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The Effect of Different Homogenization Processes on the Physical Properties of an Ice Cream Mixture and the Resulting Ice Cream when the Percentage of Fat is Varied and the Solids not Fat Remain Constant

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The Effect of Different Homogenization Pressures on the Physical Properties of an Ice Cream Mixture and the Resulting Ice Cream When the Percentage of Fat is Varied and the Solids not Fat Remain Constant

Wm. H. E. Reid and L. B. Russell*

Abstract.—Homogenization of an ice cream mixture disintegrates the fat globules, increases the surface area of the fat, causes the mixture to be more receptive to the incorporation of air and lessens the stability of the ice creams. Increasing the butterfat of an ice cream mixture decreases the amount of free serum, increases the viscosity and surface tension, permits the use of a lower homogenization pressure and improves the quality of the resultant ice creams. The temperature of the mixture in the freezer reflects directly upon the total time to freeze and control of the overrun.

There are three major physical variables which largely determine the quality of an ice cream. These variables are butterfat content, solids not fat content, and the pressures at which the mixture is processed.

This investigation is confined to a study concerning the effect of different homogenization pressures on the physical properties of an ice cream mixture and the resulting ice cream when the percentage of fat is varied and the solids not fat remain constant.

REVIEW OF LITERATURE

Bancroft[1], states that when particles are agglomerated loosely into spherical masses, the viscosity will increase because the water in the voids inside the spherical agglomerates no longer counts as free water.

Hatschek[8], has shown that subdivision of emulsified globules demands force which increased enormously as the size of the globule decreases.

Clayton[3], cites evidence from Wiegner and Briggs which shows that absorption of casein is manifested by the large increase in viscosity.

The investigations of Mortensen[10], Evanson and Ferris[7], Williams[14], Dahlberg[4], Dahle[6] and Reid and Scism[12], agree in that homogenization increases the viscosity of an ice cream mixture.

Dahlberg and Henning[5], show that high viscosity in whipping cream is the result of the clumping of the fat globules which correlates itself with the work of Mortensen[9], who shows that by homogenizing the ice cream mixture, the fat is brought together in large clusters, and that undoubtedly more or less serum is enclosed by the fat globules, which form such clusters.

*The data presented in this bulletin were taken from a thesis submitted by the junior author in partial fulfillment of the requirements for the degree of Master of Arts in the Graduate School of the University of Missouri, 1928.

Turnbow and Raffetto[13], states that homogenization increases viscosity by dividing the fat globules many times, thereby increasing the surface area. The greater the surface area exposed for the absorption of the water and other colloids, the greater is the viscosity, because of the reduction of the free serum.

Zoller, as quoted by Bogue[2], believes that as the fat content of the ice cream mixture is raised, there must be a corresponding increase in the protein content, to act as a film-forming material for the finely divided fat when the mixture is homogenized. At the same time there must be a sufficiency of the milk proteins present to form the membrane around the enmeshed air during the freezing process.

Turnbow[13], shows that gelatin, a typical reversible colloid, and other colloids have the greatest effect upon viscosity, because they have the physical property of forming a colloidal network structure which develops when the mixture is aged and held at low temperatures for a period of time.

Dahlberg and Henning[5] found that the surface tension of cream decreased as the fat content increased. The greatest change in surface tension occurred from zero to twenty per cent fat. Ageing resulted in a decrease of surface tension in most cases.

Mortensen[10], Williams[14], Evanson and Ferris[7], Dahle,[6] Dahlberg[5], and Reid and Moseley[11], concur in their opinions that homogenization improves the quality of the ice cream.

PROCEDURE

Studies were made on mixtures containing ten, twelve, fourteen, and sixteen per cent of butter fat. The milk solids not fat remained constant at eleven per cent, sugar at thirteen per cent, and gelatin at five-tenths of one per cent.

Five preliminary series of pressures were chosen for each percentage of fat and a separate mixture was made for each series.

A sixth series represented the best pressures of each of the five preliminary series.

A seventh series represented the most satisfactory pressures for each percentage of fat and furnish a comparison between mixtures of different percentages of fat.

Each mixture was heated to 62.80° C. (145° F.), held for thirty minutes, and processed at the different pressures with a Gaulin two stage homogenizer.

Sixty pounds of unprocessed mixture were drawn from each batch and a like amount of each of the different pressures. Each of these mixtures were cooled immediately to 4.4° C. (40° F.), and aged at 1.6°C. (35° F). Samples were obtained for determination of viscosity and surface tension. These samples were maintained at the same temperature as the sixty pound batches until the respective determinations were made.

Series	Pressure in Pounds
A.	0.000, 1000, 2000, 2500, 3000, 3500, 4000 and 5000.
B.	0.000, 2000-1000, 2500-1000, 3000-1000, 3500-1000, 4000-1000, and 5000-1000.
C.	0.000, 2500-2000, 3000-2000, 3500-2000, 4000-2000, and 5000-2000.
D.	0.000, 3500-3000, 4000-3000, and 5000-3000.
E.	0.000 and 5000-4000.

After ageing for 24 hours, 52 pounds of each mixture were frozen in a fifty-quart horizontal brine freezer. No color or flavor was used, thus eliminating any possibility of a judge placing any one sample above the others because of personal preference to a certain concentration of flavor or color. Samples were obtained from each batch at the beginning of the draw period for scoring determination.

The best ice cream of each series was determined and a sixth series, Series F, was arranged for each percentage of fat. Scoring determinations were made on this series. From Series F evolved Series G, composed of the best ice cream of each percentage of fat. The same determinations were made on this series as were made on Series F.

Overrun and temperature determinations were made every thirty seconds during the freezing process and immediately following the withdrawal of the first, third, fifth, seventh, and tenth gallons of ice cream.

It was found in the freezing of Series A, of sixteen per cent fat, that the application of higher pressures was unsatisfactory, therefore, a mixture containing sixteen per cent fat was not used in Series B, C, D, and E.

EXPERIMENTAL DATA

The Effect of Different Homogenization Pressures and Ages on the Viscosity of the Ice Cream Mixtures

The Improved MacMichael Viscosimeter was used for all determinations in viscosity at a temperature of 20° C. (68° F.).

The samples were tempered for 3 hours at 20° C. (68° F.), and tests were made at 24 hour intervals for a period of 72 hours.

In Series A of each percentage of fat, the viscosity of the ice cream mixtures increased at the initial five hour period as the pressures increased. Two variations from this were apparent in mixtures of twelve per cent fat, homogenized at 1000 and 4000 pounds pressure respectively and may be due to the rate at which they were cooled.

The viscosity increased with age and similarly with the increase in pressure. In the mixtures of ten per cent fat, the viscosity at the end of 72 hours continued to increase; while in the mixture of twelve and fourteen per cent fat the maximum viscosity was found at the 48 hour period. The decrease in viscosity of Series A, containing fourteen per cent fat, at the end of the 24 hour period may be attributed to the hydration of the neutral particles of alkali protein. The viscosity of the sixteen per cent fat was taken only at the initial five hours, and is not included in the data. Figures 1, 2, and 3, show the viscosity of Series A.

In Series B, the per cent of variation in viscosity between the unprocessed mixtures and the mixtures processed at the highest pressures of the series, is not as great as in Series A. Ageing does not increase the viscosity to such a marked degree as it does in the preceding series. Figures 4, 5, and 6, show the viscosity of Series B.

Tables 6 to 12, and Figures 7 to 12, inclusive, show the same trend in variation of viscosity as does Series B.

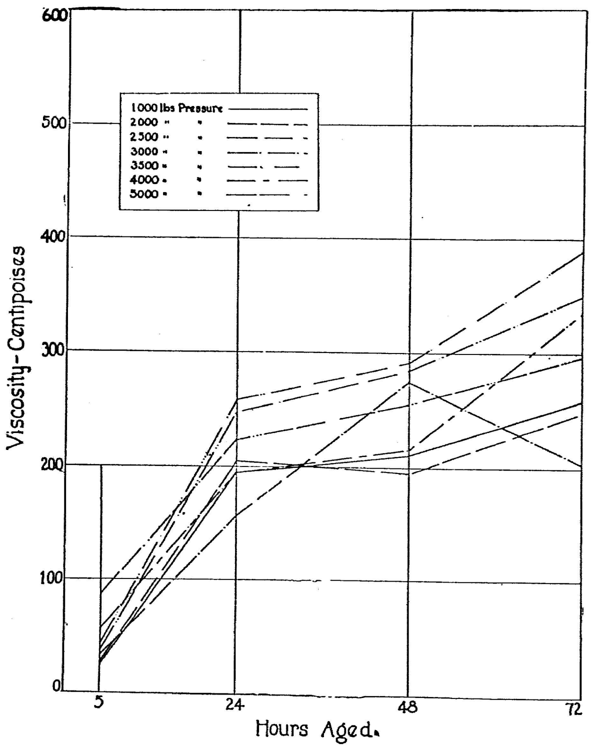

Figure 1. Series A. Viscosity of Mixture Containing Ten Per Cent Fat at Different Homogenization Pressures and Ages.

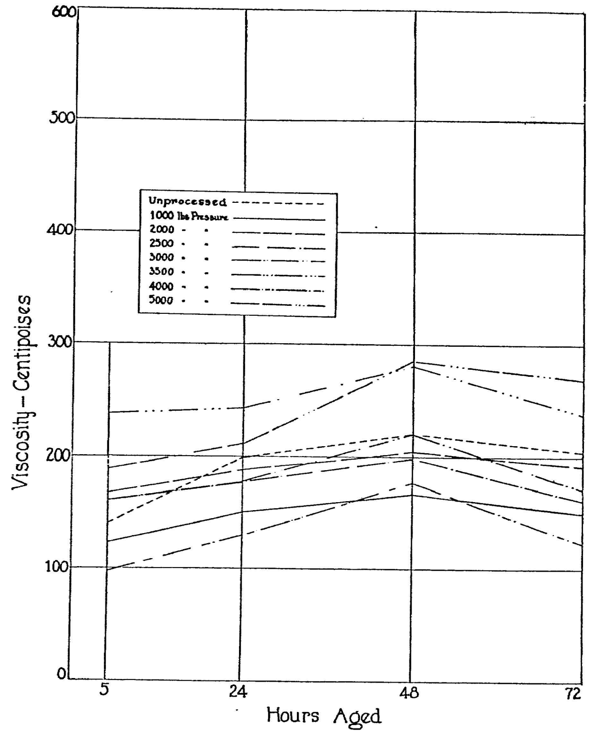

Figure 2. Series A. Viscosity of Mixtures Containing Twelve Per Cent Fat at Different Homogenization Pressures and Ages.

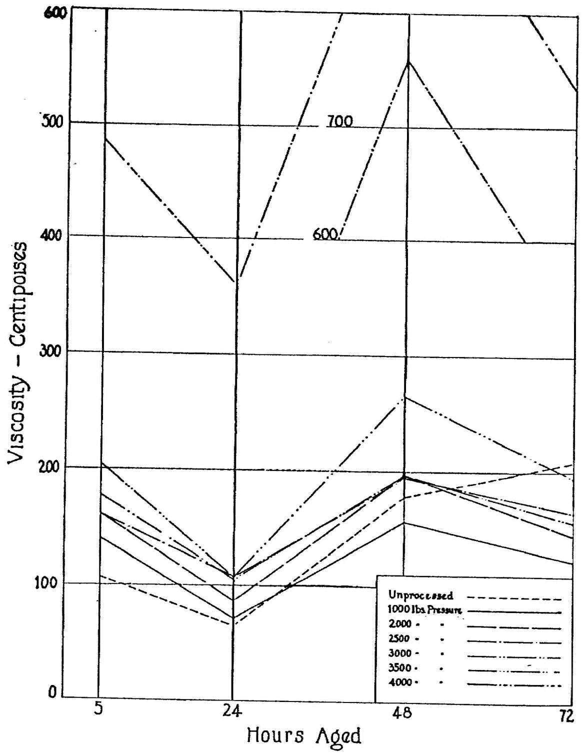

Figure 3. Series A. Viscosity of Mixtures Containing Fourteen Per Cent Fat at Different Homogenization Pressures and Ages.

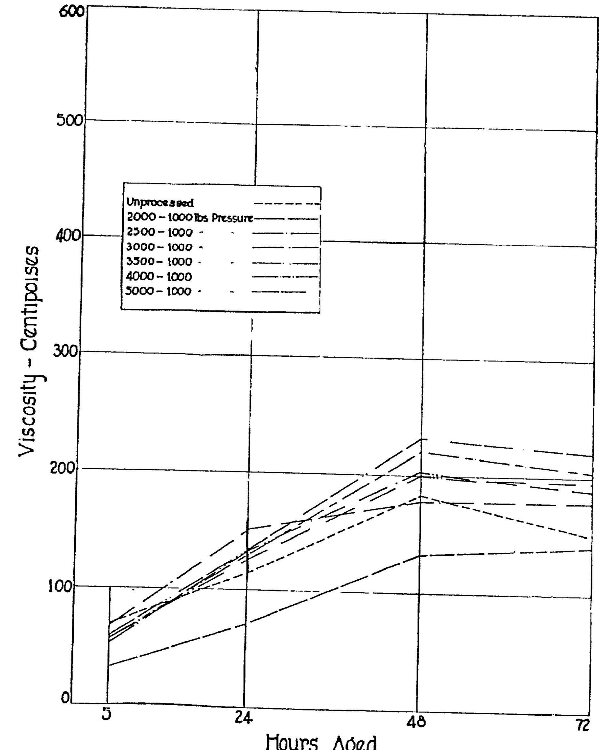

Figure 4. Series B. Viscosity of Mixtures Containing Ten Per Cent Fat at Different Homogenization Pressures and Ages.

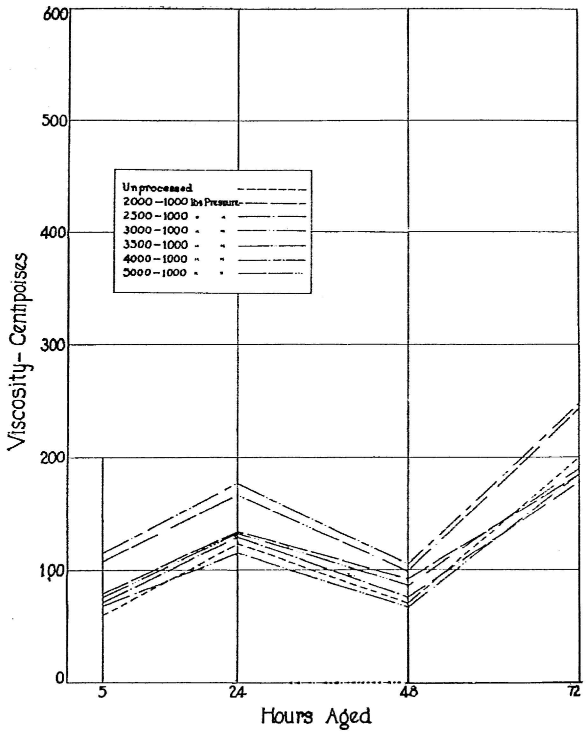

Figure 5. Series B. Viscosity of Mixture Containing Twelve Per Cent Fat at Different Homogenization Pressures and Ages.

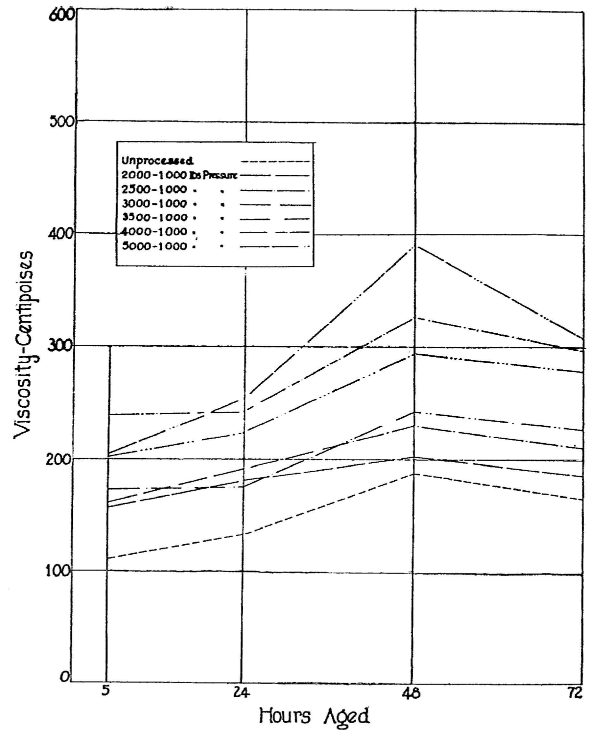

Figure 6. Series B. Viscosity of Mixtures Containing Fourteen Per Cent Fat at Different Homogenization Pressures and Ages.

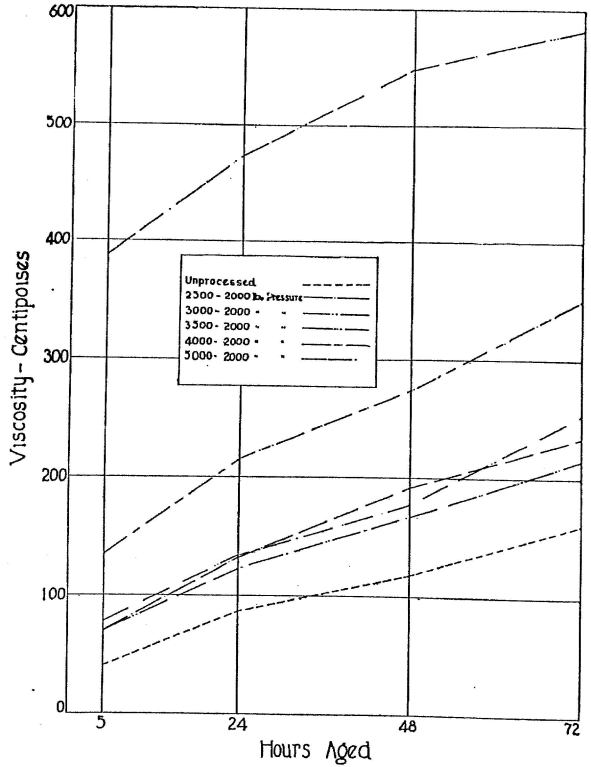

Figure 7. Series C. Viscosity of Mixtures Containing Ten Per Cent Fat at Different Homogenization Pressures and Ages.

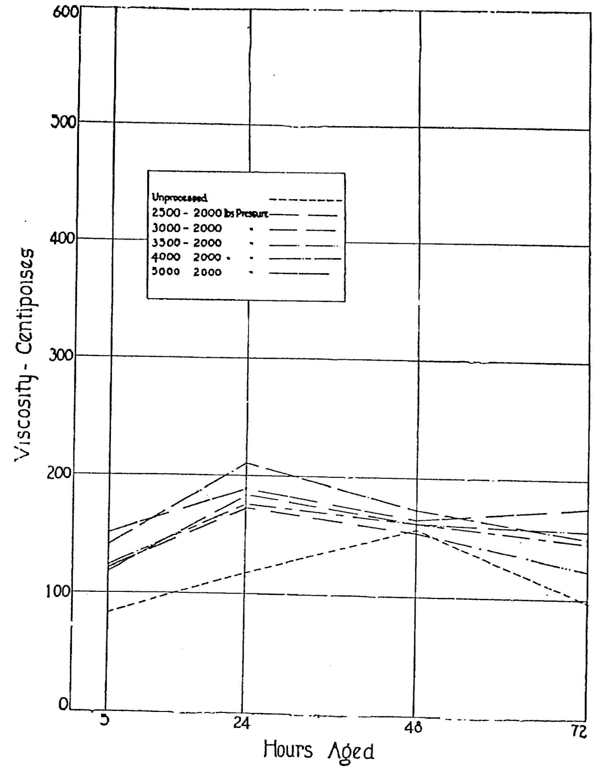

Figure 8. Series C. Viscosity of Mixtures Containing Twelve Per Cent Fat at Different Homogenization Pressures and Ages.

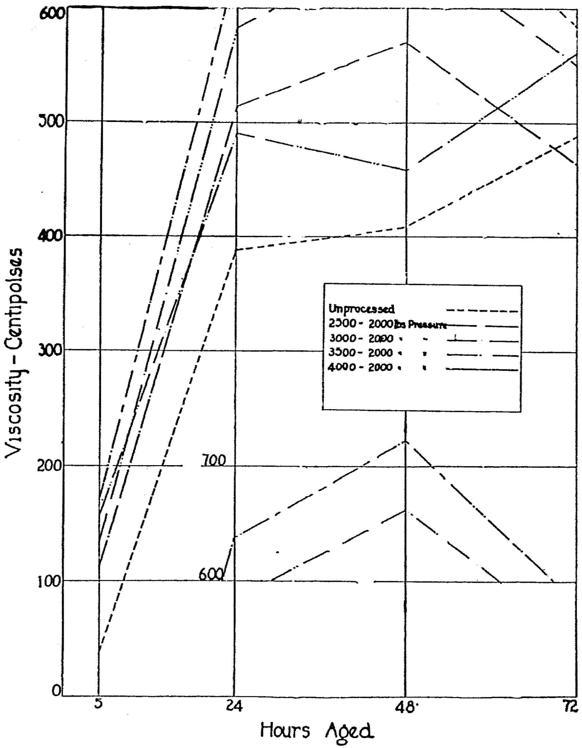

Figure 9. Series C. Viscosity of Mixtures Containing Fourteen Per Cent Fat at Different Homogenization Pressures and Ages.

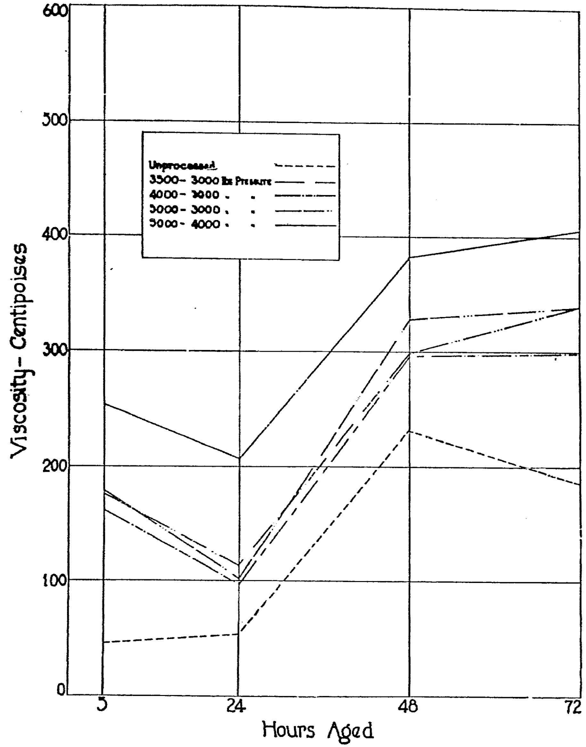

Figure 10. Series D and E. Viscosity of Mixtures Containing Ten Per Cent Fat at Different Homogenization Pressures and Ages.

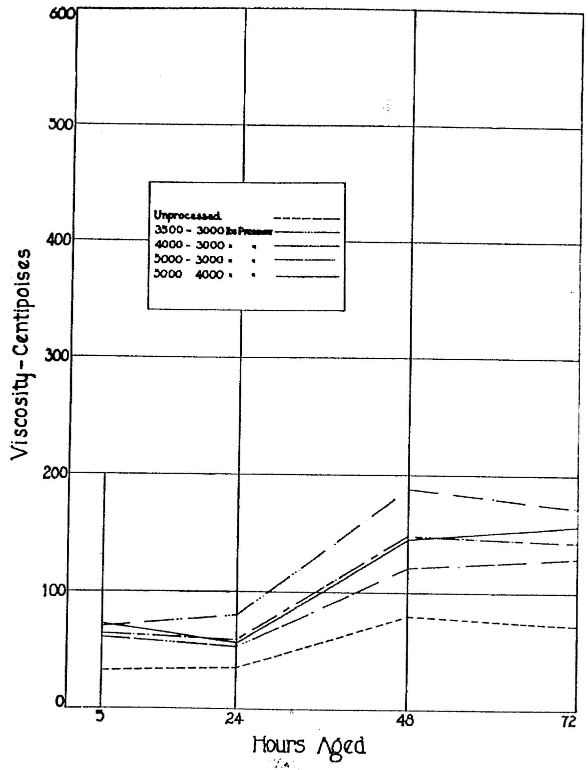

Figure 11.—Series D and E. Viscosity of Mixtures Containing Twelve Per Cent Fat at Different Homogenization Pressures and Ages.

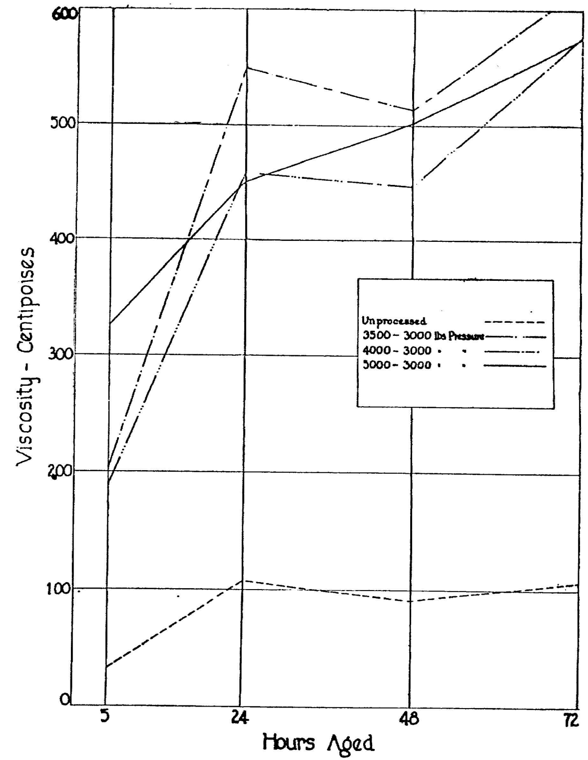

Figure 12. Series D and E. Viscosity of Mixtures, Containing Fourteen Per Cent Fat, at Different Homogenization Pressures and Ages.

The Effect of Different Homogenization Pressures and Ages on the Surface Tension of Ice Cream Mixtures

The DuNuoy surface tension apparatus was used in making determinations, which are expressed in dynes.

In Series A, homogenized with the single stage, representing mixtures of ten, twelve, fourteen, and sixteen per cent fat, the surface tension was found to increase as the pressure applied increased. Ageing the mixtures caused an increase in the surface tension. A greater increase in surface tension with ageing, was found where the higher pressures of the series were applied. Tables 1 to 3, inclusive, represent the results of the determinations of Series A.

Within each mixture, representing a given percentage of fat of Series B, C, D, and E, there was a gradual increase in surface tension, irrespective of the increase of pressure on the first gauge with the pressure on the second gauge constant, or an incresse of the pressure on both gauges.

This would indicate that as the total pressure applied was increased, no matter on which gauge the increase was exerted, there was a corresponding increase in surface tension. This is shown in Tables 4 to 12, inclusive.

The higher percentages of fat showed the greatest per cent of increase in surface tension on ageing. It was impossible to make surface tension determinations on mixtures of sixteen per cent fat and homogenized at higher pressures.

As the fat globules in the mixture are disintegrated, the surface area of the fat is increased, causing an increase in surface tension as a result of a greater surface contact. In a large number of samples a uniform increase in pressure on the single stage machine gave a uniform increase in surface tension. With the application of pressure on both stages a high per cent of increase was found between the unprocessed and the highest pressures of any series than with the single stage pressure.

TABLE 1.—SERIES A. SURFACE TENSION OF MIXTURE CONTAINING TEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed				
1000 Lbs.	50.02	48.99	49.68	49.68
2000 Lbs.	50.37	50.02	50.37	50.71
2500 Lbs.	50.37	50.02	50.71	50.71
3000 Lbs.	50.71	50.37	50.71	50.71
3500 Lbs.	50.71	50.71	52.44	52.44
4000 Lbs.	51.06	51.40	52.44	52.78
5000 Lbs.	51.40	51.06	53.13	53.82

TABLE 2.—SERIES A. SURFACE TENSION OF MIXTURE CONTAINING TWELVE PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.30	48.30	50.37	50.71
1000 Lbs.	48.64	49.68	50.02	50.37
2000 Lbs.	49.38	51.40	51.75	51.75
2500 Lbs.	49.68	50.37	51.40	51.75
3000 Lbs.	48.99	50.71	52.09	51.75
3500 Lbs.	49.33	50.37	51.40	51.75
4000 Lbs.	49.33	50.37	51.06	51.06
5000 Lbs.	49.33	50.37	52.09	52.44

TABLE 3.—SERIES A SURFACE TENSION OF MIXTURE CONTAINING FOURTEEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.30	49.68	48.99	49.33
1000 Lbs.	48.64	50.37	49.68	49.68
2000 Lbs.	48.64	50.37	49.68	49.33
2500 Lbs.	47.95	48.99	49.33	50.02
3000 Lbs.	47.61	48.64	49.33	50.02
3500 Lbs.	49.33	50.37	51.40	51.75
4000 Lbs.	51.40	53.47	54.85	52.09
5000 Lbs.	61.41	59.68	64.86	65.55

TABLE 4.—SERIES B. SURFACE TENSION OF MIXTURE CONTAINING TEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	50.37	50.37	50.71	49.68
2000-1000 Lbs.	51.75	50.37	50.71	49.68
2500-1000 Lbs.	53.13	49.68	48.99	50.02
3000-1000 Lbs.	52.44	51.40	51.75	50.37
3500-1000 Lbs.	51.06	51.40	51.40	50.37
4000-1000 Lbs.	52.44	51.06	52.44	52.44
5000-1000 Lbs.	54.51	50.71	50.71	52.44

TABLE 5.—SERIES B. SURFACE TENSION OF MIXTURE CONTAINING TWELVE PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.64	49.68	49.68	48.99
2000-1000 Lbs.	49.33	50.02	50.02	49.68
2500-1000 Lbs.	49.33	50.37	49.33	49.33
3000-1000 Lbs.	49.68	50.02	48.99	48.99
3500-1000 Lbs.	50.02	50.37	49.68	49.33
4000-1000 Lbs.	50.02	49.68	49.33	49.68
5000-1000 Lbs.	50.37	50.37	49.68	49.33

TABLE 6.—SERIES B. SURFACE TENSION OF MIXTURE CONTAINING FOURTEEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.64	51.06	51.06	48.30
2000-1000 Lbs.	48.64	49.33	49.68	51.06
2500-1000 Lbs.	49.33	50.02	50.02	49.68
3000-1000 Lbs.	49.68	50.37	50.37	50.02
3500-1000 Lbs.	50.02	50.71	50.37	49.68
4000-1000 Lbs.	50.37	51.40	51.06	50.37
5000-1000 Lbs.	50.71	51.06	51.06	50.02

TABLE 7.—SERIES C. SURFACE TENSION OF MIXTURE CONTAINING TEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.64	49.33	49.33	49.68
2500-2000 Lbs.	49.33	50.02	50.71	51.06
3000-2000 Lbs.	49.68	50.71	51.06	51.06
3500-2000 Lbs.	50.02	52.09	52.09	52.09
4000-2000 Lbs.	50.71	52.09	52.78	53.13
5000-2000 Lbs.	51.40	54.85	55.20	55.89

TABLE 8.—SERIES C. SURFACE TENSION OF MIXTURE CONTAINING TWELVE PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.30	48.99	49.33	48.99
2500-2000 Lbs.	48.99	49.33	50.02	49.33
3000-2000 Lbs.	49.35	49.68	50.37	48.99
3500-2000 Lbs.	49.35	49.68	50.71	49.35
4000-2000 Lbs.	49.68	50.02	51.06	49.68
5000-2000 Lbs.	49.68	49.68	50.71	49.68

TABLE 9.—SERIES C. SURFACE TENSION OF MIXTURE CONTAINING FOURTEEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.99	50.71	51.06	53.13
2500-2000 Lbs.	50.71	53.13	53.13	53.13
3000-2000 Lbs.	52.44	54.41	53.82	53.82
3500-2000 Lbs.	50.02	52.09	52.09	52.09
4000-2000 Lbs.	50.71	52.09	52.78	53.13
5000-2000 Lbs.	51.40	54.85	55.20	55.89

TABLE 10.—SERIES D AND E. SURFACE TENSION OF MIXTURE CONTAINING TEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.64	49.33	49.33	49.68
3500-3000 Lbs.	49.68	49.33	50.02	50.71
4000-3000 Lbs.	50.02	50.71	50.71	51.40
5000-3000 Lbs.	50.71	51.06	51.40	51.75
5000-4000 Lbs.	51.40	52.44	52.78	52.78

TABLE 11.—SERIES D AND E. SURFACE TENSION OF MIXTURE CONTAINING TWELVE PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	48.30	49.68	49.68	50.37
3500-3000 Lbs.	49.68	50.02	50.71	51.40
4000-3000 Lbs.	50.02	50.71	50.71	51.40
5000-3000 Lbs.	50.71	51.06	51.40	51.75
5000-4000 Lbs.	51.40	52.44	52.78	52.78

TABLE 12.—SERIES D AND E. SURFACE TENSION OF MIXTURE CONTAINING FOURTEEN PER CENT FAT AT DIFFERENT HOMOGENIZATION PRESSURES AND AGES

Pressures Applied	Age of Mixture in Hours			
	5	24	48	72
Unprocessed	49.33	49.68	49.33	49.68
3500-3000 Lbs.	50.37	53.82	52.44	55.89
4000-3000 Lbs.	51.06	55.20	53.82	60.72
5000-3000 Lbs.	61.41	62.10	60.72	64.54
5000-4000 Lbs.	53.10	54.51	59.34	53.13

The Relation of Homogenization Pressures to the Freezing Process

The Control of the Overrun During the Whipping Period.—All batches of mixtures in this study were frozen in a horizontal brine freezer at -17° C. (0° F.).

Overrun determinations and temperature readings of the ice cream mixtures were made at intervals of thirty seconds. Overrun determinations were made with a weight by volume overrun tester, and temperatures were taken with a standardized Centigrade thermometer.

In studying the freezing methods an attempt was made to determine the best method of control in the freezing process and to determine the relation of the temperature of the ice cream mixture, during the freezing process, to the length of time required to obtain a desired overrun.

The true cause of the smoothness of an ice cream remains undetermined. Some authorities contend that it is the prolonged whipping after the first stiffening of the ice cream that causes the smoothness, while other authorities affirm that it is the size of the ice crystals which form during the freezing process that causes smoothness of the ice cream.

The size of the ice crystals is determined by the rate of freezing, the accompanying amount of free water remaining at the time the ice cream is drawn from the freezer, and the nature of the surrounding media which limits the area in which the ice crystals can grow.

The homogenized protein and fat in the mixture hold a part of the water, either chemically or physically, and thus reduce the amount of free water capable of forming ice crystals in homogenized mixtures.

The homogenization process increases the surface area of the fat, the amount of protein absorbed on encasing the fat, and the amount of water held physically or chemically in the mixture.

Figures 13 to 24, inclusive, show the freezing results of the preliminary series. Temperature readings are expressed in Centigrade.

The Control of the Overrun During the Draw Period.—To draw the ice cream from the freezer at some desired per cent of overrun, and to maintain that overrun throughout the draw period, is a problem of utmost importance, both from the standpoint of quality, and from an economic standpoint. The overrun can be controlled by mechanical methods, proper control of brine pressure and temperature, and through the control of the temperature of the freezing mixture.

The data indicate that there is a range of temperature during the draw period, within which the ice cream mixture may hold the air already incorporated or may incorporate more air, depending upon the physical properties of the mixture. Beyond this range of temperature, which is individualistic for an ice cream mixture of a certain composition and possessing certain physical properties, there is a decrease in the amount of overrun, due to the loss of air previously incorporated.

In this study where a decided decrease in per cent of overrun occurred between the first gallon and the tenth gallon drawn, a decrease in the temperature of the ice cream drawn at these points was found. The greatest decrease in the per cent of overrun occurred with the greatest decrease in the temperature of the ice cream.

In the series where the temperature of the ice cream approached the upper limits of the optimum range of temperature for the freezing of the ice cream, a rather constant overrun was maintained throughout the draw period.

There was a general tendency for mixtures on which medium pressures were used to incorporate air more readily than mixtures to which the higher pressures were applied. The unprocessed mixtures were least responsive to the incorporation of air.

It was determined that the most efficient method of controlling the overrun was by controlling the temperature of the ice cream mixture within the freezer.

The temperature of the ice cream mixture in the freezer seems to be the determining factor in controlling the overrun during the draw period. Ice cream with the overrun on the ascending curve, with the temperature rapidly declining at the beginning of the draw period, loses its overrun rapidly and to such an extent as to be detrimental to the quality. The opposite condition presents itself when the overrun is on the downward curve, but the ice cream mixture is at an optimum temperature for that mixture.

Figures 13 to 24 inclusive, show the trend of the overrun of the respective ice creams at the beginning of the draw period and the overrun and temperature subsequent to the withdrawal of definite volumes of ice cream. Temperature readings are expressed in degrees Centigrade.

The Effect of Different Homogenization Pressures and Pressure Combinations on the Stability of the Ice Cream at Summer Temperatures

A melting chamber with a thermostatic heat control was used to furnish a constant temperature of 30° C. (86° F.) for the melting of the ice cream. The bricks of ice cream were weighed at the beginning of the melting period and at the end of each hour for a period of three hours.

The pressure applied in homogenization determines, to a marked degree, the ability of the ice cream to offer resistance to summer temperatures.

In all series of each percentage of fat, there was a general tendency toward a decrease in stability as the pressures were increased. In the majority of the determinations the stability of the ice cream decreased with the pressure, inclusive of the medium pressure of each series and then increased as the pressures reached the maximum for that series.

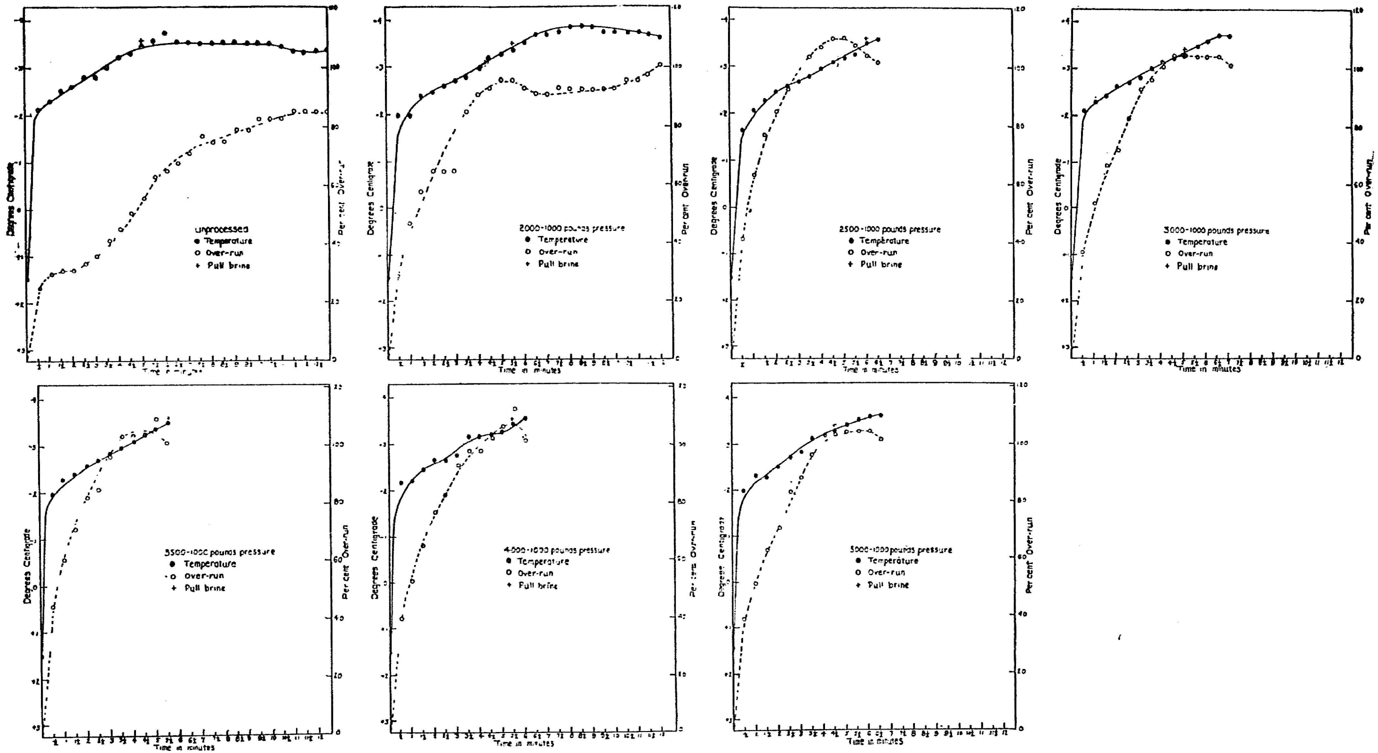

Figure 13. Series A. Ten Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent of Overrun and the Time Required to Freeze.

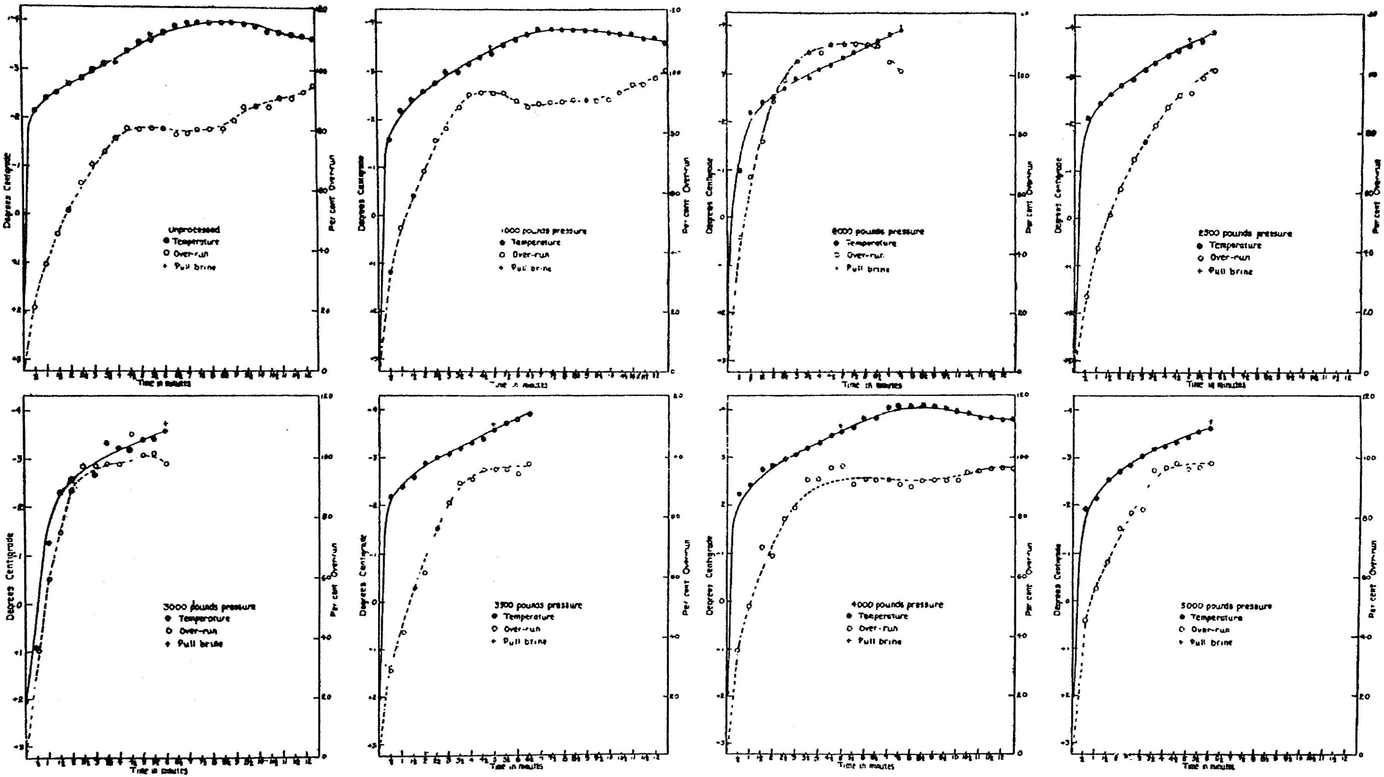

Figure 14. Series A. Twelve Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent of Overrun and the Time Required to Freeze.

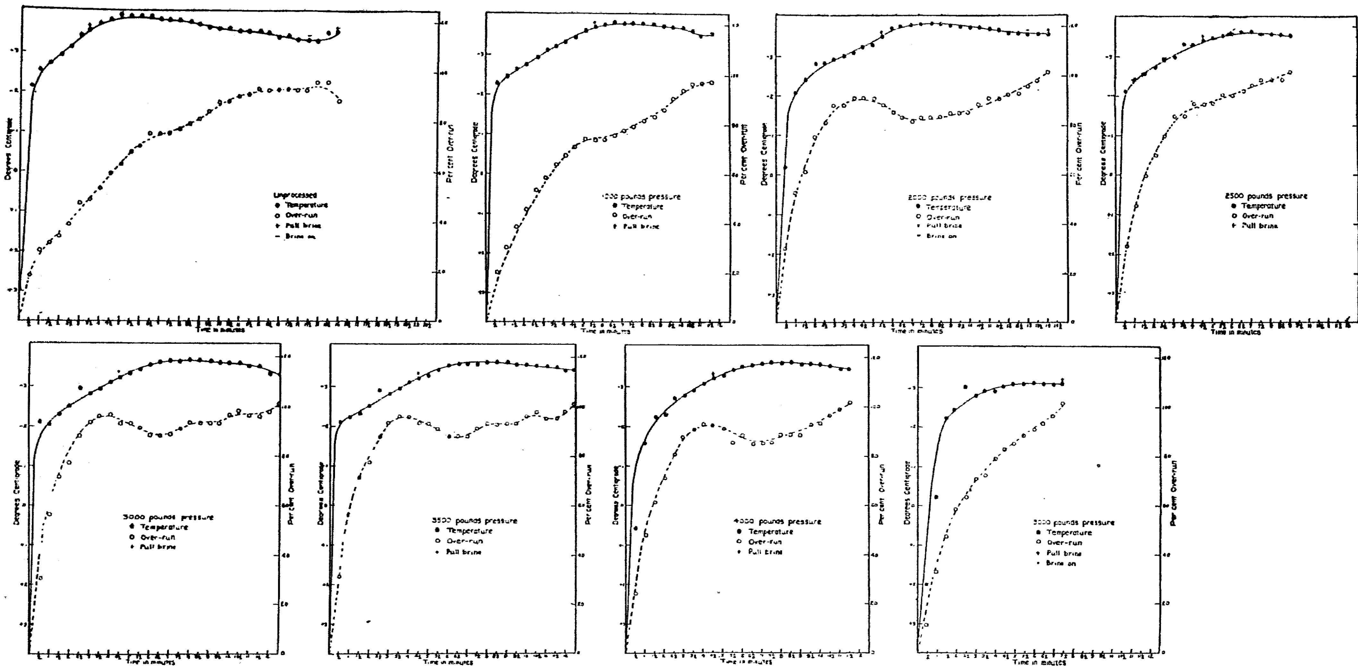

Figure 15. Series A. Fourteen Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent of Overrun and the Time Required to Freeze.

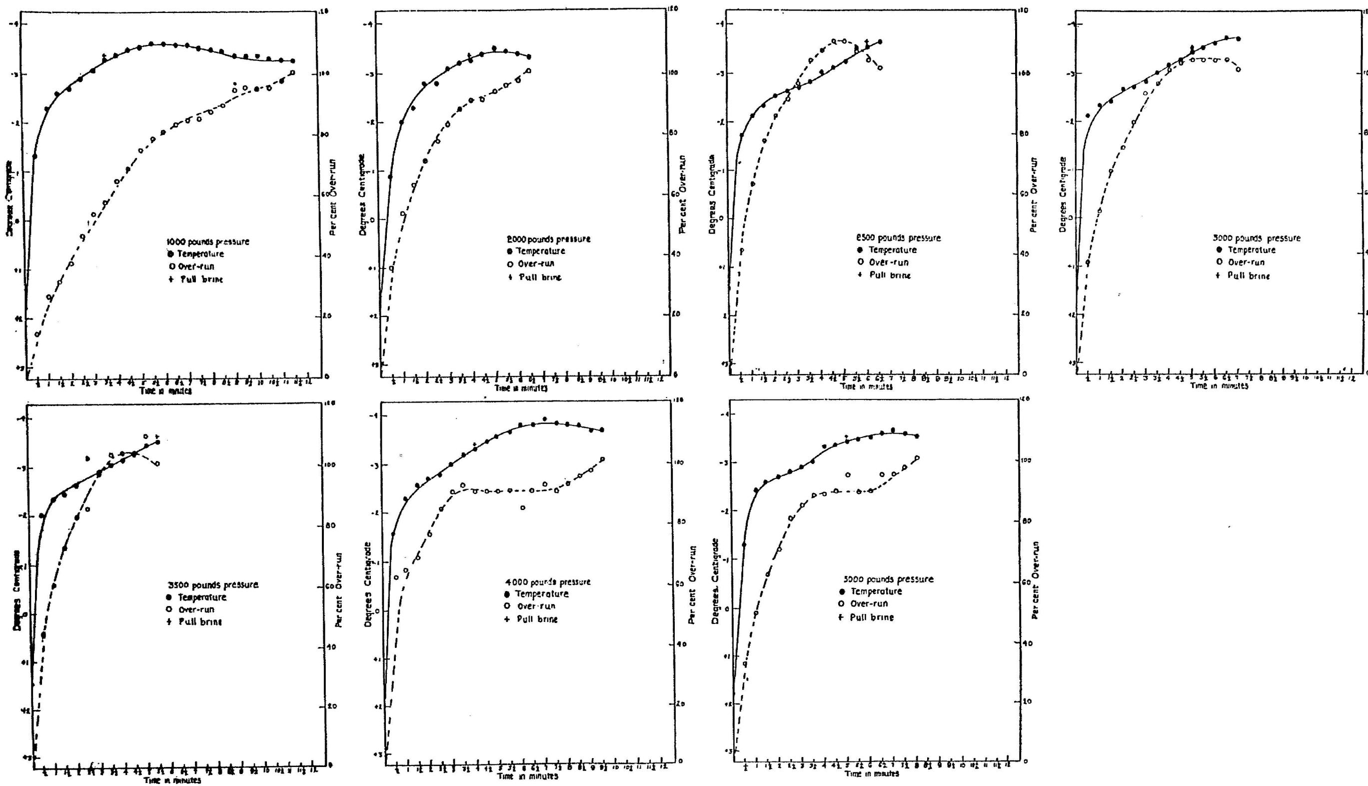

Figure 16. Series B. Ten Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent Overrun and the Time Required to Freeze.

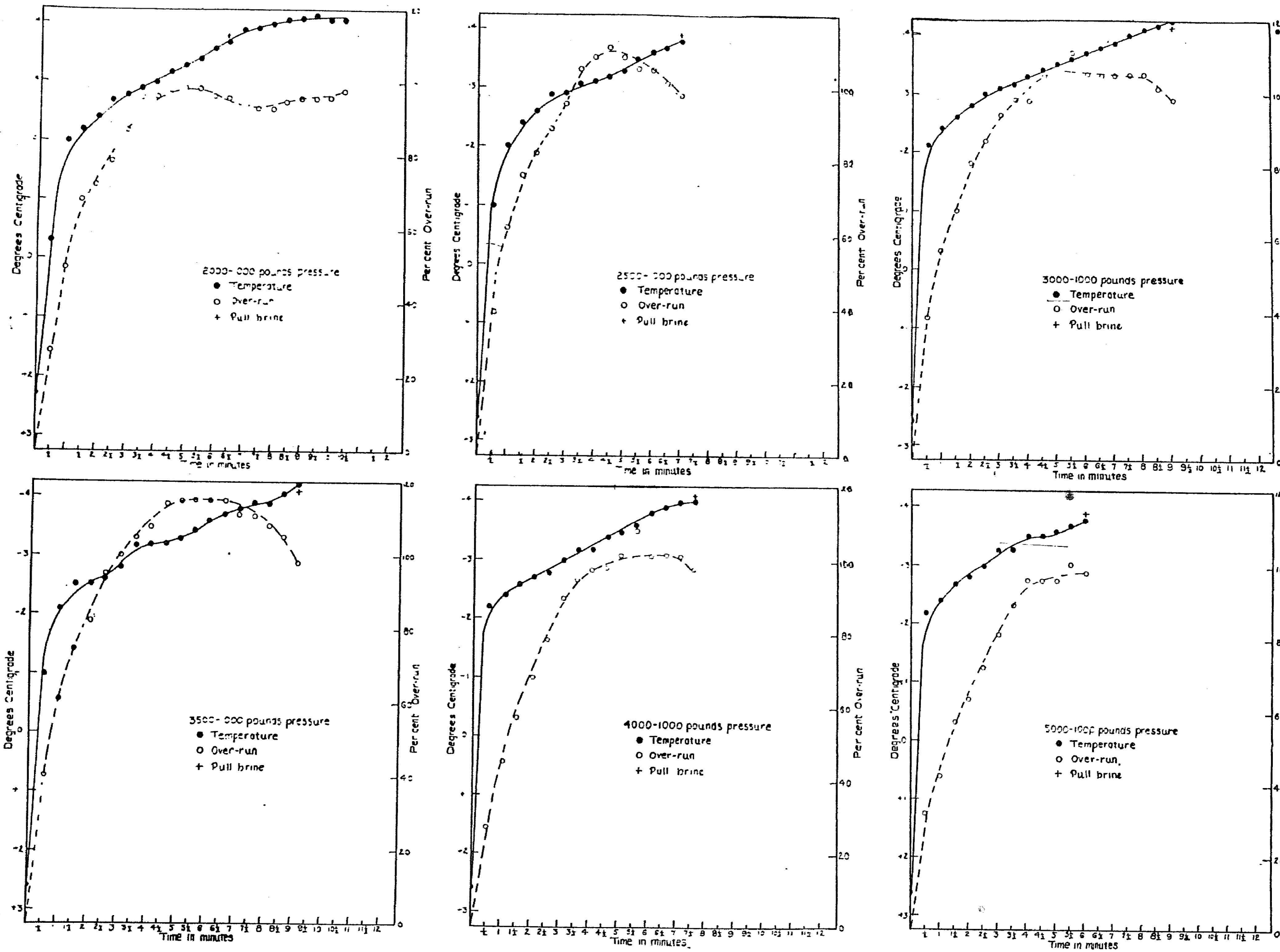

Figure 17. Series B. Twelve Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent Overrun and the Time Required to Freeze.

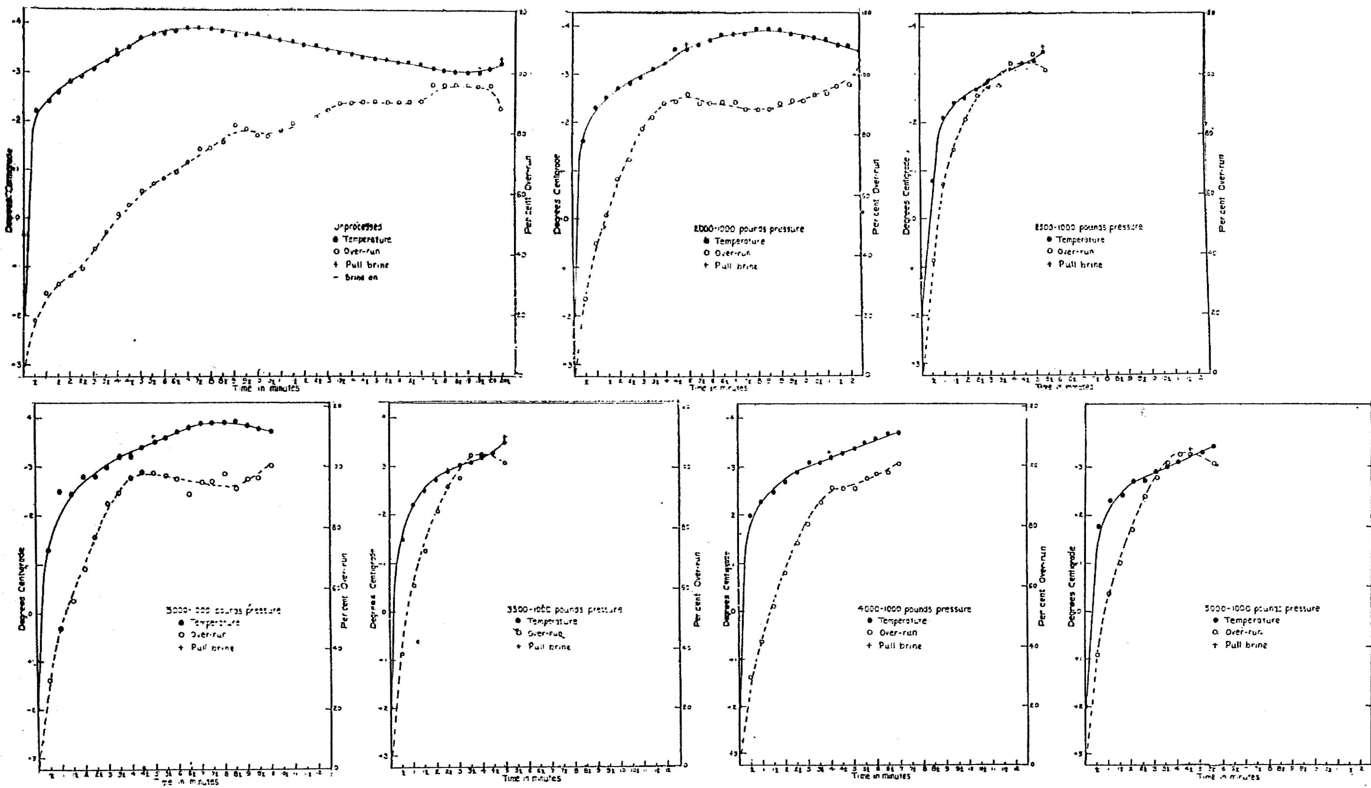

Figure 18. Series B. Fourteen Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent Overrun and the Time Required to Freeze.

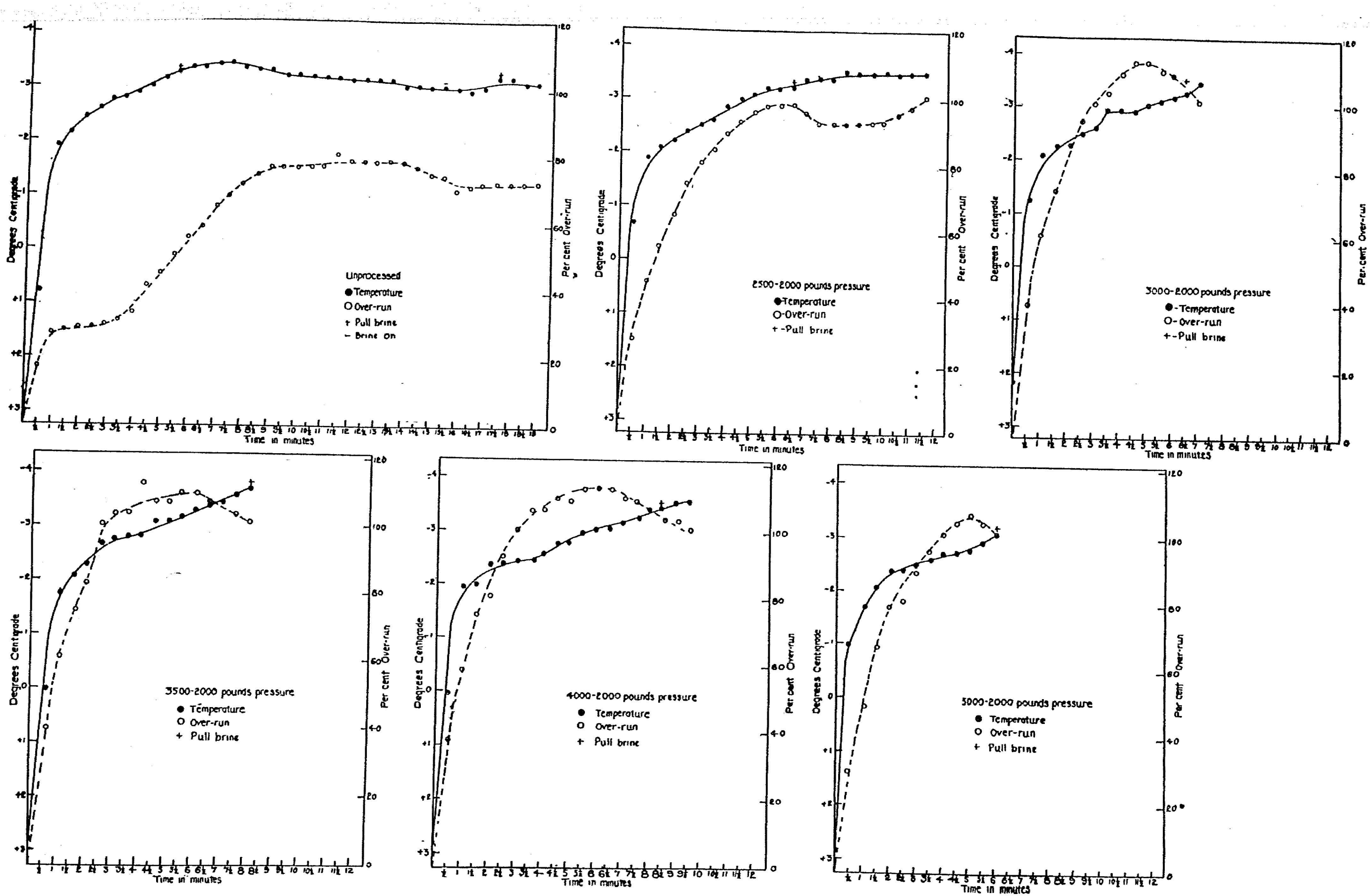

Figure 19. Series C. Ten Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent Overrun and the Time Required to Freeze.

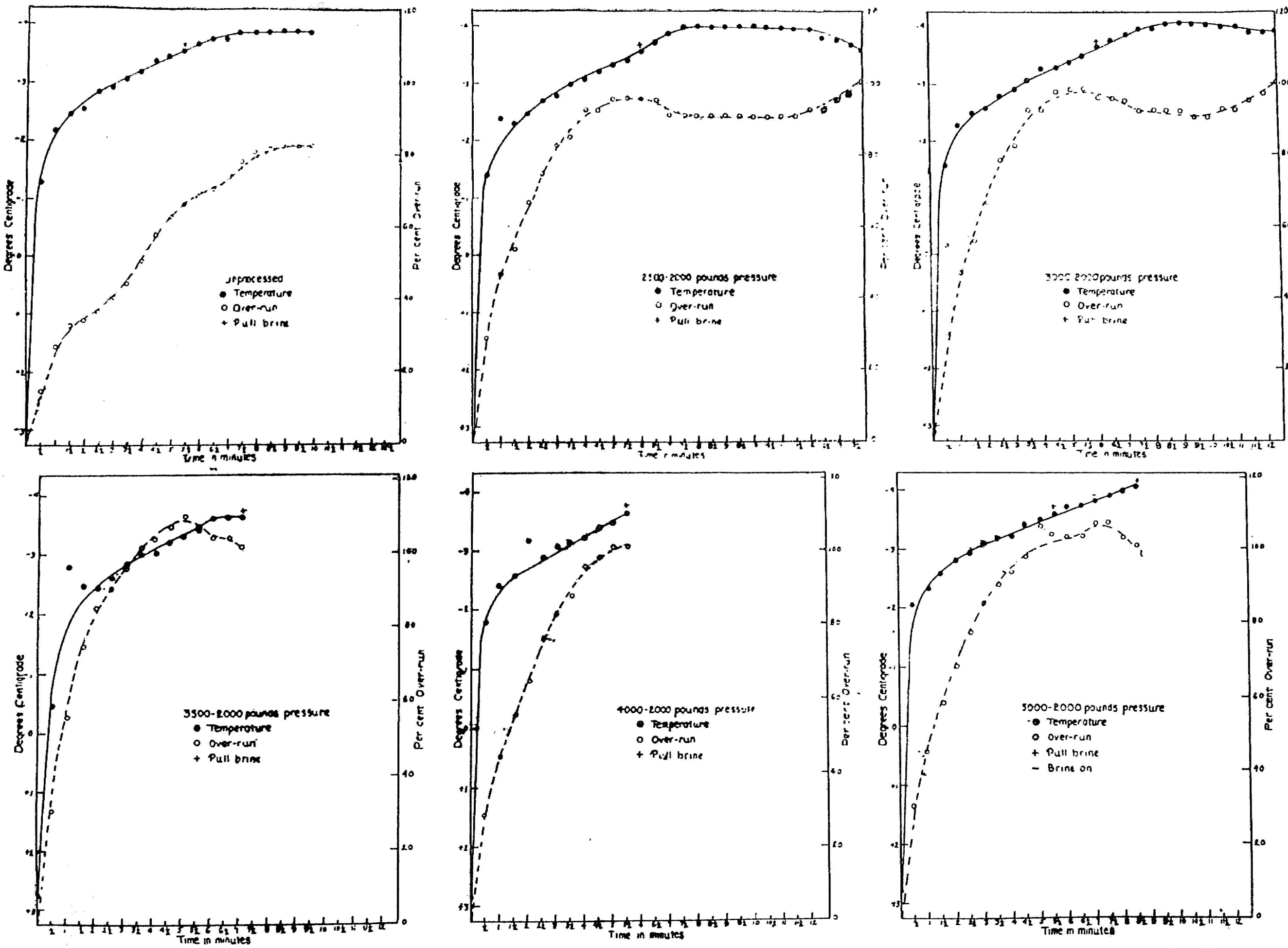

Figure 20. Series C. Twelve Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent Overrun and the Time Required to Freeze.

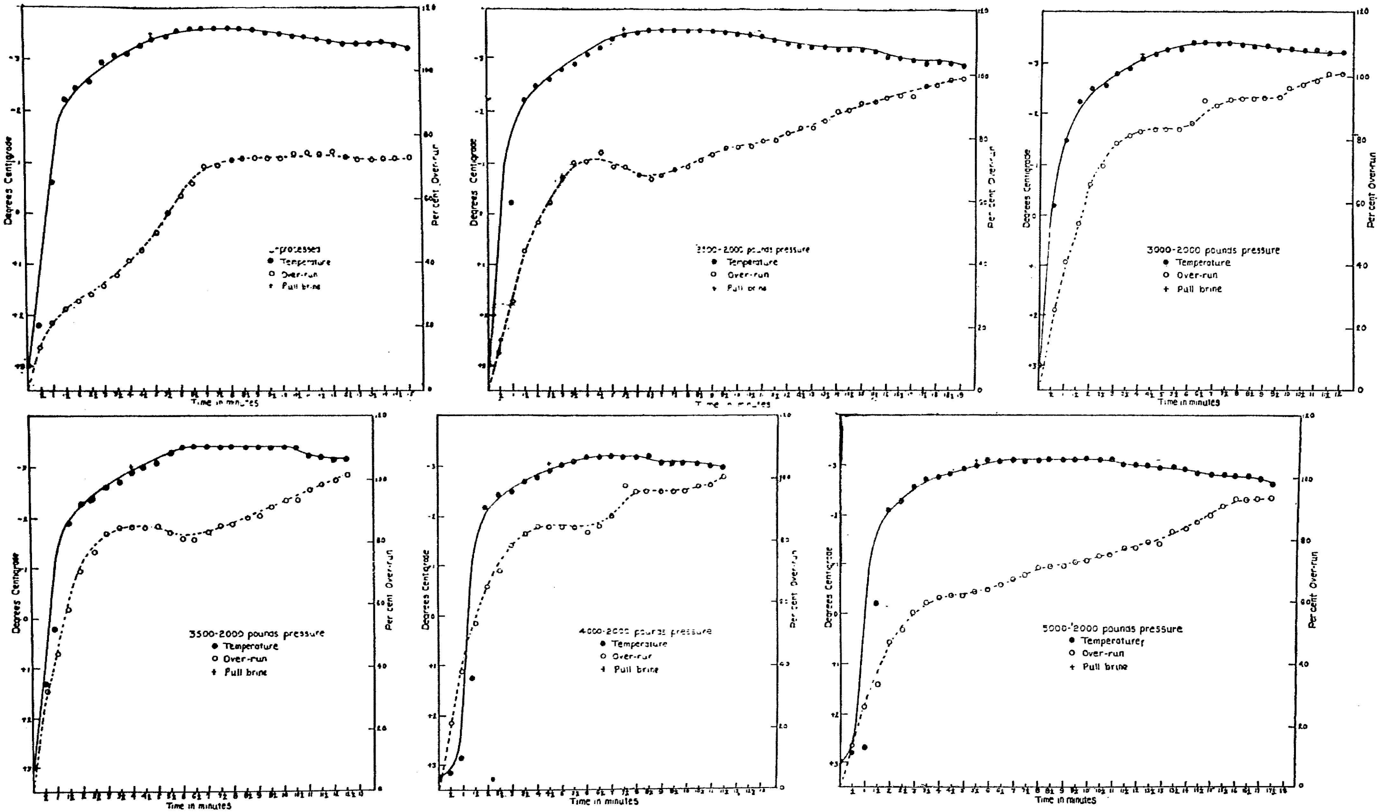

Figure 21. Series C. Fourteen Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent Overrun and the Time Required to Freeze.

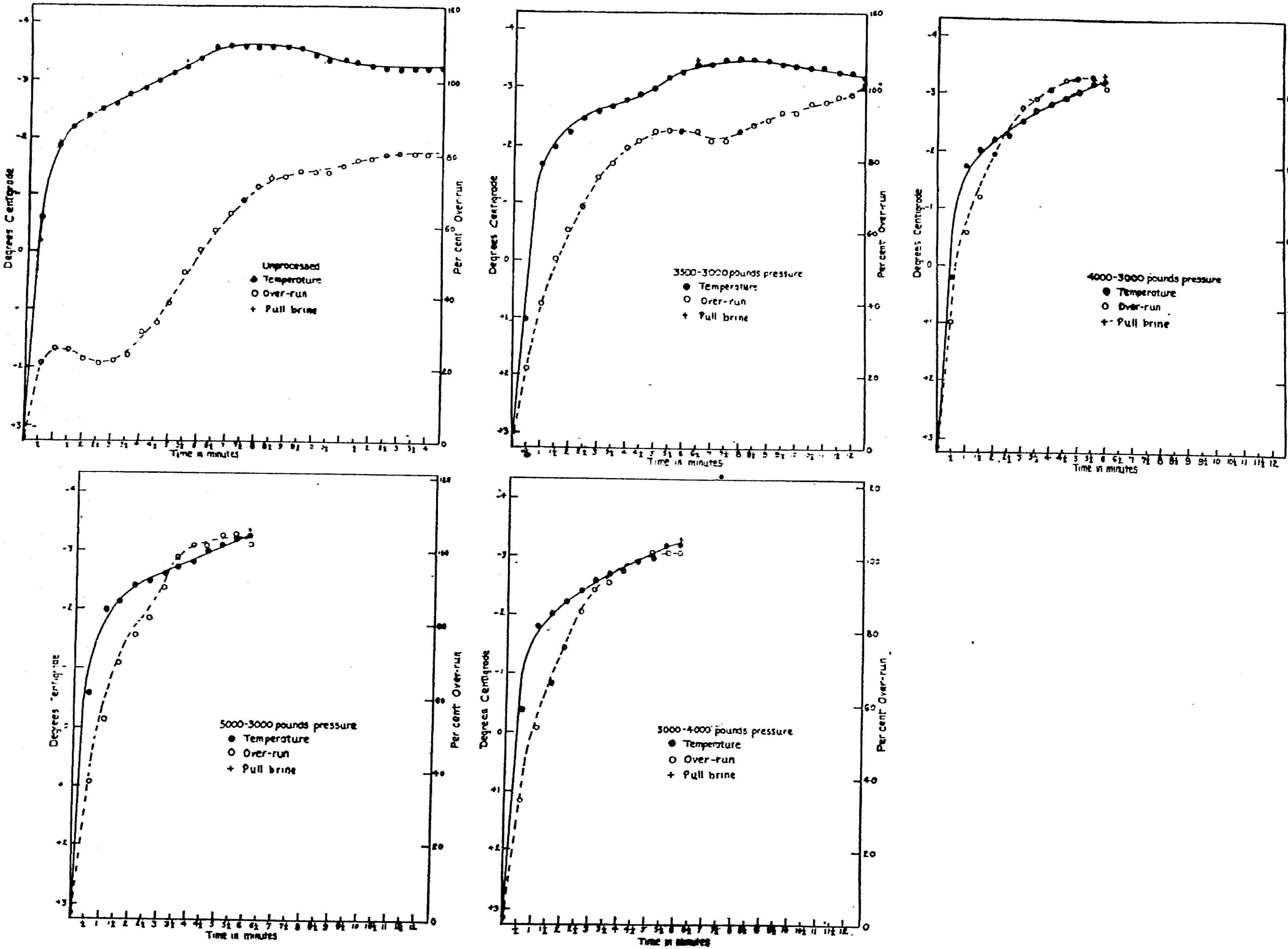

Figure 22. Series D. and E. Ten Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent of Overrun and the Time Required to Freeze

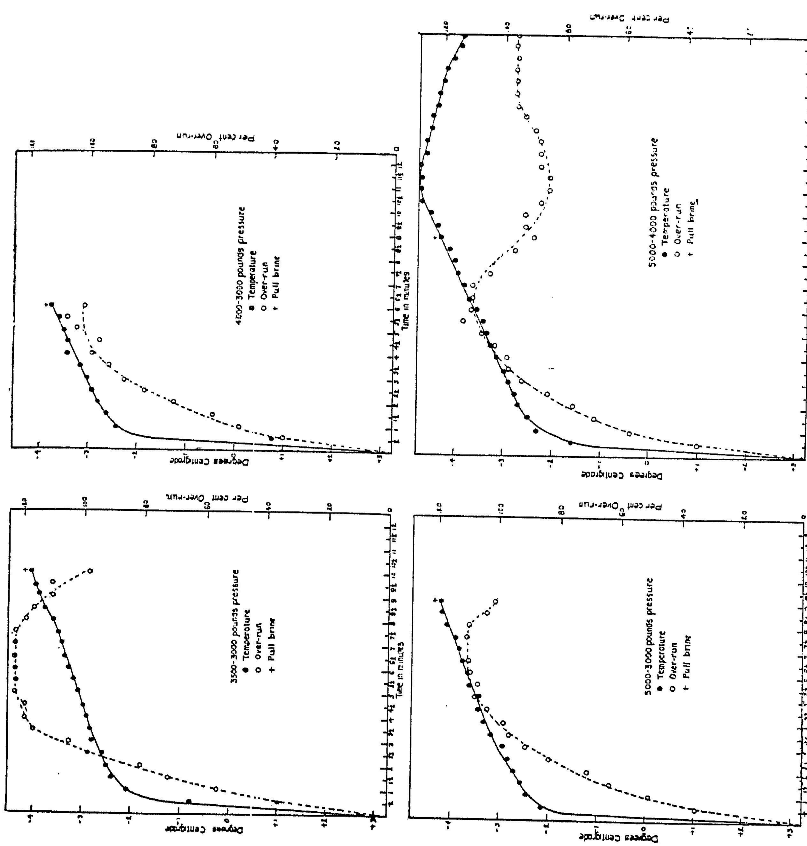

Figure 23. Series D and E. Twelve Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent of Overrun and the Time Required to Freeze.

With an increase of fat content there was a decided increase in stability of the ice cream that had been homogenized.

Comparing the stability of the ice creams processed at the different series of pressures, it was found that as the pressure on the first stage was held constant and increased on the second stage, that the stability of the ice cream was increased.

Tables 13 to 25 inclusive, show the loss in grams on melting at the different periods of time, and the per cent of loss during these periods.

Homogenization decreased the ability of the ice cream to withstand summer temperatures, the unprocessed ice cream offering greater resistance and proving more stable than those ice creams made from processed mixtures. In general, the ability of the ice cream to withstand summer temperatures is decreased with an increase of pressure. An increase in the butterfat content improved the stability of the ice cream.

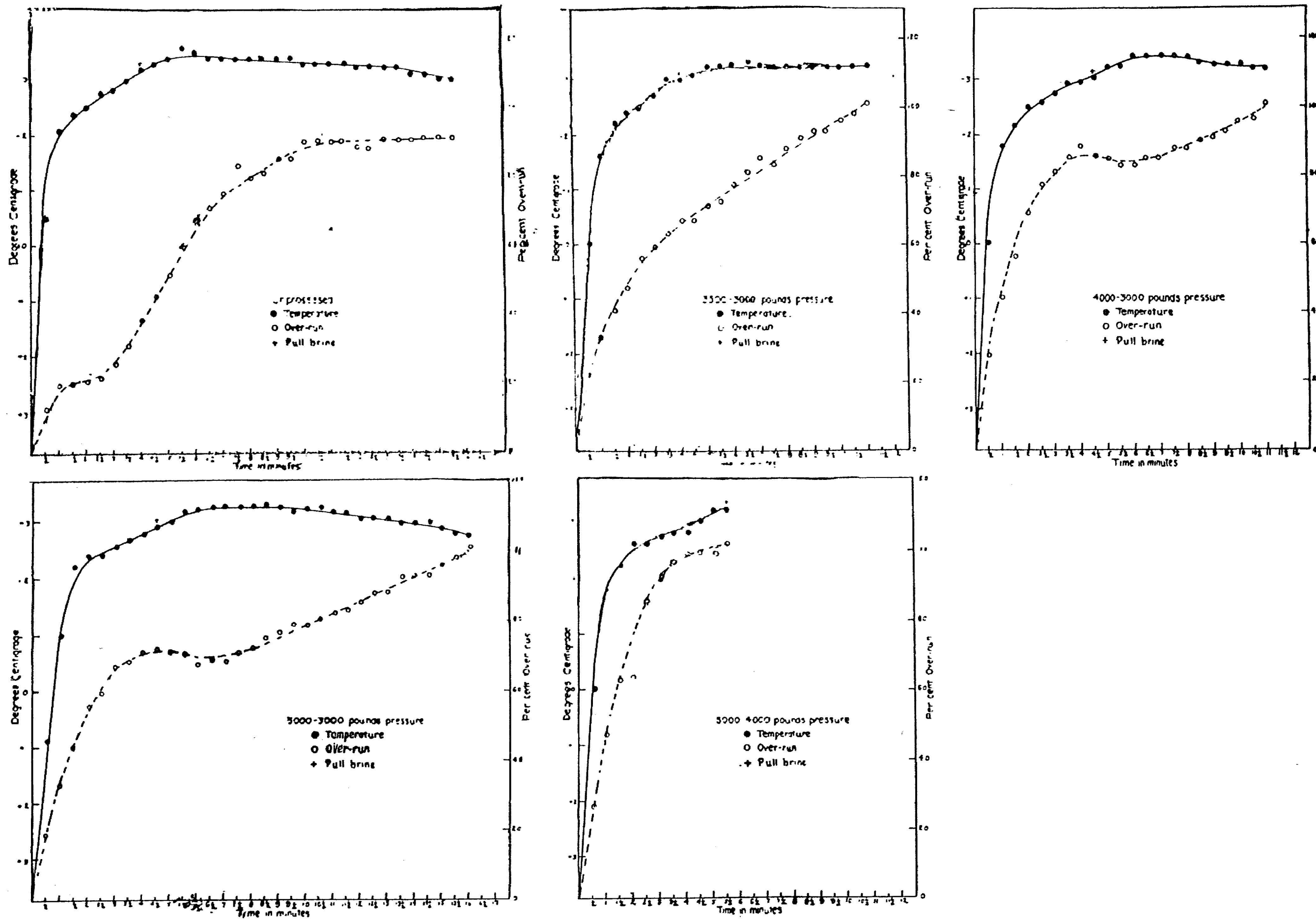

Figure 24. Series D and E. Fourteen Per Cent Fat. The Relation of Pressure and Temperature to the Per Cent Overrun and the Time Required to Freeze.

Table 13.—The Effect of Different Homogenization Pressures on the Stability of Ice Cream When Exposed to Summer Temperatures

Series A. Ten Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	81.4	−3.3	14.5	629	48	240	414	7.63	38.15	65.81
1000 Lbs.	101.3	−3.3	11.5	543	71	270	432	13.07	49.72	79.53
2000 Lbs.	101.3	−3.35	6.5	540	139	376	521	25.74	69.62	96.48
2500 Lbs.	101.3	−3.6	4.5	547	140	386	525	25.59	70.56	97.22
3000 Lbs.	101.3	−3.7	6.0	553	131	382	527	23.68	69.07	95.29
3500 Lbs.	101.3	−3.5	4.0	540	115	361	498	21.29	76.66	92.23
4000 Lbs.	101.3	−3.7	9.5	532	157	377	508	29.51	70.89	95.48
5000 Lbs.	101.3	−3.5	9.0	527	191	413	518	36.24	78.36	98.29

Table 14.—The Effect of Different Homogenization Pressures on the Stability of Ice Cream When Exposed to Summer Temperatures

Series A. Twelve Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
1000 Lbs.	101.3	−3.6	12.5	536	74	290	432	13.80	54.10	80.59
2000 Lbs.	101.3	−3.9	7.5	586	134	394	521	22.86	67.23	88.90
2500 Lbs.	101.3	−3.9	6.0	535	133	353	500	24.85	65.98	93.45
3000 Lbs.	98.0	−3.6	6.0	577	177	432	564	30.67	74.87	97.74
3500 Lbs.	98.0	−3.9	6.5	551	131	395	536	23.74	71.69	97.27
4000 Lbs.	96.5	−3.75	12.5	527	140	390	510	26.56	74.00	96.77
5000 Lbs.	98.0	−3.6	6.0	572	94	355	533	16.40	61.95	93.01

TABLE 15.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series A. Fourteen Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	88.4	−3.5	16.0	649	22	194	367	3.39	29.89	56.54
1000 Lbs.	101.3	−3.5	11.5	531	2	126	281	.37	23.72	52.91
2000 Lbs.	101.3	−3.5	14.0	572	35	210	414	6.11	36.71	72.37
2500 Lbs.	101.3	−3.5	9.0	538	46	245	431	8.55	45.53	80.11
3000 Lbs.	101.3	−3.4	12.5	545	33	239	438	6.05	43.85	80.39
3500 Lbs.	101.3	−3.4	12.5	530	30	243	415	5.66	45.84	78.30
4000 Lbs.	101.3	−3.4	11.5	546	9	185	386	1.64	33.88	70.69
5000 Lbs.	101.3	−3.1	8.0	559	0	60	249	0.	10.73	44.54

TABLE 16.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series A. Sixteen Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	88.4	−2.8	15.0	634	0	7	216	0	1.10	34.06
1000 Lbs.	104.1	−3.0	18.5	559	0	50	207	0	8.94	37.03
2000 Lbs.	67.0	−2.7	25.0	590	0	95	240	0	16.10	40.67
2500 Lbs.	59.7	−2.7	18.5	711	0	64	278	0	9.56	39.09
3000 Lbs.	53.1	−2.5	14.5	719	0	5	219	0	.69	30.45

TABLE 17.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series B. Ten Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	85.6	−3.6	13.0	599	30	255	433	5.0	42.57	72.28
2000-1000 Lbs.	101.3	−3.7	12.0	545	50	282	454	9.17	51.74	83.03
2500-1000 Lbs.	101.3	−3.6	6.5	556	51	298	486	9.17	53.59	87.41
3000-1000 Lbs.	101.3	−3.7	7.0	536	65	313	477	12.12	58.39	88.99
3500-1000 Lbs.	101.3	−3.5	5.5	527	71	312	469	13.47	59.20	88.99
4000-1000 Lbs.	101.3	−3.6	6.0	534	73	313	478	13.67	58.61	89.51
5000-1000 Lbs.	101.3	−3.6	6.5	519	87	328	482	16.76	63.19	92.87

TABLE 18.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF THE ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series B. Twelve Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	79.2	−3.35	18.5	636	34	261	433	5.34	41.03	68.08
2000-1000 Lbs.	98.0	−4.1	10.5	561	58	282	460	10.26	50.26	81.99
3500-1000 Lbs.	98.0	−3.8	7.0	565	72	333	411	12.74	58.93	72.24
3000-1000 Lbs.	98.0	−4.3	9.0	566	88	344	524	15.54	60.77	92.57
2500-1000 Lbs.	98.0	−4.25	9.0	582	77	332	530	13.23	57.04	91.06
4000-1000 Lbs.	98.0	−4.25	7.5	555	65	310	490	11.71	55.85	88.28
5000-1000 Lbs.	98.0	−3.9	6.0	524	84	323	484	16.03	61.64	92.36

TABLE 19.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series B. Fourteen Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	88.4	−3.2	21.0	618	31	232	350	5.01	37.54	56.63
2000-1000 Lbs.	101.3	−3.5	12.5	535	90	294	437	16.82	54.95	81.68
2500-1000 Lbs.	101.3	−3.5	5.5	555	94	331	497	16.93	59.63	89.54
3000-1000 Lbs.	101.3	−3.75	10.0	523	86	317	471	16.44	60.61	90.05
3500-1000 Lbs.	101.3	−3.5	5.0	552	109	328	483	19.74	59.42	87.50
4000-1000 Lbs.	101.3	−3.7	7.0	508	109	321	464	21.45	63.18	91.34
5000-1000 Lbs.	101.3	−3.4	5.5	544	101	329	482	18.56	60.47	88.60

TABLE 20.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series C. Ten Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	72.9	−3.2	20	650	48	239	441	7.38	36.76	67.84
2500-2000 Lbs.	101.3	−3.5	11.5	559	74	264	465	13.23	52.77	83.18
3000-2000 Lbs.	101.3	−3.5	7.0	562	84	313	511	14.94	55.69	90.92
3500-2000 Lbs.	101.3	−3.7	8	563	93	311	491	16.51	55.23	87.21
4000-2000 Lbs.	101.3	−3.6	9.5	544	63	294	470	11.58	54.04	86.39
5000-2000 Lbs.	101.3	−3.1	6.0	544	40	234	429	7.35	43.01	78.86

TABLE 21.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series C. Twelve Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	83.7	−3.9	10.0	588	14	41	405	2.38	6.97	68.87
2500-2000 Lbs.	101.3	−3.6	14.0	554	85	309	480	15.34	55.77	86.64
3000-2000 Lbs.	101.3	−3.9	12.5	540	120	365	511	22.22	67.59	94.62
3500-2000 Lbs.	101.3	−3.6	7.0	558	114	381	532	20.43	68.27	95.34
4000-2000 Lbs.	101.3	−3.6	5.5	528	113	367	501	21.40	69.50	94.88
5000-2000 Lbs.	101.3	−4.1	8.0	542	87	349	509	16.05	64.39	93.91

TABLE 22.—THE EFFECT OF DIFFERENT HOMOGENIZATION PRESSURES ON THE STABILITY OF ICE CREAM WHEN EXPOSED TO SUMMER TEMPERATURES

Series C. Fourteen Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	72.9	−3.2	14.5	663	6	151	291	.904	22.79	43.89
2500-2000 Lbs.	98.6	−2.9	19.0	563	121	197	355	21.49	34.99	63.05
3000-2000 Lbs.	101.3	−3.2	12.0	565	37	247	418	6.54	43.71	73.96
3500-2000 Lbs.	101.3	−3.15	12.5	559	19	192	366	3.39	34.34	65.47
4000-2000 Lbs.	101.3	−3.0	11.5	559	9	159	351	1.62	28.44	62.79
5000-2000 Lbs.	93.4	−2.6	15.0	578	22	182	367	3.80	31.48	63.49

Table 23.—The Effect of Different Homogenization Pressures on the Stability of Ice Cream When Exposed to Summer Temperatures

Series D. and E. Ten Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	81.4	−3.3	14.5	638	18	211	404	2.82	33.7	63.2
3500-3000 Lbs.	101.3	−3.2	12.5	535	18	425	425	3.17	46.54	79.43
4000-3000 Lbs.	101.3	−3.2	6.0	556	27	467	467	4.67	51.25	83.99
5000-3000 Lbs.	101.3	−3.2	6.0	558	25	461	461	4.49	48.74	82.91
5000-4000 Lbs.	101.3	−3.2	6.0	447	23	447	447	4.12	49.28	80.10

Table 24.—The Effect of Different Homogenization Pressures on the Stability of Ice Cream When Exposed to Summer Temperatures

Series D. and E. Twelve Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
3500-3000 Lbs.	98.6	−4.1	10	586	140	402	551	23.89	68.60	94.02
4000-3000 Lbs.	101.3	−3.75	6	530	155	390	531	29.25	73.58	96.75
5000-3000 Lbs.	101.3	−4.2	9	585	195	432	543	33.33	73.84	96.26
5000-4000 Lbs.	96.0	−3.85	18	532	90	337	498	16.91	63.34	93.60

Table 25.—The Effect of Different Homogenization Pressures on the Stability of Ice Cream When Exposed to Summer Temperatures

Series D. and E. Fourteen Per Cent Fat

Pressures Applied	Per Cent Overrun When Drawn	Temperature When Drawn (°C.)	Minutes Frozen When Drawn	Original Weight of Brick	Loss in Grams In			Loss in Per Cent In		
					1 hr.	2 hrs.	3 hrs.	1 hr.	2 hrs.	3 hrs.
Unprocessed	90.9	−3.0	15.5	615	34	239	372	5.54	38.86	60.48
3500-3000 Lbs.	101.3	−3.2	11.0	562	82	306	478	14.59	54.44	85.06
4000-3000 Lbs.	101.3	−3.2	11.5	564	67	305	543	11.87	54.07	96.27
5000-3000 Lbs.	101.3	−2.8	17.0	563	11	219	423	1.95	38.88	75.13
5000-4000 Lbs.	101.3	−3.2	5.5	573	60	292	533	10.45	50.87	92.85

THE JUDGING OF THE ICE CREAM

Determining the Quality of the Ice Cream

The purpose of scoring the ice cream in this investigation was to determine the effects of various homogenization pressure and pressure combinations on the physical properties of ice cream; to determine the best ice cream of each series, of each percentage of fat, and to determine the relative quality of each percentage of fat.

The most desirable ice cream for commercial purposes can only be determined by organoloptic means.

The one-quart bricks used for judging were taken at the beginning of the draw period. These samples were allowed to age for 48 hours at -17.7° C. (0°F.).

A score card was used in judging the ice creams and the opinion of each judge, working individually, was obtained. The placings were then summarized and first place awarded on points earned, giving first place five points, second place three points, and third place one point.

From each of the five series of pressures, the following individual pressures were chosen by the judges as yielding the best ice cream for their respective series.

10 per cent fat, Series A, 3500; Series B, 3000-1000; Series C, 3500-2000; Series D, 3500-3000; Series E, 5000-4000 pounds pressure.

12 per cent fat, Series A, 2500; Series B, 2500-1000; Series C, 3500-2000; Series D, 3500-3000; Series E, 5000-4000 pounds pressure.

14 per cent fat, Series A, 2000; Series B, 3000-1000; Series C, 2500-2000; Series D, 3500-3000; Series E, 5000-4000 pounds pressure.

16 per cent fat, Series A, 1000 pounds pressure.

Judging and Comparison of the Best Ice Cream of Series F of the Different Percentages of Fat

The purpose of Series F was to determine the pressure of the five different series yielding the best ice cream for each percentage of fat used.

An unprocessed mixture and mixtures homogenized at pressures judged as yielding the best ice cream of each series of the different percentages of fat constituted Series F. The ice cream was scored in the same manner as was the previous series.

In the mixtures containing 10 per cent fat of Series F, the ice cream homogenized at 3500-2000 pounds pressure was considered to be the most desirable. It was described as having a close texture, medium resistant body, warm feel, melting gradually in the mouth, and to be smooth, but without a feeling of toughness or rubberiness to the mouth.

The ice creams containing 12 per cent fat and processed at 3500-1000 pounds and 3500-2000 pounds gave similar results. They were described as having close texture, smooth and resistant body, warm to the mouth, and medium resistant to melting. In the 14 per cent fat mixtures, the 2000 pound pressure was determined to be the best. The judges described the latter ice cream as having a close texture, and resistant smooth, but slightly doughy body, and warm feel to the mouth.

A very porous ice cream of icy resistance such as is obtained in the freezing of the unprocessed mixtures gave a rough feeling in the mouth, due to the presence of large ice crystals. The unprocessed ice creams presented a watery resistance in the mouth, while those processed at extremely high pressures were doughy and required chewing to cause them to break down. Ice cream processed at 3500-2000 pounds pressure was considered the best ice cream manufactured from mixtures containing ten per cent fat. When 3500-1000 and 3500-2000 poudns pressure were applied to the same mixture the resulting ice cream was judged to have the same quality as the mixtures containing twelve per cent fat. In the fourteen and sixteen per cent fat mixtures, the 2000 and 1000 pound pressures, respectively were considered to be the best pressures.

SUMMARY AND CONCLUSIONS

1. Homogenization of an ice cream mixture disintegrates the fat globules, thereby increasing the surface area of the fat.
2. An increase in the butterfat content of an ice cream mixture decreases the amount of free serum and results in an increase in the viscosity and the surface tension.
3. Ice cream mixtures are made more receptive to the incorporation of air as a result of having been homogenized.
4. The total time required to freeze an ice cream and the control of the per cent overrun are governed, in part, by the temperature of the mixture in the freezer.
5. Homogenization lessens the stability of an ice cream at summer temperatures.
6. There is no relation between length of time of freezing and quality of the resulting ice cream, when drawn at the proper consistency.
7. As the butterfat content of an ice cream increases and the solids not fat remained constant, the pressure, judged as producing the best quality ice cream, decreased.
8. The quality of an ice cream is improved as the percentage of fat is increased within the range of ten to sixteen per cent fat.
9. A simultaneous increase of pressure and decrease of the fat content and maintenance of the solids not fat at a constant does not produce an ice cream comparable to a product manufactured from a mixture containing a higher percentage of fat.

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