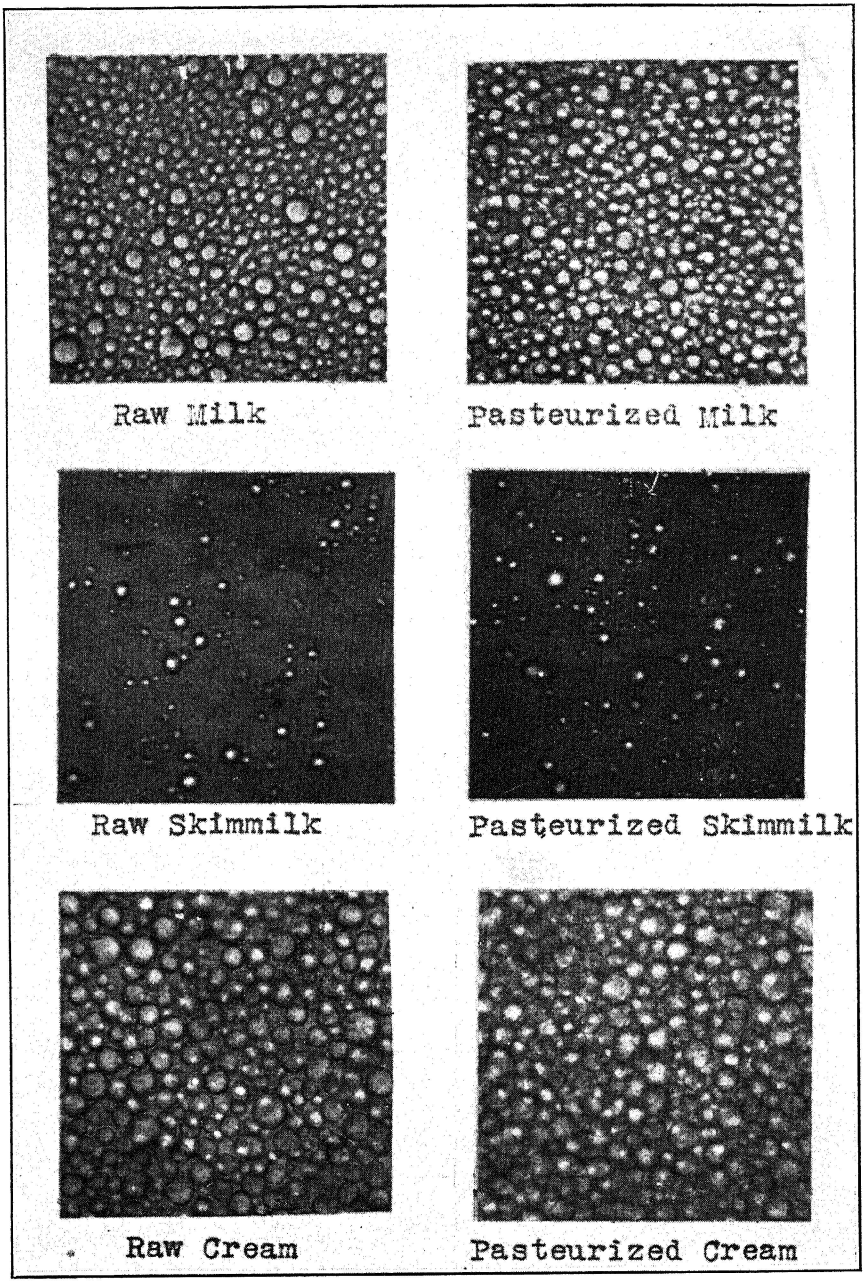

Figure 5.—Microphotographs of Whole Milk, Skimmilk, and Cream Before and Subsequent to Pasteurization at 140°F. (60°C.).

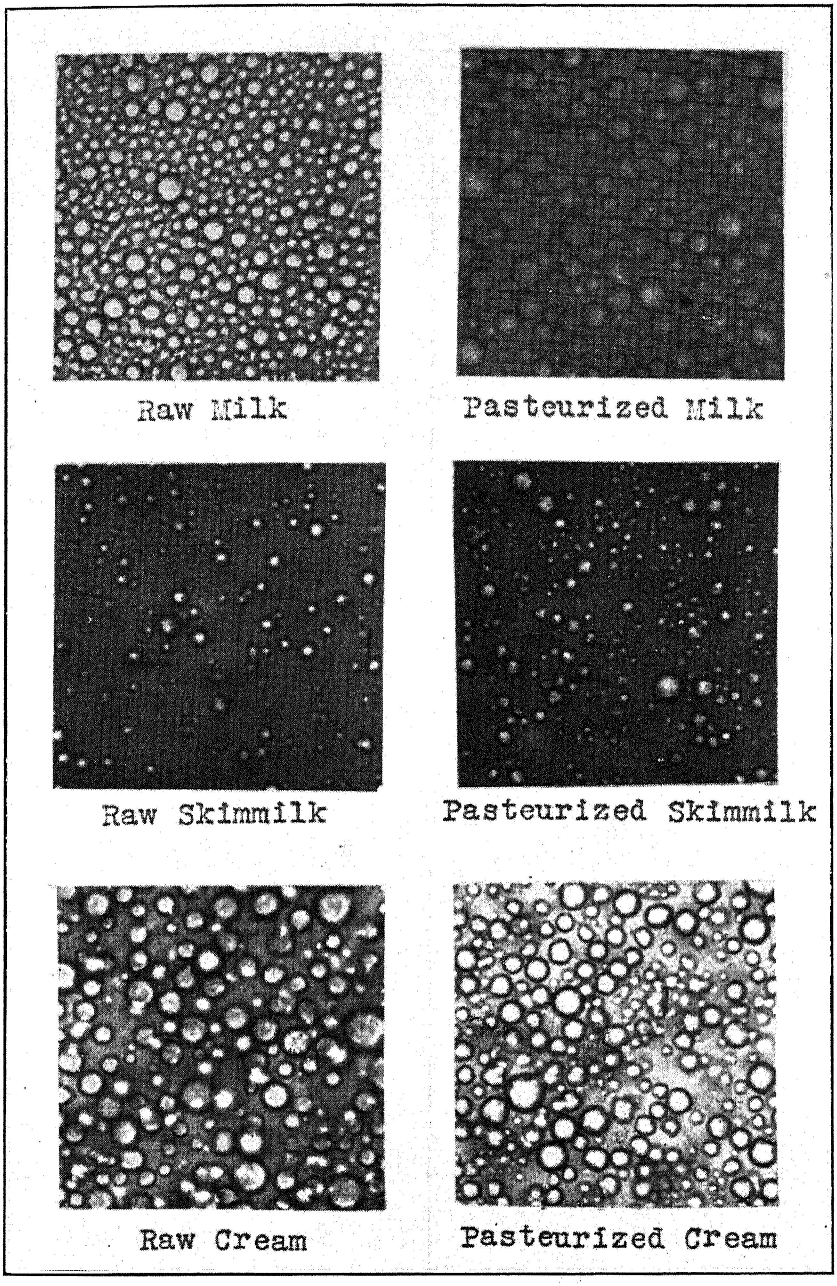

Figure 6.—Microphotographs of Whole Milk, Skimmilk and Cream Before and Subsequent to Pasteurization at 145°F. (62.78°C.).

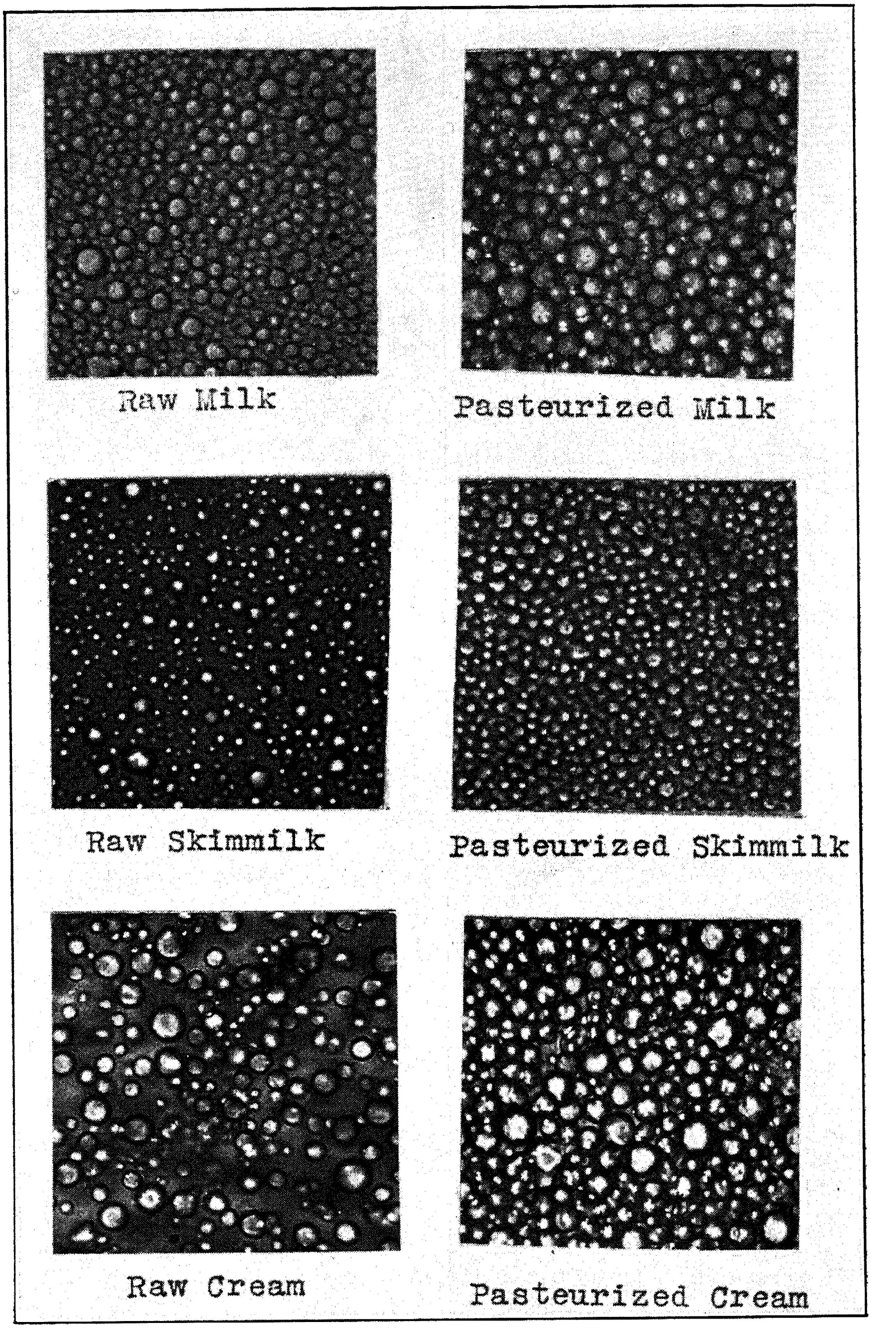

Figure 7.—Microphotographs of Whole Milk, Skimmilk, and Cream Before and Subsequent to Pasteurization at 155°F. (68.33°C.).

EXPERIMENTAL DATA

TABLE 1.—THE EFFECT OF DIFFERENT PASTEURIZATION TEMPERATURES ON THE LENGTH OF CREAM COLUMN*

Pasteurization Temperatures	Kind of Milk	Average of Ten Readings	Decrease in Cubic Centimeters	Cream Column Per cent
140°F. (60°C.)	Unpasteurized Pasteurized	16.15 15.39	.76	4.71
142°F. (61.11°C.)	Unpasteurized Pasteurized	16.20 15.08	1.12	6.92
145°F. (63.78°C.)	Unpasteurized Pasteurized	16.13 14.50	1.63	10.11
150°F. (65.55°C.)	Unpasteurized Pasteurized	15.50 10.00	5.00	32.25
155°F. (68.33°C.)	Unpasteurized Pasteurized	15.50 6.00	9.50	61.29

*Expressed in Cubic Centimeters after aging samples 24 hours at 40°F. (4.44°C.).

Pasteurization of milk at increased temperatures decreased the length of the cream column. The data, Table 1, showed a decrease in the cream layer with each increase of the pasteurization temperature. Heating milk to a temperature exceeding 145°F. (62.78°C.), caused a rapid recession in the cream layer; the greatest decrease occurring when the milk was pasteurized at 155°F. (68.33°C.). Figures 1 to 4 inclusive reveal the slight decrease in the length of the cream layer when milk is pasteurized at 140°F. (60°C.), the length of the cream column markedly decreasing as the temperature was increased to include 155°F. (68.33°C.).

TABLE 2.—THE EFFECT OF DIFFERENT PASTEURIZATION TEMPERATURES ON THE VISCOSITY OF MILK*

Pasteurization Temperatures	Original Milk		Aged 24 Hours at 40°F. (4.44°C.)	
	Unpasteurized	Pasteurized	Unpasteurized	Pasteurized
140°F. (60°C.)	39.0	37.5	47.0	42.5
142°F. (61.11°C.)	38.5	35.0	40.5	40.0
145°F. (62.78°C.)	42.0	37.0	40.5	41.5
150°F. (65.55°C.)	41.0	40.0	41.5	42.5
155°F. (68.33°C.)	40.0	39.0	42.0	39.5

*Readings expressed in Centipoises.

That increased pasteurization temperatures affect the viscosity of milk is shown in Table 2. The viscosity was decreased when the temperature was increased to 145°F. (62.78°C.) reaching a maximum decrease of five Centipoises. Higher temperatures had no marked effect on the viscosity, the decrease being less than when milk was pasteurized at the lowest temperature. When the samples were aged for 24 hours at 40°F. (4.44°C.) there was no uniformity in the viscosity readings of the unpasteurized and pasteurized samples.

TABLE 3.—THE EFFECT OF DIFFERENT PASTEURIZATION TEMPERATURES ON THE SPECIFIC GRAVITY OF MILK

Pasteurization Temperatures	Original Milk		Aged 24 Hours at 40°F. (4.44°C.)	
	Unpasteurized	Pasteurized	Unpasteurized	Pasteurized
140°F. (60°C.)	1.0299	1.0318	1.0278	1.0311
142°F. (61.11°C.)	1.0295	1.0309	1.0312	1.0316
145°F. (62.78°C.)	1.033	1.0328	1.0312	1.0326
150°F. (65.55°C.)	1.0313	1.0316	1.0321	1.0332
155°F. (68.33°C.)	1.032	1.031	1.0314	1.0323

Pasteurization of milk at different temperatures did not materially affect the specific gravity of the milk. Table 3 shows that with each increase in the pasteurization temperature the specific gravity of the respective samples was slightly increased. However, the increase was so small as to be considered negligible. Aging the samples for 24 hours at 40°F. (4.44°C.) caused no marked change in the specific gravity to become apparent, although there was a slight tendency toward a general increase in the specific gravity as the pasteurization temperatures were increased.

TABLE 4.—THE EFFECT OF DIFFERENT PASTEURIZATION TEMPERATURES ON THE SURFACE TENSION OF MILK*

Pasteurization Temperatures	Original Milk		Aged 24 Hours at 40°F. (4.44°C.)	
	Unpasteurized	Pasteurized	Unpasteurized	Pasteurized
140°F. (60°C.)	68.0	69.0	70.0	71.0
142°F. (61.11°C.)	71.5	72.0	71.5	73.0
145°F. (62.78°C.)	72.0	72.0	71.5	72.0
150°F. (65.55°C.)	72.5	73.0	71.5	72.5
155°F. (68.33°C.)	72.5	72.0	72.0	72.0

*Readings expressed in Dynes.

The surface tension of milk was not affected by pasteurizing milk at different temperatures as shown by Table 4. Even when aged for 24 hours at 40°F. (4.44°C.) there was no change in the surface tension of the different samples of milk.

MICROPHOTOGRAPHS OF WHOLE MILK, SKIM MILK, AND CREAM BEFORE AND SUBSEQUENT TO PASTEURIZATION

The microphotographs, Figures 5 to 7 inclusive, of whole milk, skim milk, and cream before and subsequent to pasteurization at different temperatures serve to show the effect of the process on the butterfat globules contained in the several samples of milk. In milk pasteurized at 140°F. (60°C.), the butterfat globules showed by their slightly distorted appearance and uneven circumferences that the process does alter the physical appearance of the globules. At that low pasteurization temperature there is very little tendency for the globules not to gravitate to form a cream line. Figure 5 indicated by the small number of butterfat globules appearing in the pasteurized skim milk that when the butterfat was concentrated in the cream column the irregularity of the circumference and distortion of the globules was quite apparent.

The distortion and unevenness of the circumference of the butterfat globules was somewhat greater when the milk was pasteurized at 145°F. (62.78°C.), than at the lower temperature. The number of butterfat globules in the pasteurized skim milk, Figure 6, indicated that an increase in temperature retards the gravitation of butterfat globules.

A pasteurization temperature of 155°F. (68.33°C.) caused many of the butterfat globules to form in small clumps. A larger number of globules were markedly distorted and had uneven circumferences than when lower temperatures were used, Figure 7. The pasteurized skim milk contained a large number of small fat globules and shows that the gravitation of the fat globules was decidedly retarded.

DISCUSSION OF EXPERIMENTAL DATA

The pasteurization of milk at different temperatures caused a decrease in the length of the cream column. The decrease in the cream column when milk was pasteurized at 140°F. (60°C.) and 142°F. (61.11°C.) was negligible and was thought to be due to a slight disintegration of the groups of fat globules caused primarly by the temperature to which the milk was heated and the agitation to which the milk is exposed during the pasteurizing process. When milk was pasteurized at 145°F. (62.78°C.), the decrease in the length of the cream column was 10.11 per cent, Table 1, and considered quite discernable to the average consumer of milk and to be the maximum decrease that should be tolerated. Should a close comparison be made of the cream column of milk unpasteurized and milk pasteurized at 145°F. (62.78°C.), a very slight decrease could be observed. Heating the milk to 150°F. (65.55°C.) for pasteurization purposes caused the cream column to diminish 32.25 per cent. This decrease becomes even more marked by pasteurizing the milk at 155°F. (68.33°C.) and was equal to 61.29 per cent, or more than half the length of the cream column of the original unpasteurized milk.

In milk pasteurized at a temperature exceeding 145°F. (62.78°C.) there was a greater tendency for the groups of butterfat globules to disintegrate, and upon being cooled the viscosity of the milk increased markedly thereby offering greater resistance to the gravitation of the small butterfat globules. The result was that the globules that were unable to overcome this resistance were retained in the serum and unable to gravitate to form a cream column. Even on long standing many of the smaller globules were unable to rise in the serum.

Different pasteurization temperatures did not affect the viscosity of milk to any great extent. The slight difference that did occur was due to the breaking up of the fat clumps which had a tendency to decrease the viscosity.

The specific gravity of milk is increased by solids-not-fat and decreased by fat. This is because the solids-not-fat are relatively heavier. The difference in specific gravity of milk heated to different pasteurization temperatures was considered to be negligible however, the slight change that did occur although not considerably important, was thought to be due to the different pasteurization temperatures used. The same was true in respect to the small differences occurring in the surface tension determinations.

That different pasteurization temperatures did affect the physical arrangement of the butterfat globules was evidenced by the number of globules appearing in the photographs of samples of skim milk. As the pasteurization temperature was increased the number of fat globules present in the skim milk markedly increased as a result of a disintegration of the fat clumps. The globules tended to dissociate themselves in the milk serum and when present as individuals were unable to gravitate to form a cream layer. This was particularly true of the smaller globules, as they were unable to overcome the resistance to which they were subjected by the serum. The unevenness of the circumferences and the distortion of some of the butterfat globules, particularly those in the milk pasteurized at the higher temperatures, was perhaps caused by agitation created during the process.

CONCLUSIONS

The pasteurization of milk at temperatures exceeding 145°F. (62.78°C.) causes a decided diminution of the cream column in milk which reflects unfavorably upon pasteurized milk.

Different pasteurization temperatures have a negligible effect on the viscosity, specific gravity and surface tension of milk.

Pasteurization of milk at temperatures exceeding 145°F. (62.78°C.) dissembles the groups of butterfat globules, thereby retarding their gravitation and causing a larger number of the globules to be suspended in the serum.