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Effect of Several Ingredients Used in the
Manufacture of Commercial Ice Cream
on the Change in Temperature Dur-
ing the Freezing Process

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Effect of Several Ingredients Used in the Manufacture of Commercial Ice Cream on the Change in Temperature Dur- ing the Freezing Process

WM. H. E. REID AND D. H. NELSON

ABSTRACT.—The several ingredients utilized in preparation of an ice cream mixture cause changes in the temperature during the freezing process. An increase in the milk solids gives an increase in the viscosity, titrable acidity, lowers the freezing point, increases time required to freeze the mixture, and lengthens the rate of melting of the frozen mixture.

In the manufacture of ice cream, two obvious changes take place in the ice cream mixture: first, a change in physical nature; and second, a change in temperature. It is generally known that the finished cream tends to be coarse-grained and weak-bodied when the change in temperature is rapid and when the formation of the ice crystals is slow. Change in temperature is therefore one of the most important factors in controlling the physical nature of the finished product.

Zoller¹ studied the freezing process of various ice cream mixtures and ices. He found that: (1) The freezing point lowering was three to five times greater than the theoretical molecular lowering and attributed it to a supercooling phenomenon. (2) There was no direct relation between the temperature of the brine and the amount of supercooling. (3) The crystallization point, or point of ice separation, was not sufficiently sharp for different mixtures to be termed a physical constant. (4) There was a typical L shape to the freezing curve. Zoller² also gives evidence that supercooling can be reduced by the addition of 0.5 per cent gelatine, fine sand, or lactose crystals. He attributes this reduction in supercooling to the rapid separation of ice crystals in a finely divided state by preventing convection—thereby giving more smoothness and a better texture to the finished ice cream. He also found that any substance which would tend to increase the viscosity of the mixture tended to retard supercooling.

Manhart³ studied the relation of various gelatines on viscosity. He found that the increase in viscosity was directly proportional to the

¹Zoller, H. F., The Separation of Ice Crystals in the Freezing of Ice Cream, *Ice Cream Trade Journal* 17, No. 9, pp. 45-47, 1921.

²Zoller, H. F., Separation of Ice in Freezing Ice Cream Mixtures, *Ice Cream Trade Journal* 17, No. 10, pp. 50-52.

³Manhart, V. H., Relative Influence of Three Gelatines upon Viscosity of Ice Cream, *Ice Cream Review* 6, No. 12, p. 8.

jelling power of the gelatine and that the stability or resistance to melting of the finished ice cream was proportional to the jelling power of gelatine used in the mixture.

RESULTS OF INVESTIGATION

The present study was made with the hope of correlating the various phases of the freezing process with the various commercial tests on the ice cream mixture. The relation of the serum solids in the mixture to the change in temperature during the freezing process was first studied. A standard set of mixtures was used in which all ingredients remained constant except the milk solids not fat, and these were used in the following amounts: 6, 10, 12, 14, and 18 per cent, these being the minimum, average, and maximum amounts used in the commercial manufacture of ice cream. To determine whether the source of the milk solids not fat had any effect on the change in temperature during freezing, the following products were used as the only source of the milk solids not fat: evaporated milk, skimmed milk powder, whole milk powder, and sweetened condensed milk.

The mixtures were prepared in 1000-gram batches, carefully standardized to 0.15 per cent gelatine, 12 per cent sugar, 10 per cent fat, and 6, 10, 12, 14, or 18 per cent milk solids not fat. It was found that 0.15 per cent of the quality gelatine used gave the same results as 0.5 per cent of the average gelatine used in commercial practice. The mixtures were then aged for 24 hours, tested for acidity and viscosity, and frozen.

The Nafis acidity test was used to determine the acidity of each mixture. The viscosity was determined by the rate of flow through a capillary tube under constant pressure and at constant temperature as compared to that of distilled water, the latter taken as unity. The freezing process was carried out in a modification of the Hortvet Cryoscope. In using the Cryoscope, great care was taken to have the depth and temperature of the ether bath constant at all times, as this greatly affected the slope of the freezing curve. Arrangements were made to insure a constant and uniform stirring of the mixture while being frozen. It is believed that this procedure made the freezing process similar to that in a commercial freezer and that the results obtained would be as comparable as if obtained in commercial work. Beckmann thermometers were used and the temperatures read accurately to the nearest hundredth of a degree. No ice crystals or other material was inserted (as called for in directions for using Hortvet Cryoscope for freezing point determinations) to hasten crystallization, because it was desired to observe supercooling as it occurs in the ice cream freezer. In each case,

the time was noted when the mixture reached a temperature of -21°C . and records made of the length of time required to reach the crystallization point and freezing point. This time was taken by a stop watch and recorded in fifths of seconds.

In the first series of mixtures, skimmed milk powder was used as a source of milk solids not fat and the only variant in these mixtures was the content milk solids not fat. After aging for 24 hours, the mixtures were tested for acidity and viscosity with the results shown in Table 1.

TABLE 1.—THE ACIDITY AND VISCOSITY OF THE SKIMMED MILK POWDER MIXTURES

% Milk solids not fat	% Acidity	Viscosity
6	0.09	1.33
10	0.19	1.62
12	0.24	1.81
14	0.29	2.09
18	0.38	2.73

These data show that the titratable acidity increases 0.025 per cent for each one per cent increase in the milk-solids-not-fat content of the mixture. No exact relation was found between the milk-solids-not-fat content and the viscosity of the mixture.

Several freezings were then made of each mixture and the results averaged. Table 2 gives the freezing data on these mixtures.

TABLE 2.—FREEZING DATA ON THE SKIMMED MILK POWDER MIXTURES
(Temperatures in degrees Centigrade.)

% Milk solids not fat	Temp. at beginning	Temp. $1\frac{1}{2}$ min. later	Time required to reach crystallization point		Time required to reach freezing point		Crystallization point	Freezing point
			<i>min.</i>	<i>sec.</i>	<i>min.</i>	<i>sec.</i>		
6	-21	-2.237	2	31	3	21	-3.024	-1.412
10	-21	-1.390	5	33	6	43	-3.650	-1.810
12	-21	-1.730	7	4	8	5	-4.120	-2.210
14	-21	-1.300	4	22	5	17	-3.400	-2.500
18	-21	-1.740	7	4	7	40	-4.330	-3.000

The mixtures in the second series were made exactly the same as those in the first series except that whole milk powder was substituted for skimmed milk powder as a source of milk solids not fat. These mix-

tures were treated exactly as those of the first series and the results are given in Tables 3 and 4.

TABLE 3.—THE VISCOSITY AND ACIDITY OF THE WHOLE MILK POWDER MIXTURES

% Milk solids not fat	% Acidity	Viscosity
6	0.140	2.05
10	0.175	2.02
12	0.240	2.30
14	0.275	2.53
18	0.380	5.74

TABLE 4.—FREEZING DATA ON THE WHOLE MILK POWDER MIXTURES
(Temperatures in degrees Centigrade.)

% Milk solids not fat	Temp. at beginning	Temp. 1½ min. later	Time required to reach crystallization point		Time required to reach freezing point		Crystallization point	Freezing point
			min.	sec.	min.	sec.		
6	-.21	-1.50	2	10	2	23	-1.57	-1.56
10	-.21	-1.67	3	38	4	18	-2.95	-1.83
12	-.21	-1.68	5	51	6	35	-3.48	-2.20
14	-.21	-1.77	5	33	6	26	-4.20	-2.53
18	-.21	-2.08	6	16	7	19	-4.54	-3.19

The mixtures of a third series were made exactly like the first two series except that plain evaporated milk was substituted as a source of the milk solids not fat. These mixtures were treated in exactly the same manner as those of the other series. Tables 5 and 6 give the results obtained.

TABLE 5.—THE VISCOSITY AND ACIDITY OF THE EVAPORATED MILK MIXTURES

% Milk solids not fat	% Acidity	Viscosity
6	0.15	1.59
10	0.27	2.06
12	0.30	3.23
14	0.42	3.02

In addition to these three series of mixtures were two additional mixtures made up and treated in the same manner. The first was a water ice having the same composition as the mixtures in the first three series except it contained no milk solids not fat. The second was a milk sherbet

which had the same composition as the previous mixtures except that the milk-solids-not-fat content was 4 per cent and that fresh sweet milk served as a source of the milk solids not fat. No milk powder or condensed milk was used in making either of these mixtures. Tables 7 and 8 give the results obtained.

TABLE 6.—FREEZING DATA ON THE EVAPORATED MILK MIXTURES
(Temperatures in degrees Centigrade.)

% Milk solids not fat	Temp. at beginning	Temp. 1½ min. later	Time required to reach crystallization point		Time required to reach freezing point		Crystallization point	Freezing point
			min.	sec.	min.	sec.		
6	-.21	-1.68	4	49	5	42	-3.46	-1.54
10	-.21	-1.57	8	0	9	8	-4.01	-2.04
12	-.21	-2.30	6	6	7	6	-3.82	-2.21
14	-.21	-1.78	7	4	8	3	-4.37	-2.56

TABLE 7.—THE VISCOSITY AND ACIDITY OF WATER ICE AND MILK SHERBET

% Milk solids not fat	% Acidity	Viscosity
Water ice.....	0.01	1.23
4 (sherbet).....	0.105	1.46

TABLE 8.—FREEZING DATA ON WATER ICE AND MILK SHERBET
(Temperatures in degrees Centigrade.)

% Milk solids not fat	Temp. at beginning	Temp. 1½ min. later	Time required to reach crystallization point		Time required to reach freezing point		Crystallization point	Freezing point
			min.	sec.	min.	sec.		
Water ice...	-.21	-----	0	49	1	46	-1.245	-0.857
4 (sherbet)...	-.21	-1.455	2	28	3	21	-2.910	-0.925

Figure 1 brings together in groups the freezing curves of the mixtures having the same composition and shows the effect of the source of the milk solids not fat. There is a wide but inconsistent variation in the freezing curves due to the source of the milk solids not fat.

In addition to the work previously noted each freezing of a mixture was placed in a constant-temperature brine bath and melted. This

melting process required a period of not more than 10 minutes. The brine bath was held at a constant temperature of 0° C. The test tube containing the sample of frozen mixture was removed from the Hortvet Cryoscope and inserted into the brine bath, the time and temperature being immediately recorded. The sample of frozen mixture was stirred constantly and uniformly during the melting process, and the temperature recorded every ten seconds.

Figures 2, 3, 4, and 5 show the melting curves of the three series of ice cream mixtures, the water ice, and the milk sherbet. Although the slope of these curves does not change directly with the change in the milk-solids-not-fat content of the mixture, they appear to follow along a straight line as the milk-solids-not-fat content is increased. The melting curves of the mixtures containing 6 per cent milk solids not fat have a fairly uniform shape, being quite flat for a considerable time and then rising very rapidly toward the end of the melting period. As the milk solids not fat are increased the flat portion of the curve is shorter and the rise is much more rapid. Therefore, it would almost appear that an increase in milk-solids-not-fat content would increase the ability to absorb heat units. This phenomenon does not seem coherent with the fact that an increase in milk solids not fat retards the liberation of heat units which is indicated by the freezing curves.

SUMMARY

1. An increase in the milk solids not fat produces an increase in the viscosity which is due to an increase in the concentration of the mixture and should be expected. See figure 6.
2. An increase in the milk solids not fat produces an increase in the titratable acidity. See figure 6. This should also be expected, due to the buffer action of the serum solids.
3. There is no exact relation between acidity and viscosity. See figure 6. Combs and Martin⁴ have also studied the relation of viscosity to acidity and found no definite relation.
4. An increase in the milk solids not fat lowers the freezing point. See figure 7. This is in accord with Zoller's results.
5. The amount of supercooling below the freezing point is not affected by the acidity, viscosity, or milk-solids-not-fat content of the mixture. See figure 8.
6. There is a definite lowering of the crystallization point. See figure 7. This should be expected with a lowering of the freezing point.

⁴Combs, W. B., and Martin, W. H., How Acidity Affects the Quality of the Mix, *Ice Cream Trade Journal* 19, No. 11, pp. 75-76.

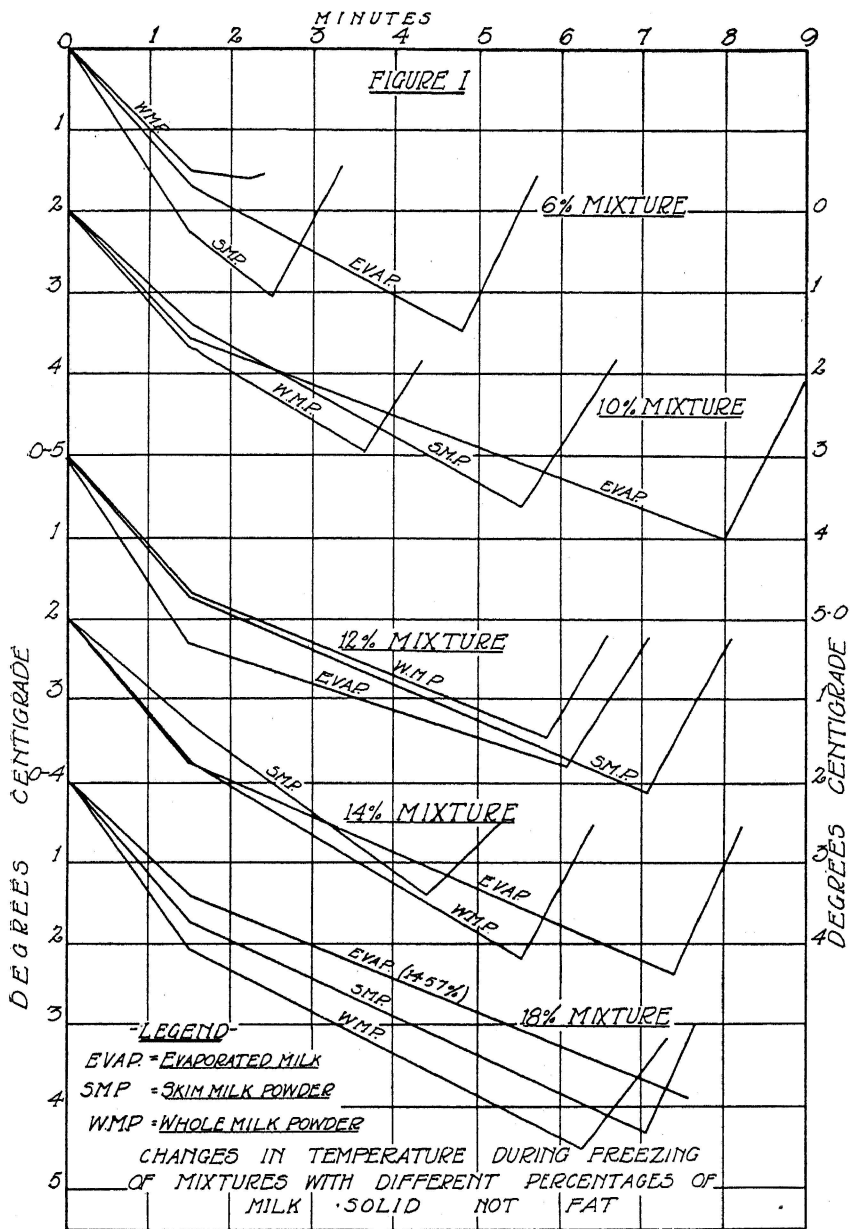


Fig. 1.—Changes in Temperature During Freezing of Mixtures With Different Percentages of Milk Solids Not Fat.

This does not agree with Zoller's statement that any substance which increases viscosity reduces supercooling.

7. The time required to freeze is increased by an increase in milk-solids-not-fat content. See figure 8. This data does not indicate whether the increase in time required to reach the freezing point is due to the increase in viscosity, the increase in acidity, the effect of low heat conductivity of serum solids, or to a combination of all.

8. The rate of melting of the frozen mixture increases with an increase in the milk-solids-not-fat content. This does not necessarily mean that ice cream containing a high percentage of milk solids not fat would be less stable than one with low percentage of milk solids not fat, but that the temperature would rise more rapidly. An increase in the milk solids not fat content increases the viscosity of the mixture, the stability of the finished ice cream, and the ability of the ice cream rapidly to absorb heat units.

The freezing curves presented do not have the typical L shape of the curves presented by Zoller. This variation is probably due to the difference in the amount of agitation during the freezing process. Physical agitation tends to coax crystallization, therefore, the greater the agitation the smaller would be the amount of supercooling.

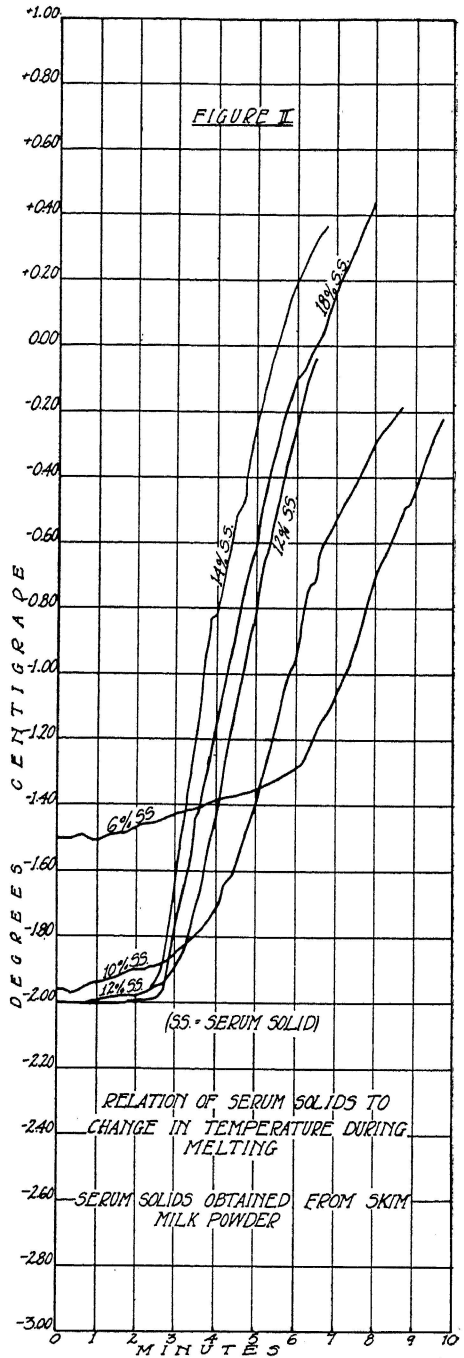


Fig. 2.—Relation of Serum Solids to Change in Temperature During Melting. Serum Solids Obtained from Skim Milk Powder.

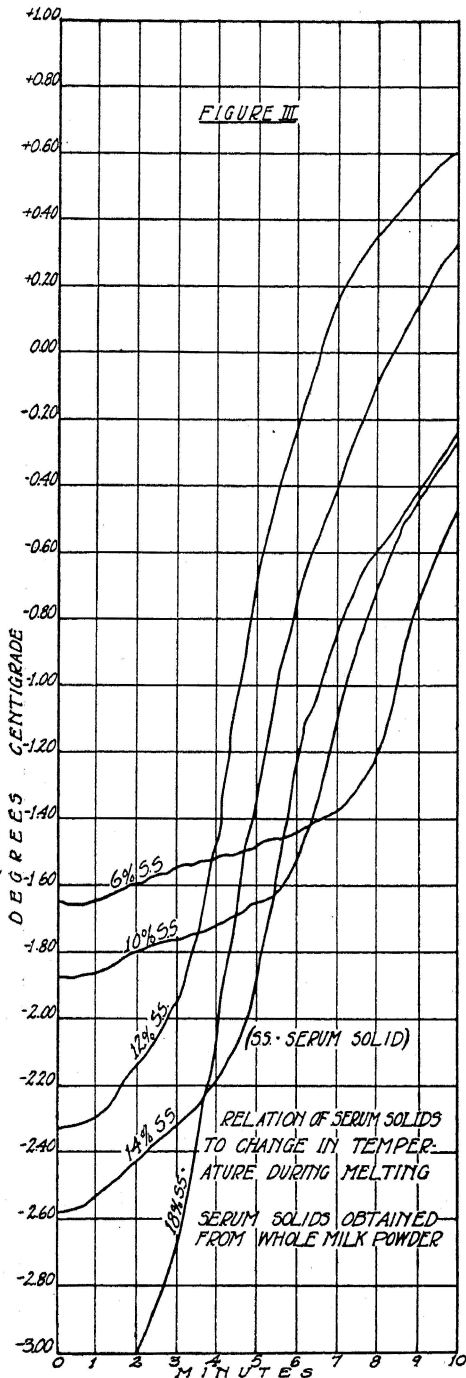


Fig. 3.—Relation of Serum Solids to Change in Temperature During Melting. Serum Solids Obtained from Whole Milk Powder.

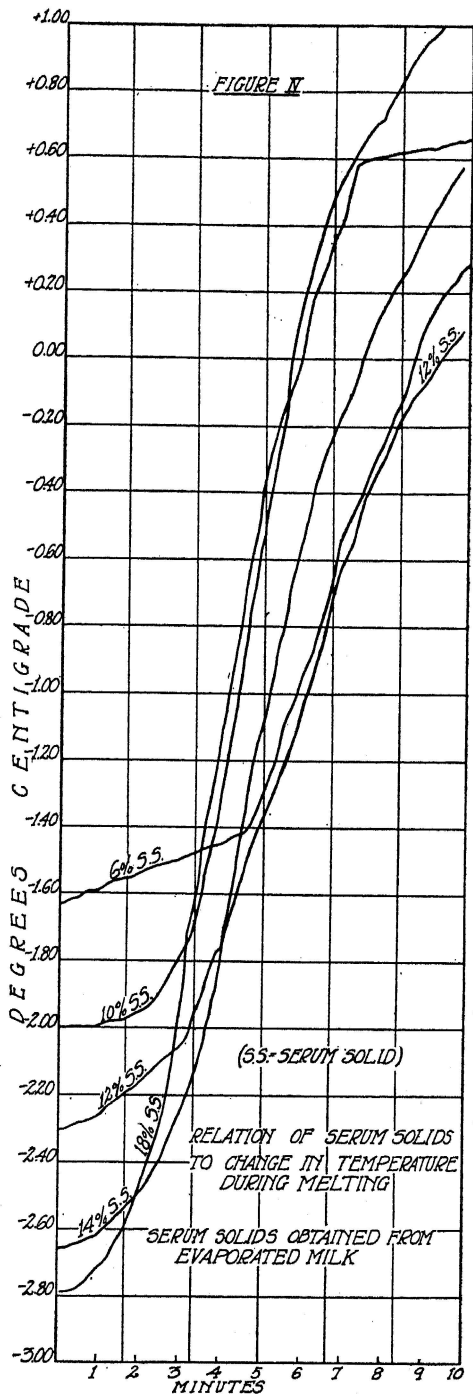


Fig. 4.—Relation of Serum Solids to Change in Temperature During Melting. Serum Solids Obtained from Evaporated Milk.

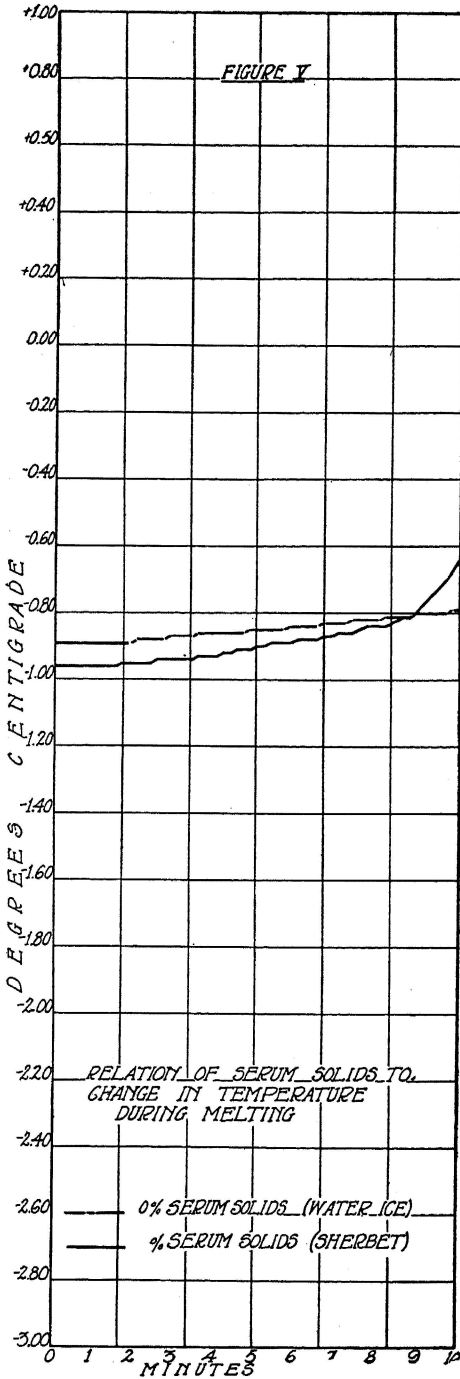


Fig. 5.—Relation of Serum Solids to Change in Temperature During Melting.

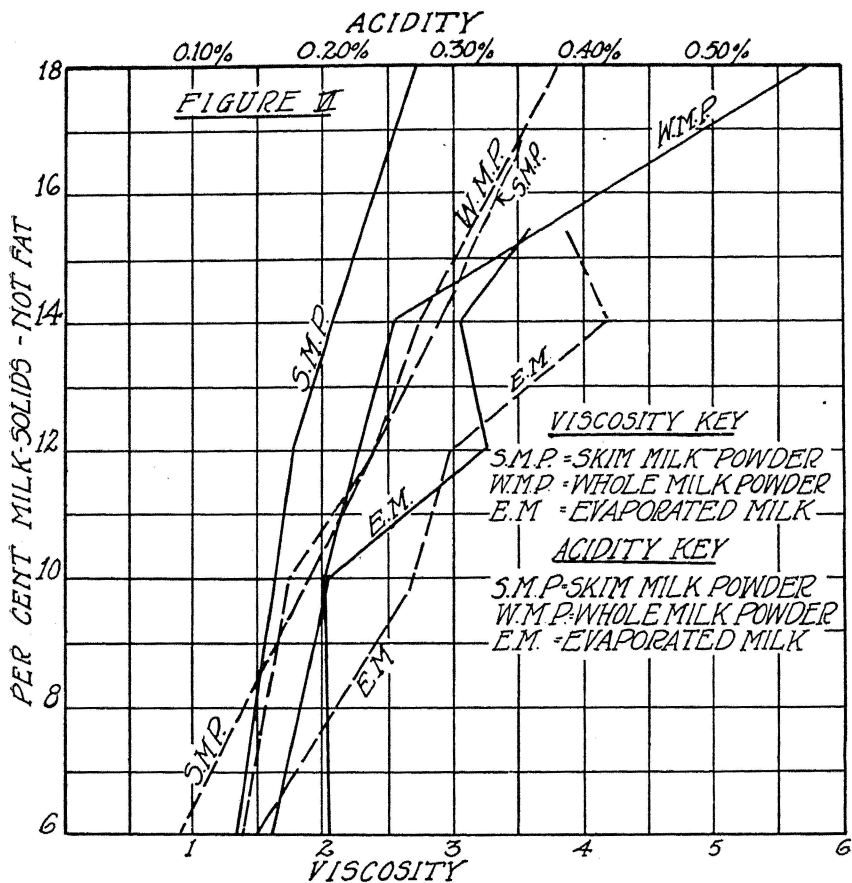


Fig. 6.—Relation of Milk Solids Not Fat to Titrable Acidity.

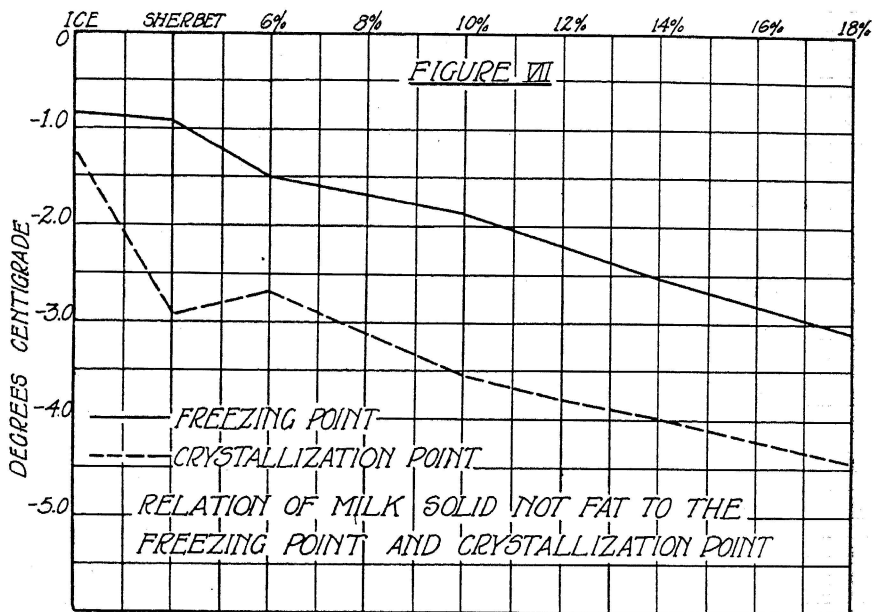


Fig. 7.—Relation of Milk Solids Not Fat to the Freezing Point and Crystallization Point.

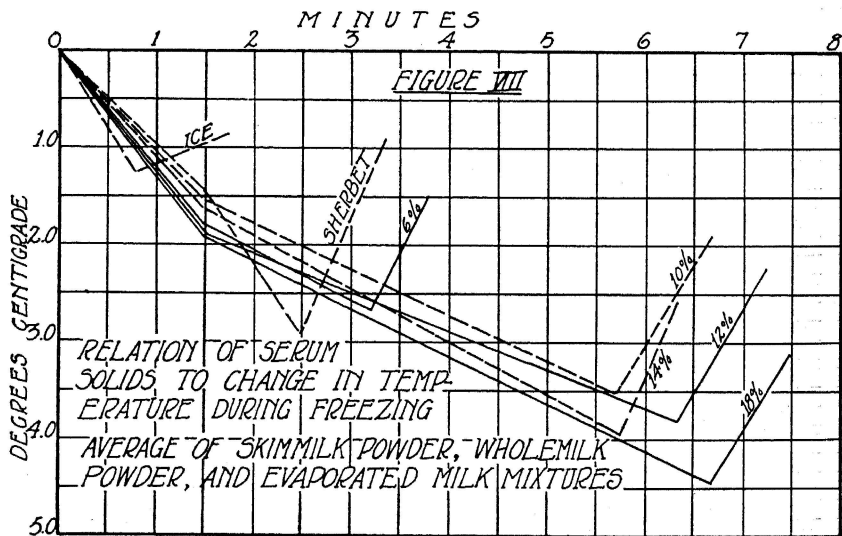


Fig. 8.—Relation of Serum Solids to Change in Temperature During Freezing.