SOME PROCESSING METHODS
WHICH MAY AFFECT QUALITY IN
ICE CREAM

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SOME PROCESSING METHODS WHICH MAY AFFECT QUALITY IN ICE CREAM

SOME PROCESSING METHODS WHICH MAY AFFECT QUALITY IN ICE CREAM

By

ROGER HAROLD WILKOWSKE

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INTRODUCTION

This investigation was initiated as a part of a larger study of quality in ice cream. Since quality is dependent upon the mix ingredients, processing, and subsequent handling of the frozen product, the factors investigated were some of those about which questions are frequently asked. This field is so broad that it was necessary to limit the scope of the investigation to the effect of processing methods.

The plant operator finds it difficult to measure accurately changes brought about by simple variations in processing. Many such changes may be ascertained only by the use of chemical apparatus or bacteriological methods. Similarly, defects in ice cream may be attributed incorrectly to specific procedures and changes made which are not detrimental to quality. Changes in pasteurization, homogenization, aging, freezing, and hardening may or may not affect slightly or profoundly the type of ice cream, but it is vital that the plant processor know the trend of this effect. Consequently, the factors considered in this thesis have been those which are encountered in all ice cream plants. They are those commonplace factors which may be varied by accident or carelessness, may be changed to avoid a defect, or may be adjusted merely to improve the resulting product.

A vast amount of research has been devoted to the effect of processing methods on the quality of the ice cream. Much of this work has been assembled and cited in the review of literature; however, the results of these previous studies in some cases are not applicable to this study due to the differences in present mix composition, processing equipment, and testing methods.

REVIEW OF LITERATURE

The problem of quality has long been one of moment to men in the field of dairying. In the ice cream industry, there has been a great deal of investigation and research on quality. In this thesis an effort has been made to record as much of this information as is available and pertinent to the problem of the effect of processing methods on quality.

Pasteurization. Gregory and Manhart (45) concluded that methods of preparation and treatment of ice cream mixes affect both the physical and chemical properties of the mix. They reported that pasteurization reduces the viscosity of the mix, which results in lesser overrun obtainable unless the viscosity is restored. The advantages of pasteurization, as listed by Martin (66), are that pasteurization improves keeping qualities, destroys harmful bacteria, aids in dissolving mix ingredients, and reduces the bacteria count.

Martin, Swope, and Knapp (69) found that increasing the pasteurization temperature from 145°F. to 165°F. has no appreciable effect on the acidity, pH, overrun obtained, or time required for freezing. They noted that the higher the pasteurization temperature the more efficient was the destruction of bacteria. Dahle, Keith, and McCullough (21) noted that higher pasteurization temperatures produces the desired overrun in somewhat shorter time. Dahle and Barnhart (20) found that pasteurizing the mix at 170°F. to 180°F. increases protein stability but decreases fat clumping, viscosity, and freezing time. They concluded that higher pasteurization temperatures have a greater effect on the viscosity, overrun

and protein stability than do higher homogenization temperatures. Sommer (90) stated that dairy products heated to 170°F. or higher develop a slight cooked flavor, but that they are less likely to develop an oxidized flavor.

Working on prolonged holding at pasteurization temperature, Martin (65) observed that holding at 150°F. for 3.5 hours resulted in a slight decrease in viscosity and an increase in protein stability. He reported that the holding did not impair the whipping properties or quality.

There have been other methods of pasteurization suggested. Dahle and Knutsen (22) reported that the Electropure process of pasteurization is more efficient than the holding method in destroying bacteria. Dowd and Anderson (29), working with a high-temperature-short-time unit, concluded that ice cream mix, made from cream, milk, and skim milk flakes, can be successfully pasteurized. They added that 180°F. for 19 seconds is as effective as 160°F. for 30 minutes.

Fabricius (38) reported that vacreated ice cream mix in comparison to vat pasteurized mix is superior in flavor score by 1.29 points and that vacreation delays the development of stale, oxidized, and metallic flavor in the finished ice cream. Very favorable results from the use of the Vacreator in making ice cream mixes were reported by Wilster (98). Wilster and Lu (99) reported similar results and concluded that vacreation efficiently reduces bacteria, causes no protein destabilization, and produces a fine flavored mix.

There has been considerable work done on the effectiveness of pasteurization in reducing bacterial population. Fabian and Cromley (37) first reported that pasteurization resulted in a 94.5 to 99.9 per cent reduction in the bacterial count of the mix. They noted that any subsequent operation has a general tendency to increase the plate count. It was observed by Fay and Olson (43), Olson and Fay(77), and Brannon (9) that extreme pasteurization temperatures are unnecessary in producing ice cream of low bacterial content. Fabian and Coulter (36), Paley and Isaacs (78), and Speck (93) agree that ice cream mix exerts a protective action for bacteria at the pasteurization temperatures. Dubois and Martin (30) reported that in mixes made from pasteurized dairy products, the flora consists largely of slow acid formers.

Various investigators - Hahn and Tracy (48), Burgwald and Giberson (10), Caulfield and Martin (11), Hahn and Tracy (48), and Nelson, Caulfield, and Martin (76) - have investigated the applicability of the phosphatase test to ice cream. They agree that the test can successfully be used on ice cream mix and that a pasteurization temperature of 150°F. for 30 minutes will give a negative test. Martin, Nelson, and Caulfield (68) noted that although there was a certain relationship between various tests, the difference was enough to necessitate a variety of tests to ascertain the true quality of ice cream. After examination of thermal death point of pathogens, work on the coliform group, and results of the phosphatase test, Armstrong (5) concluded that 150°F. for 30 minutes is a satisfactory minimum requirement for pasteurization. Sommer (90) supported the conclusion stating that for ice cream mix, made from reasonably good ingredients, a pasteurization temperature of 150°F. for 30 minutes is adequate.

Homogenization. Homogenization has become an indispensable process in the preparation of an ice cream mix and is necessary to prepare quality ice cream with modern freezers. The process of homogenization brought additional problems. Reid and Moseley (84) stated that processing the mix increased the viscosity by increasing the surface area of the fat and by causing clumping of the fat globules. They added that the smoothness of the ice cream is increased by increasing the dispersion of the fat in the mixture.

Doan (27) reported that when fat is present, homogenization destabilizes the proteins of dairy fluids and increases the pH. He attributed the loss of stability partially to the change in pH and partially to the calcium ion. Dahle, Keith, and McCullough (21) reported that the destabilization of the proteins by homogenization also is true in ice cream mixes. The decrease in pH was attributed to the temperature increase during homogenization by Sommer and Menos (92). Doan (28) reported that in the presence of fat the stability of milk proteins, as measured by the alcohol coagulation test, is greatly decreased by homogenization.

The clumping of fat globules in homogenized milk products was first noted by Mortensen (71). DePew (25) concluded that there are two types of viscosity, apparent and basic. He noted that an increase in homogenization pressure causes an increase in viscosity and an increase in the clumping of the fat globules. Early work by Doan (26) states that fat clumping is greatly stimulated in milk and cream mixtures by an increase in either the fat content or the homogenization pressure. However, he noted that the acidity of the plasma had little influence on fat clumping in milk and cream mixtures. Dahle (19) found an increasing tendency for the fat globules to clump as the ratio of the serum solids to the fat decreased.

Reid and Garrison (82) reported that processing the mix decreases the size of the fat globules and causes clumping, but they were unable to obtain any relationship between the size of the clumps and the pressure at which the mix was processed. They found the homogenizing pressure markedly affects the whipping ability of an ice cream mixture and increased pressure results in a greater ease of air incorporation. At the Missouri station, Reid and Skinner (87) and Reid and Russell (85) confirmed earlier work by reporting that an increase in homogenization pressure renders ice cream mix more receptive to the incorporation of air.

The fact that mixes with a high viscosity incorporated overrun more slowly and in smaller amounts than those with less viscosity was noted by DePew (25). Wright (100) agreed, reporting that the whipping properties decreased as the viscosity increased. Hening (53) noted that the lower the homogenization pressure, the larger the fat globules. He also noted that viscosity increased as homogenization pressure increased.

Reid and Moseley (84) and Reid and Russell (85) noted that homogenization lessened the melt down stability of an ice cream mix at summer temperatures. Wright (100) reported that as viscosity increases the rate of melt down is decreased and the manner is also influenced. Erb and Whitworth (34) observed that the higher the homogenizing pressure, the more rapid and smoother the melt down. Leighton, Leviton, and Williams (60) declared that viscosity is an indication of change in quality and physical action when only one factor is varied.

Dahle (19) stated that the pH is lowered slightly when the homogenization pressure is increased from 2500 to 3500 pounds per square inch. Leighton and Leviton (59) found that an increase in homogenization pressure increases stability and maximum overrun. Farrall (41) observed that a higher degree of protein stability is obtained when homogenization is attained without the use of excessive pressures.

Erb and Whitworth (34) stated that the body is improved and a smoother and more rapid rate of melt down is obtained when ice cream mix is processed at the higher pressures. They continued that the higher the homogenization pressure or the more often it was homogenized, the wetter the appearance of the ice cream when drawn from the freezer. Increasing the pressure or rehomogenizing the mix, according to Erb (33), resulted in a wetter appearance when drawn from the freezer. He attributed this condition to the thoroughness of the fat dispersion.

It was reported by DePew (25) that a homogenization temperature of 145°F. produced a greater viscosity of the mix after aging than one of 110°F. He attributed this to the greater dispersion of the fat at higher temperatures. Doan (27) noted that heated plasma has an inhibiting effect on the production of fat clumps by the homogenizer. Dahle (28) found that clumping is decreased as the homogenization temperature is increased. He added that mix homogenized at 170°F. as compared with lower temperatures whips faster and shows less clumping.

Horrall (55) reported that processing the mix at higher temperatures gives better body and texture, decreases fat clumping and basic viscosity, and improves whipping ability. Leighton, Leviton, and Williams (60) observed that increasing homogenization temperature tends to reduce the amount of gelatin or milk fat necessary to produce the same viscosity. In later work, Leighton and Leviton (59) noted that an increase in homogenization temperatures accelerates aging under some conditions.

Reid and Scism (86) stated that emulsification, viscolization, or homogenization caused an increase in viscosity, while re-viscolization or re-homogenization decreased the viscosity. Martin and Dahle (67) have shown that two-stage homogenization reduced the clumping, decreased the viscosity, and increased the whipping ability of mixes. These findings have been confirmed by Hening (50) and others. Reid and Skinner (87) observed that an increaed pressure in a single stage homogenizer caused a uniform increase in viscosity and surface tension. They also noted that a reduction of viscosity with a second stage improved quality. They concluded that increaed homogenization pressures gave corresponding increases in smoothness, body resistance, warmth, and close texture. Working with high solids mixes, Mack (63) found that three stage homogenization entirely eliminated the problem of viscosity, decreased crumbliness, and reduced undesirable melting appearances.

Olson and Fay (77) and Fabian (35) agreed that homogenization broke up the clumps of bacteria and gave an increase in the bacterial count as determined by the agar plate method. Caulfield and Martin (11) stated that no differences were observed in the results of the phosphatase test as a result of homogenization or freezing. Dowd and Anderson (29) reported that homogenization before or after pasteurization does not affect the efficiency of bacterial reduction nor does it bring about any significant difference in viscosity.

There have been a number of comparisons between the high pressure type homogenizer and other machines. Hening (53) compared pressure and centrigugal homogenization and found that low pressure homogenization gave similar results with respect to viscosity and size of fat globules. At the higher pressures, however, he noted that the viscosity and the size of the fat clumps are increased, and also the mixes with a higher viscosity whip less readily.

In a study of rotary and pressure machines, Dahle and Moss (23) concluded that both of the rotary machines tested gave satisfactory results as to body and texture, fat globule size, overrun, and clumping. Tracy and Hahn (94) found that the rotary type machine produces comparable results to the range of 1500 to 2000 pounds pressure on the standard machine. However, they reported that the rotary machine does not produce as desirable results as the high pressure type in the range of 2000 to 3000 pounds pressure, when they checked fat globule size, viscosity, whipping ability, body, texture, and melt down characteristics.

Other studies have been made in which sonic vibrations have been used to homogenize the mix. Anderson (1) compared sonic vibration to pressure homogenization and found that the freezing and whipping time of the mix compares favorably when either of the machines are used. He added that body and texture of oscillated and homogenized mix compared favorably with mixes made from the same ingredients, including gelatin and egg powder. Chambers (12) stated that sonic homogenization has progressed to the point where it is possible on a commercial scale.

Cole and Smith (17) used a 1 per cent agueous solution of nile blue sulfate in an effort to determine the fat globule size and found that the red dye is soluble in the fat and the blue is soluble in the water faction. They recommended use of the dye as an aid for microscopic work. Farrell, Walts, and Hanson (42) reported a method of examining five or more random fields and counted the globules of various sizes. With this method, they developed an index number to give an indication of the efficiency of homogenization.

It was reported by Sherwood and Smallfield (89) that agitation causes a decided reduction in viscosity with an accompanying reduction in the size of the clumps of fat globules. Whitaker (97) observed that there are two types of viscosity and described a device that by mechanical agitation reduces the apparent viscosity to the basic viscosity. Hening (52) concluded that basic viscosity is a value secured under specific conditions and is not a correct minimum value. He reported that mechanical agitation reduces the viscosity by partially splitting the fat clumps, and that different conditions of agitation vary in their effectiveness in splitting the clumps.

Leighton, Leviton, and Williams (60) using a sagging beam method of determining viscosity noted that an increase in temperature tends to reduce the quantity of fat or gelatin necessary to produce the desired viscosity effect. They add that in a series where only one factor is varied, viscosity is an indication of change in quality and physical action of that factor in ice cream. Penczek and Dahlberg (79) reported that the hand emulsifier is more efficient and more practical than agitation to reduce apparent viscosity to basic viscosity.

Protein Stability. Sommer and Binney (91) reported that the alcohol test is helpful in detecting milk that will coagulate upon heating. Martin (65) used for a test of protein stability a mixture of mix, water, and rennet solution. He agitated this solution and noted the time until feathering occurred. Dahle and Rivers (24) and Meiser (70) suggested a test to determine protein stability. In this test they added 5 ml. of mix to 10 ml. of a mixture of 95 per cent alcohol and water. They reported the least concentration of alcohol necessary to just produce floculation in the 15 ml. mixture as the alcohol number.

Aging. Aging of the ice cream mix after processing is a practice widely followed in the ice cream industry. In early work with aging, Mortensen (71) reported that aging for 24 hours increases the yield of ice cream and that aging the mix for 48 hours produced an additional but not as large increase in yield. Gregory and Manhart (45) found that aging helped in obtaining a greater overrun.

DePew (25) observed that aging greatly increases the apparent viscosity of the mix, but that agitation, previous to freezing, in order to decrease the apparent viscosity, did not affect overrun or ease in obtaining overrun. Dahle, Keith, and McCullough (21) stated that aging 4 hours proves as effective as 24 hours with respect to whipping ability. Lucas (62) reported that the longer the aging period the greater the attainable overrun. Leighton and Leviton (59) reported that aging will increase the whipping properties if the mix has been heated.

The following investigators - Martin, Swope, and Knapp (69); Sherwood and Smallfield (89); DePew (28); Reid and Skinner (87); Dahle, Keith, and McCullough (21); Lucas (62); and Hahn (47) - reported that aging the mix will increase the viscosity. Sherwood and Smallfield (89) attribute this increase in viscosity to the grouping of the fat globules. DePew (25) and Wright (100) differ in that they believe the increase in viscosity is due to the formation of a mechanical gel structure. Reid and Skinner (87) stated that the viscosity reaches its peak after 48 to 72 hours of aging. Hahn (46) noted that in a mix containing gelatin the viscosity increases over a 48 hour period. He added that cooling the mix rapidly to 40°F., in comparison to cooling rapidly to 70°F. to 80°F. and then slowly to 40°F., resulted in lower viscosity.

Martin (64) stated that aging materially improves the texture of low solids mixes but is of no practical value with high solids ice cream mixes. Horrall (55) observed that 4 or 24 hours of aging showed little effect on body and texture. Dahle, Keith, and McCullough (21) stated that a satisfactory body and texture is obtained after 4 hours of aging at 40°F., but 24 hours of aging gives some additional improvements in body and texture. Hening (51) concluded thatthe benefits derived from the aging of mix for more than 2 to 4 hours are of minor significance and little commercial value.

Fay (43) stated that aging of the mix for fifteen to eighteen hours does not result in any material increase in bacteria count. Dahle, Keith, and McCullough (21) reported that 24 hours of aging at 40°F. results in a slight decrease in pH and no increase in titratable acidity. With reference to the phosphatase test, Hahn and Tracy (48) reported that holding mix at 40°F. for two weeks did not appreciably alter the phenol value.

Studies at the Massachusetts experiment station resulted in the conclusion by Mueller and Frandsen (74) that higher aging temperatures of 68°F. improves body and texture, increases the viscosity, increases melting resistance, and slightly retards the rate of whipping. They noticed no measurable effect on the pH, titratable acidity, or bacterial growth. Mueller and France (73) reported that aging for 6 hours at 68°F. followed by 18 hours at 38°F., or aging at 38°F. for 24 hours does not increase the bacteria count materially. Mueller (72) attributed any benefits due to higher aging to the formation of gel filiments which in turn offered mechanical obstruction to the formation of large ice crystals.

Freezing. Freezing is an important step in the manufacture of ice cream and a number of investigators have reported on the various aspects of freezing. Hall (49) observed that the size of the ice crystals make the ice cream smooth or coarse, and that quick frozen crystals are small. He also stated that in freezing, the water separates from the mix and freezes out as ice crystals. Reichart (80) noted that the speed of the dasher has no appreciable effect on the rapidity of freezing, speed of whipping, or body and texture of the ice cream. Cole (13) stated that the rate of freezing materially affects the size of the ice crystals, but he was unable to find any correlation between ice crystal size and air cell size. Cole and Boulware (16) found that a good correlation between the ice crystal size and the smoothness of the ice cream can be expected.

Munkwitz and Meade (75) reported that the rate of freezing is dependent upon the sharpness of the blades; the sharper the blades the faster the freezing time. They noted that dull blades caused coarseness in the ice cream. In tests at the University of Maryland, Farrall (40) found that freezing and whipping time are reduced 45 per cent by sharpening the blades. He concluded that dull blades are responsible for reduced capacity, poor air incorporation, coarse texture, and inferior quality.

It was noted by Heyl and Tracy (54) that there is an inverse relation between the body and texture score and the drawing temperature. Dowd and Anderson (29) found that the body and texture of ice cream is more dependent on the method of freezing than on the method of pasteurization or length of aging time.

Hening (50) noted that freezing reduces the size of the fat clusters, but could not find any uniformity in the amount of reduction.

It was also observed by Reid and Skinner (87) that freezing reduces clumping, putting each globule in an individual emulsion. Dahle and Rivers (24) reported that the freezing process does not affect protein stability.

It was observed by Leighton and Leviton (58) that there is a directly proportional relationship between the temperature and the overrun obtainable, i.e., as the freezing temperature decreases there is a decrease in the overrun obtainable. Cole (14) calculated that in a normal 12.3 per cent butterfat mix frozen to 23.9°F., only 41 per cent of the water in the mix is frozen. Leighton and Leviton (59) stated that proper adjustment of the temperature-overrun relationship will lower freezing time. Leighton (57) stated that a maximum whip consistant with the existing temperature is attained in the batch freezer shortly after the refrigeration is turned off.

The introduction of the continuous freezer resulted in investigations comparing the resultant ice cream of the batch and continuous freezer. Bradley and Dahle (7) observed that the type of freezer, as it affects the drawing temperature, will affect the texture, size of ice crystals, and rate of hardening. They found, however, that at similar drawing temperatures, continuously frozen ice cream is smoother than batch frozen ice cream. Erb (32) stated that continuously frozen ice cream is superior to batch frozen ice cream because of the air cell size. Heyl and Tracy (54) reported that ice cream drawn at the same temperature on a counter, batch, and continuous freezer are equal in body determined organoleptically. It was reported by Turnbow, Tracy, and Raffetto (96) that aging the mix 24 hours will improve the body of continuously frozen ice cream and will aid in preventing ice separation during freezing.

Reid (81) observed that dull freezer blades results in impared efficiency, low heat transmission, increased freezing time, coarseness in the ice cream, and lower body and texture scores. He noted that smaller ice crystals give a warmer feeling in the mouth. Farrall (40) noted that 23°F. to 24°F. is the best temperature for whipping and any deviation from that temperature reduces whipping ability. He observed that continuous freezers could whip sufficiently even at the lower freezing temperatures. Working with continuous freezers, Levowitz (61) reported that as the overrun is lowered the ice cream becomes more moist and finally ice lumps will appear. Forster (44) stated that air can not be incorporated until the mix was partially frozen. The longer the time required to get the mix to the proper consistency, the less the time available for whipping and air incorporation.

Fluctuating temperatures, reported Cole (13), will result in the melting of the small ice crystals and refreezing of the melted portion on the large crystals tending to make them larger. Bradley and Dahle (7) found that air circulation, low drawing temperature, and low overrun reduce hardening time. They added that the more rapid the hardening of ice cream, the smaller the size of the ice crystals. Horrall (55) reported that ice cream stored at -10°F. has a better body and texture than that stored at 10°F. Scism (88) noted that ice cream stored at -25°F. resists deterioration exceptionally well, the first noticeable effect being loss of desirable body and texture.

Hardening Ice Cream. In a study of the hardening of ice cream, Tracy and McCowen (95) found that the center temperature remains relatively constant for 5 hours and then drops to 0°F. in 13 hours in a -18°F. hardening room. They added that the rate of hardening is dependent upon the area and shape of the package, and that circulating air increases the rate of hardening 100 per cent. Hahn and Tracy (48) found that storage of ice cream at -20°F. for 12 weeks results in a decrease in phenol values for most of the samples. Arbuckle (2) reported that an increase in overrun tends to decrease the ice crystal and air cell size.

Ice Crystal Size. In early work with photomicrographs of frozen ice cream, Brainerd (8) observed that the finer the division of the fat globules the better the keeping qualities and the smaller the ice crystals in the ice cream. Dahlberg (18) reported that the air cells in homogenized ice cream average 60 microns. He could find no relation between the size of the air cells and texture. Cole (13) stated that the rotary microtome at -18°F. gave the best results when sectioning frozen ice cream. Because of the great difference between the index of refraction of air and of ice crystals, Reid and Hales (83) suggested the use of an embedding material of alcohol and kerosene mixed to have a refractive index of 1.420 at 21°F.

Arbuckle, Decker, and Reid (4) separated the crystals in ice cream and studied their optical properties using a petrographic microscope. In a study of texture and structure, Arbuckle (2) (3) described a technique to examine ice crystals. He reported that as overrun increases, the ice crystal and air cell size decreases. Keller et al (56) used polarized light to distinguish lactose and ice crystals by their optical properties. They used the same sectioning and embedding technique developed earlier at Missouri and outlined by Arbuckle (2).

PLAN OF EXPERIMENT

This investigation was limited to the study of processing methods and their effect on quality. Throughout the problem, only one factor was varied and the ice cream was tested to see how that one variable affected the quality of the resultant product. The mix used throughout the problem was prepared according to the same formula, thereby eliminating any influence which may be attributed to a change in the mix composition. A standardized method of preparation was used in each section so that the only variable would be the one processing method.

The nature of this study was such that it was divided into sections. Consequently, each section was devoted to studying one of the following phases used in the processing of the ice cream:

I. Pasteurization Temperature

II. Homogenization Pressure

III. Homogenization Temperature

IV. Aging Period

V. Hardening Temperature

The phases were studied in the above order since that was the logical sequence for processing ice cream mix under commercial conditions.

A number of different factors are associated with the quality of the ice cream. Consequently, varied tests were conducted on the samples in order to determine quality. Among the tests that would determine the quality of the ice cream and would be affected by the processing methods were the following:

1. Acidity

2. pH
3. Viscosity
4. Surface Tension
5. Alcohol Number
6. Fat Globule Size and Clumping
7. Whipping Characteristics
8. Body and Texture Score
9. Melt Down Characteristics
10. Ice Crystal Size

I. THE EFFECT OF VARYING THE PASTEURIZATION TEMPERATURE ON THE QUALITY OF ICE CREAM

In these experiments all factors but one were constant, and the resulting product was tested to determine how that one variable factor affected quality. Pasteurization temperatures of 150°F., 160°F. and 170°F. respectively were used to pasteurize the mix, and the resulting product was tested to see how that variation affected quality.

Procedure

Ingredients and Composition of the Mix. The mix composition used throughout this investigation was as follows: 39.0 per cent total solids, 12.1 per cent butterfat, 10.9 per cent serum solids, 15.7 per cent sugar, and 0.31 per cent stabilizer. The sweetness of the mix was 15 per cent sucrose when the relative amount and sweetness of the various sugars used were considered. The ingredients used in the preparation of the mix included fresh cream containing 40 per cent butterfat; fresh skimmilk containing 9 per cent solids; roller process skimmilk powder containing 97 per cent milk solids; cane sugar; dextrose containing 92 per cent solids; Sweetose syrup containing 82 per cent solids; and Vestirine. Raw materials used in the preparation of the experimental mixes were obtained from the College Creamery. The following table shows the composition of the mix used throughout the problem.

Table 1. Composition of the Mix.

Ingredients	Pounds	Pounds Fat	Pounds S.S.	Pounds Sugar	Pounds Stab.	Total Solids
Cream	786	314.4	42.4	-	-	356.8
Skimmmilk	1243	-	111.9	-	-	111.9
Skim Powder	134	-	130.0	-	-	130.0
Cane Sugar	273	-	-	273.0	-	273.0
Dextrose	70	-	-	64.4	-	64.4
Sweetose	86	-	-	70.5	-	70.5
Vestirine	8	-	-	-	8.0	8.0
Total	2600	314.4	284.3	407.9	8.0	1014
Per Cent	100	12.1	10.9	15.7	0.31	39.0

Preparation of the Ice Cream. The ingredients used in the mix were combined in a 300 gallon Creamery Package Series B steam vapor pasteurizing vat and heated until all of the ingredients were dissolved and thoroughly mixed. Three portions were then separated from the large batch and placed into ten gallon milk cans. Cans containing the mix were placed in hot water baths and heated until a temperature of 150°F., 160°F., and 170°F. respectively were reached. The mixes were then held at the various pasteurization temperatures for 30 minutes. At the end of the pasteurization period, the mixes were cooled to 150°F. at which temperature they were homogenized in a Manton-Gaulin 25 gallon per hour laboratory homogenizer. The pressure used was 2500 pounds per square inch on a single stage valve with a breaker ring.

Immediately after homogenization the mix was placed in milk cans which were immersed in a 50°F. water bath.

Following aging at 40°F. for 24 hours, the mixes were removed from the cold storage room and frozen in a 40 quart Creamery Package Fort Atkinson Direct Expansion ice cream freezer. The mixes were frozen until the Draw-rite controller read 6 amperes at which time the ammonia was shut off. The temperature of the ice cream at this point was approximately 23.5°F. The ice cream was permitted to whip until an overrun of 90 per cent was reached. At this point samples were obtained directly from the freezer and placed in a hardening room at -10°F. where they were permitted to harden at that temperature under still air conditions. In order to obtain overrun characteristics for the individual mixes, the ice cream remaining in the freezer was whipped for a period of 20 minutes.

Tests for Quality. Included in the tests for quality were the following determinations: acidity, pH, viscosity, surface tension, protein stability, fat globule size and clumping, whipping characteristics, body score, melt down, and ice crystal size. These tests were conducted on samples taken before and after processing and after freezing and melting The procedures used in obtaining these data are explained in the following paragraphs.

1. Acidity. A 9 ml. sample of the mix was placed in a beaker and diluted with 9 ml. of distilled water used to rinse the pipette. Four drops of a one per cent alcoholic solution of phenolphthalein was added to the sample which was then titrated with a 0.1 N NaOH solution. The sample was titrated with constant stirring until a faint permanent pink color was obtained.

2. pH. The pH of each of the samples of mix was determined by means of a Beckman pH Meter, model G (Laboratory Model), equipped with a glass electrode. The potentiometer was standardized immediately before use with a standard buffer solution. All readings were made at a temperature of 20°C.

3. Viscosity. The viscosity of the samples was obtained by following the directions of Eimer and Amend (31), manufacturers of the Improved MacMicheal Viscosimeter used in these experiments. The following conditions were applied in standardization and use of the instrument. A disk bob was submerged to a depth of 3 cm. in the solution at 20°C, and the cup containing the liquid was revolved at a speed of 20 r.p.m. The k (constant) for the instrument was determined by checking it against oils of known viscosity supplied by the Bureau of Standards, U. S.

Department of Commerce. The samples were tempered in a 20°C. water bath for two hours before the readings were made, and the resulting values in MacMichael degrees were then substituted into a formula supplied with the standard oils and converted to centipoise. The samples were tempered in a 20°C. tempered water bath for two hours before the readings were made. For standarizing the instrument a disk bob was submerged to a depth of 3 cm. in a cup containing oils of a known viscosity supplied by the Bureau of Standards, U. S. Department of Commerce. After the k (constant) for the instrument was determined the resulting readings in MacMichael degrees were then substituted into a formula supplied with the standard oils and the readings were converted to centipoises.

4. Surface Tension. A DuNouy tensiometer was used to determine the surface tension of the mixes studied. The procedure followed was that recommended by the Central Scientific Company, manufacturer of the instrument. In each case the tensiometer was standardized before being used, and the surface tension was determined after the mix had been tempered for two hours in a water bath at 20°C.

5. Protein Stability. The alcohol number of the mix was used as an indication of the protein stability. The procedure used was one suggested by Doan (27) and modified by Meiser (70). This procedure involved mixing in a test tube, 5 ml. of mix with 10 ml. of a solution of water and 95 per cent ethyl alcohol, and inverting the tube five times to insure complete mixture. The 10 ml. volume of water-alcohol solution remained constant but the ratio of alcohol to water was varied. This resulted in 15 ml. of mixed solution in which the amount of mix

remained constant while the amount of water and alcohol varied inversely to each other. The alcohol number was the least amount of alcohol necessary to produce precipitation of the protein in the mixture.

6. Fat Globule Size and Clumping. The fat globule size and clumping was determined by a direct microscopic examination of the mix. The microscope was standandized so that the size of the fat globules could be observed at the same time that the sample was examined for clumping. The procedure used was a modification of one suggested by Doan (26). In the procedure used, the mix was diluted 1:100 with distilled water, prepared in a hanging drop slide, and examined directly with a microscope at 970X magnification. Certain problems were encountered in the observations. Not all of the globules were in the same plane and the globules, particularly the larger ones, had a tendency to rise to the top layer. therefore, when examining the mix five fields were used and by moving the focus up and down and the average size of the fat globules and the degree of clumping were observed. The size of the fat globules was measured by a scale in the eyepiece of the microscope. The relative degree of clumping was expressed from 0 to +++++ depending upon the amount of clumping observed: 0 when no clumping was observed, + when clumps of 2 to 5 globules were observed, ++ when clumps of 5 to 10 globules were observed, +++ when clumps of 10 to 20 globules were observed, ++++ when clumps of 20 to 50 globules were observed, and +++++ when clumps of over 50 globules were observed.

7. Whipping Characteristics. The whipping characteristics of each of the the mixes was determined by taking an overrun reading on the ice cream at one minute intervals for a period of 20 minutes after the

ammonia was turned on. In all cases the mix was frozen to a reading of 6 amperes on the Draw-rite controller which gave a drawing temperature of 23.5°F.

8. <u>Body and Texture Score</u>. The body and texture score was obtained for each of the samples of ice cream prepared in this experiment. The samples were stored in a -10°F. hardening room until scoring and then placed at room temperature for a few minutes prior to being scored for body and texture organoleptically. In keeping with the standards set up by the Committee on Judging of Dairy Products, American Dairy Science Association, a score of 30 points was considered a perfect score. The same ingredients were used in each of the mixes; therefore the ice cream was not scored for flavor unless some notable difference in flavor of the dairy products was detected.

9. <u>Melt Down</u>. The melting characteristics for each batch of ice cream prepared was determined by placing 100 grams of ice cream on a wire screen having a 12 by 12 melt per inch. The ice cream was permitted to melt at a temperature of 25°F. (77°F.) for one and one-half hours. The melted ice cream was caught in funnels and directed into graduate cylinders, in which it was held for a period of time sufficiently long to permit the foam to collapse. The volume of mix collected in this manner was used as an indication for the rate of melt down. The appearance of the melt down was noted and recorded during the melting process.

10. <u>Ice Crystal Size</u>. The size of the ice crystals was determined for each sample of ice cream by a direct microscopic examination of the frozen ice cream. The procedure used was modification of techniques suggested by Cole (13), Reid and Hales, (83) and Arbuckle (2), and

necessitated preparing a thin section of ice cream with the use of a table model microtome. The sectioning was most successful after the ice cream had been hardened to a temperature of -10°F. to -20°F. The slices of ice cream were then placed on a slide and covered with an embedding material consisting of a mixture of alcohol and kerosene having a refractive index of 1.420 at 20°C. Using a microscope with a 100X magnification, the size of the ice crystals could be measured with an occular micrometer in the eyepiece of the microscope. Since it was imperative that the ice cream remained firm during sectioning and examination, the above procedure had to be carried out at hardening room temperatures.

Experimental Results

Effect of Pasteurization Temperature on Acidity. Samples of each of the mixes were obtained at various stages in the processing and tested for acidity. The results of the titrations are given in the following table.

Table 2. The Effect of Varying the Pasteurization Temperature on the Acidity of the Mix.

Pasteurization Temperature	Per Cent Acidity Batch G	Batch J	Batch M	Batch R	Batch U
	Before Processing				
100°F.	0.225 %	0.230 %	0.240 %	0.226 %	0.230 %
	After Processing				
150°F.	0.235	0.235	0.240	0.220	0.232
160°F.	0.228	0.233	0.237	0.215	0.230
170°F.	0.230	0.235	0.237	0.218	0.236
	After Freezing				
150°F.	0.240	0.232	0.234	0.214	0.223
160°F.	0.248	0.230	0.238	0.215	0.227
170°F.	0.244	0.225	0.230	0.216	0.225

The results of the acidity determinations failed to show any tendency for either a decrease or increase in acidity. Therefore, it was concluded that the temperature of pasteurization does not affect the acidity.

Effect of Pasteurization Temperature on pH. Potentiometric determinations on each of the mixes were made to determine their hydrogen ion concentration. The resulting readings are given in the following table.

Table 3. The Effect of Varying the Pasteurization Temperature on the pH of the Mix.

Pasteurization Temperature	pH Readings				
	Batch G	Batch J	Batch M	Batch R	Batch U
			Before Processing		
100°F.	6.36	6.35	6.36	6.35	6.35
			After Processing		
150°F.	6.36	6.36	6.36	6.32	6.37
160°F.	6.35	6.35	6.35	6.34	6.37
170°F.	6.35	6.36	6.35	6.33	6.36
			After Freezing		
150°F.	6.35	6.34	6.36	6.37	6.37
160°F.	6.36	6.36	6.37	6.35	6.37
170°F.	6.35	6.36	6.37	6.35	6.35

The above results showed that the pH variation was insignificant in these tests and would indicate that the pasteurization temperature has little influence upon the pH of the mix.

Effect of Pasteurization Temperature on Viscosity. Viscosity determinations on the MacMichael viscosimeter were made on each of the batches of ice cream. The results of these tests are given in the table on thee following page.

It will be noted that in all of the mixes the viscosity was appreciably increased by processing and lowered by freezing. The increase in viscosity of the samples due to processing was attributable to the clumping of the fat globules induced by homogenization. Conversely, the agitation during freezing reduced the clumping, tending to put each globule in an individual suspension. The viscosity in the samples after aging varied inconsistantly showing no trend to indicate that the viscosity was affected significally by the temperature at which the mix was pasteurized.

Table 4. The Effect of Varying the Pasteurization Temperature on the Viscosity of the Mix.

Pasteurization Temperature	Centipoise				
	Batch G	Batch J	Batch M	Batch R	Batch U
	Before Processing				
100°F.	76.1	102.2	46.2	47.7	36.8
	After Processing				
150°F.	214.7	141.4	339.9	125.3	125.2
160°F.	205.7	230.1	279.7	146.3	122.7
170°F.	197.4	266.6	323.4	202.0	160.2
	After Freezing				
150°F.	45.1	93.1	63.4	51.5	48.7
160°F.	46.6	81.9	71.8	59.2	54.1
170°F.	45.9	88.4	79.4	63.5	57.7

Effect of Pasteurization Temperature on Surface Tension. At three times during the preparation, samples of the mix were secured and surface tension determinations were made on them. These readings are given in the table on the following page.

The temperature of pasteurization apparently had no effect on surface tension; however, it was noted that the readings on the frozen samples tended to be lower. This probably was due to the reduction in the amount of fat in suspension as a result of partial churning by the freezer.

Table 5. The Effect of Varying the Pasteurization Temperature on the Surface Tension of the Mix.

Pasteurization Temperature	Dynes per cm. Batch G	Batch J	Batch M	Batch R	Batch U
		Before Processing			
100°F.	48.3	46.4	46.2	46.6	43.4
		After Processing			
150°F.	46.3	48.2	49.2	49.2	48.3
160°F.	46.8	48.6	49.0	50.1	48.2
170°F.	46.9	48.1	48.8	50.0	47.9
		After Freezing			
150°F.	43.1	49.2	46.7	46.5	46.8
160°F.	41.7	48.2	45.8	47.3	45.5
170°F.	42.5	48.6	46.5	47.2	46.2

<u>Effect of Pasteurization Temperature on Protein Stability</u>. Alcohol numbers, as an indication of protein stability, were determined on each of the samples secured at various stages during preparation. The following table contains the results of the alcohol number tests.

Table 6. The Effect of Varying the Pasteurization Temperature on the Alcohol Number of the Mix.

Pasteurization Temperature	Stability: Alcohol Number Batch G	Batch J	Batch M	Batch R	Batch U
		Before Processing			
100°F.	7.4	7.3	7.6	7.4	7.4
		After Processing			
150°F.	7.5	7.5	7.3	7.4	7.4
160°F.	7.4	7.4	7.2	7.3	7.3
170°F.	7.4	7.4	7.1	7.2	7.3
		After Freezing			
150°F.	7.5	7.5	7.6	7.3	7.7
160°F.	7.4	7.5	7.4	7.3	7.6
170°F.	7.3	7.5	7.3	7.3	7.5

The results of these tests show that the alcohol number of the mix had a tendency to be lowered as the pasteurization temperature increased; however, the decrease was relatively small. The results also indicate that the freezing process did not appreciably affect the alcohol number.

<u>Effect of Pasteurization Temperature on Fat Globule Size</u>. Each of the samples of mix was diluted and observed by direct microscopic examination of a hanging drop of the mixture. The average size of the fat globules was determined by observing five or more fields and estimating the average size using the scale in the eyepiece of the microscope as a measure. The results of the examinations are given in the following table.

Table 7. The Effect of Varying the Pasteurization Temperature on the Fat Globule Size in the Mix.

Pasteurization Temperature	Size of Fat Globules in Microns				
	Batch G	Batch J	Batch M	Batch R	Batch U
	Before Processing				
100°F.	4.0	4.0	3.5	4.0	3.5
	After Processing				
150°F.	1.75	1.75	1.5	2.0	2.0
160°F.	1.75	1.5	1.5	2.0	1.75
170°F.	2.0	1.5	1.5	2.0	1.75
	After Freezing				
150°F.	2.0	2.5	2.5	3.5	4.0
160°F.	3.0	2.5	4.0	3.0	4.0
170°F.	4.0	2.0	3.5	3.0	4.0

The mix, before being processed, had globules averaging 3.5 to 4.0 microns in diameter in all of the batches prepared. The processing of the mix resulted in a finer dispersion of the fat globules averaging 1.5 to 2.0 microns in diameter. There was, however, no tendency either to decrease or increase in size as the pasteurization temperature increased. The freezing process resulted in an increase in the size of the fat globules, which probably was brought about by the mechanical agitation of the mix.

<u>Effect of Pasteurization Temperature on Fat Clumping</u>. The degree of fat clumping in each of the mixes was determined at the same time the fat

globule size was noted. The results of the observations of fat clumping are given in the following table.

Table 8. The Effect of Varying the Pasteurization Temperature on the Fat Clumping in the Mix.

Pasteurization Temperature	Extent of Fat Clumping Batch G	Batch J	Batch M	Batch R	Batch U
		Before Processing			
100°F.	0	0	0	0	0
		After Processing			
150°F.	+	+	+++	+++	++
160°F.	++	++	+++	+++	++
170°F.	++	+++	+++	+++	++
		After Freezing			
150°F.	0	+	+	+	+
160°F.	+	+	+	+	+
170°F.	+	+	+	+	+

In all of the samples it will be noted that there was no observable clumping in the mix before being processing. In all cases the processing of the mix resulted in clumping of the fat to some degree; however, there was no uniformity in the increase of clumping tendencies within or between the various batches. Homogenization of the mix induced the clumping of the fat globules during the processing. The agitation during the freezing process resulted in a decrease in fat clumping in all of the samples except one, in which the original clumping was slight, but freezing did not completely eliminate the clumping.

<u>Effect of Pasteurization Temperature on Body and Texture Score</u>. The body and texture score for each of the samples of ice cream made from the mix, pasteurized at the various temperatures used, was determined organoleptically. The resulting scores are given in the following table.

Table 9. The Effect of Varying the Pasteurization Temperature on the Body and Texture Score of the Ice Cream.

Pasteurization Temperature	Body Scores				
	Batch G	Batch J	Batch M	Batch R	Batch U
150°F.	28.50	28.50	28.00	28.00	28.25
160°F.	28.25	28.25	28.00	28.00	28.25
170°F.	28.25	28.25	28.00	28.00	28.25

It will be observed that the body and texture scores for the ice cream prepared in this phase of the experiment did not exhibit any wide variation, and that the score of the samples within a batch had a maximum variation of only 0.25 points. It was concluded that the body and texture are not significally affected by the temperature of pasteurization.

<u>Effect on Pasteurization Temperature on Rate of Melt Down</u>. A sample of each of the batches of ice cream was permitted to melt, following the procedure given earlier, to determine the rapidity of melting. The amounts of liquid obtained indicating the rate of melt down are given in the following table.

Table 10. The Effect of Varying the Pasteurization Temperature on the Rate of Melt Down of the Ice Cream.

Pasteurization Temperature	Melt Down in ml.				
	Batch G	Batch J	Batch M	Batch R	Batch U
150°F.	30 ml.	34 ml.	35 ml.	37 ml.	47 ml.
160°F.	31	35	34	36	46
170°F.	28	28	36	47	40

The results on the preceding table show that there was no consistency in the rate of melt down of the samples. In the melting process, all of the samples were observed to have a smooth, creamy melt down. No significant difference in the rate or manner of melt down was observed between or within the batches. Therefore, the conclusion that the pasteurization temperature does not appreciably affect the melt down characteristics was made.

Effect of Pasteurization Temperature on Size of Ice Crystals. A direct microscopic examination of each of the batches was made to determine the size of the ice crystals. The results of the examinations are given in the following table.

Table 11. The Effect of Varying the Pasteurization Temperature on the Size of the Ice Crystals in the Frozen Ice Cream.

Pasteurization Temperature	Size of Ice Crystals in Microns				
	Batch G	Batch J	Batch M	Batch R	Batch U
150°F.	40	40	40	30	45
160°F.	45	40	40	30	45
170°F.	40	40	40	35	45

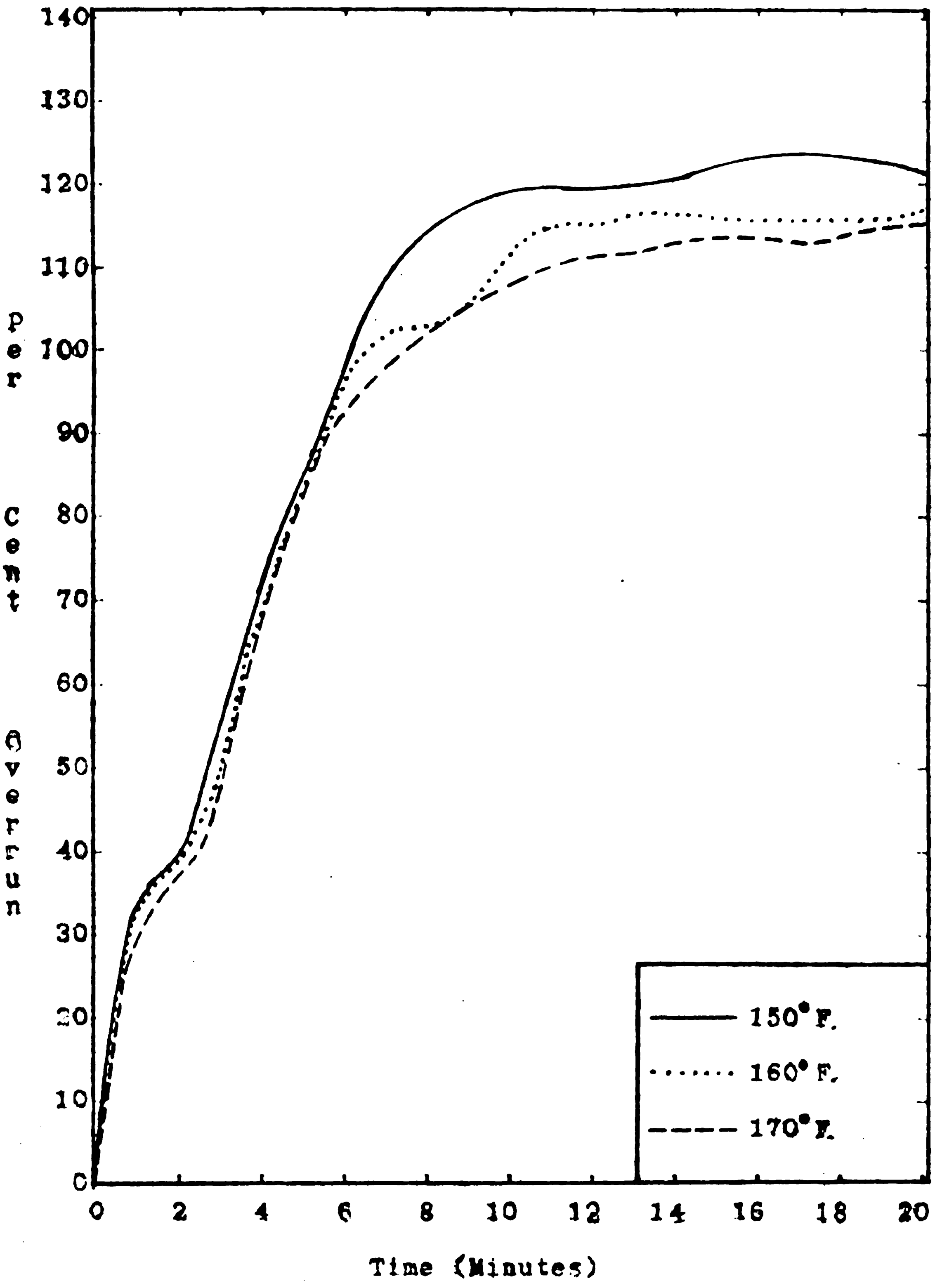
It was observed that the size of the ice crystals varied in length from 30 to 45 microns. The variation within the samples was small with no trend toward an increase or decrease in the size of the crystals. It was concluded that temperature of pasteurization is not instrumental in determining the size of the ice crystals.

Effect of Pasteurization Temperature on the Whipping Characteristics. The overrun percentages taken during the entire freezing process were recorded for each of the batches made. These readings that show the whipping characteristics of each of the batches and the average of all of the batches are plotted on the graphs on the following pages.

Overrun characteristics of the various batches of ice cream were unusually similar, there being only slight variations in the rate and capacity of whipping noted in the different batches. The uniformity of these results showed that the pasteurization temperature does not affect the whipping characteristics.

THE EFFECT OF VARYING THE PASTEURIZATION TEMPERATURE ON OVERRUN CHARACTERISTICS

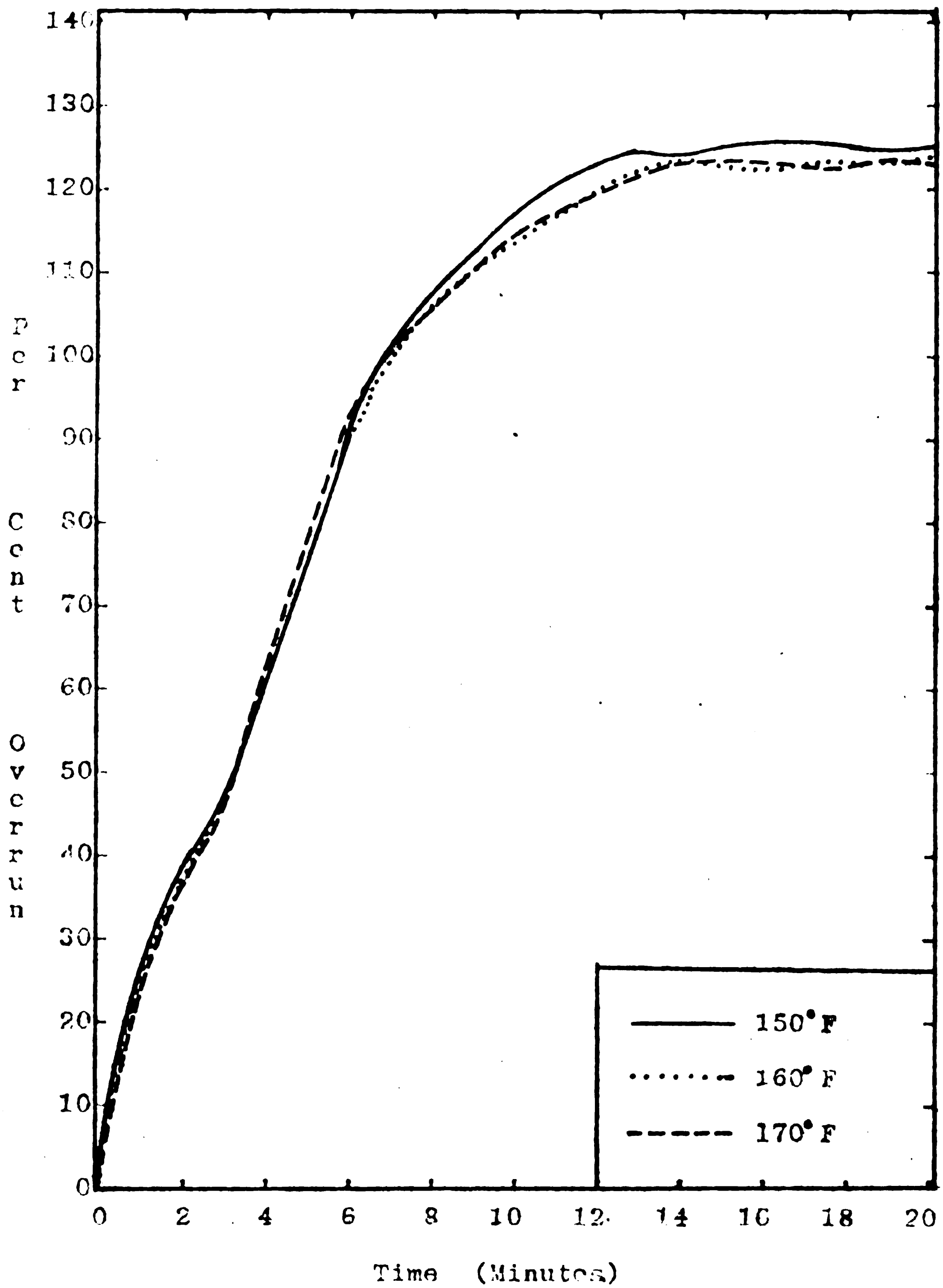
BATCH G



THE EFFECT OF VARYING THE PASTEURIZATION TEMPERATURE

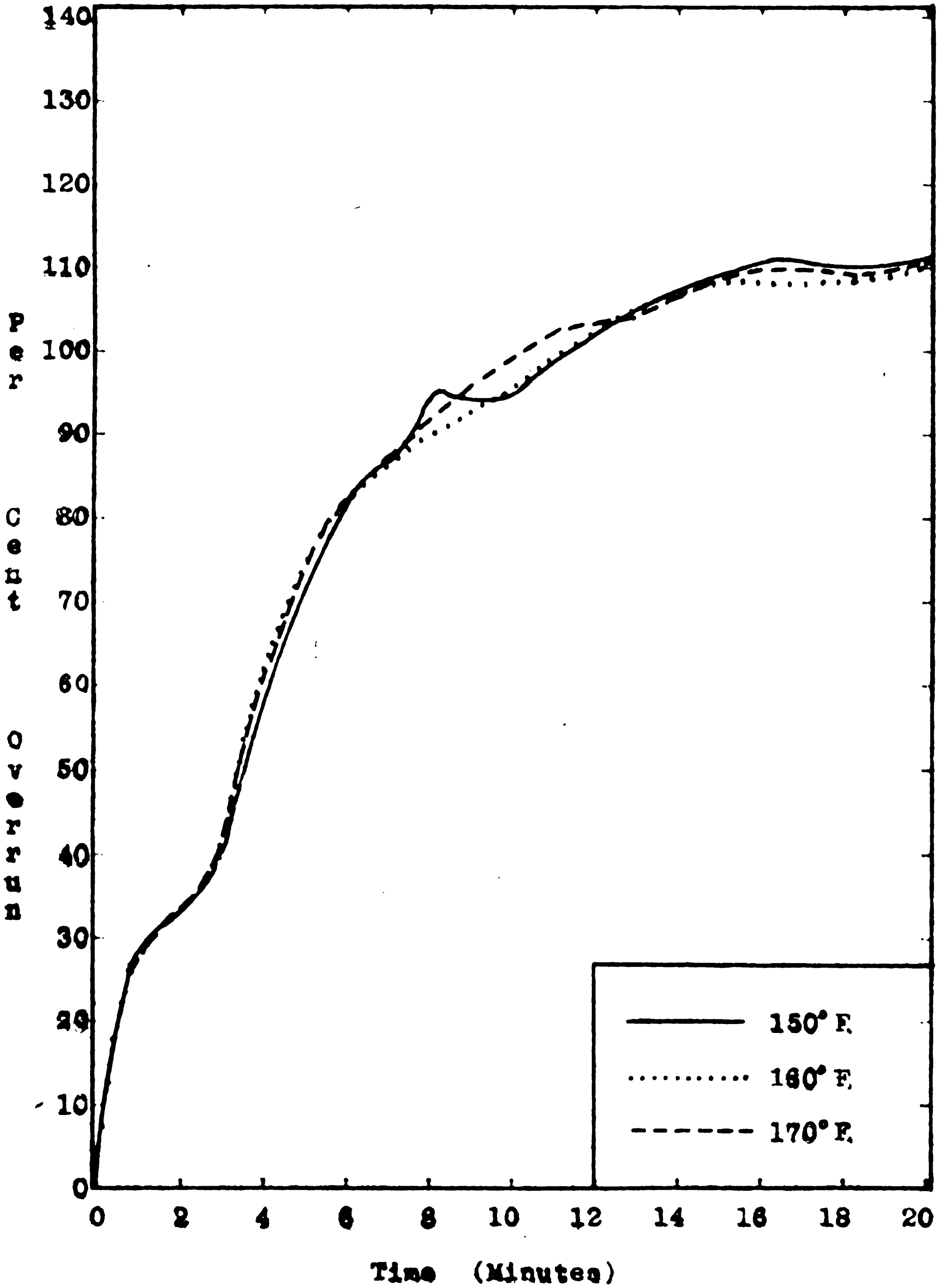
ON OVERRUN CHARACTERISTICS

BATCH J



THE EFFECT OF VARYING THE PASTEURIZATION TEMPERATURE ON OVERRUN CHARACTERISTICS

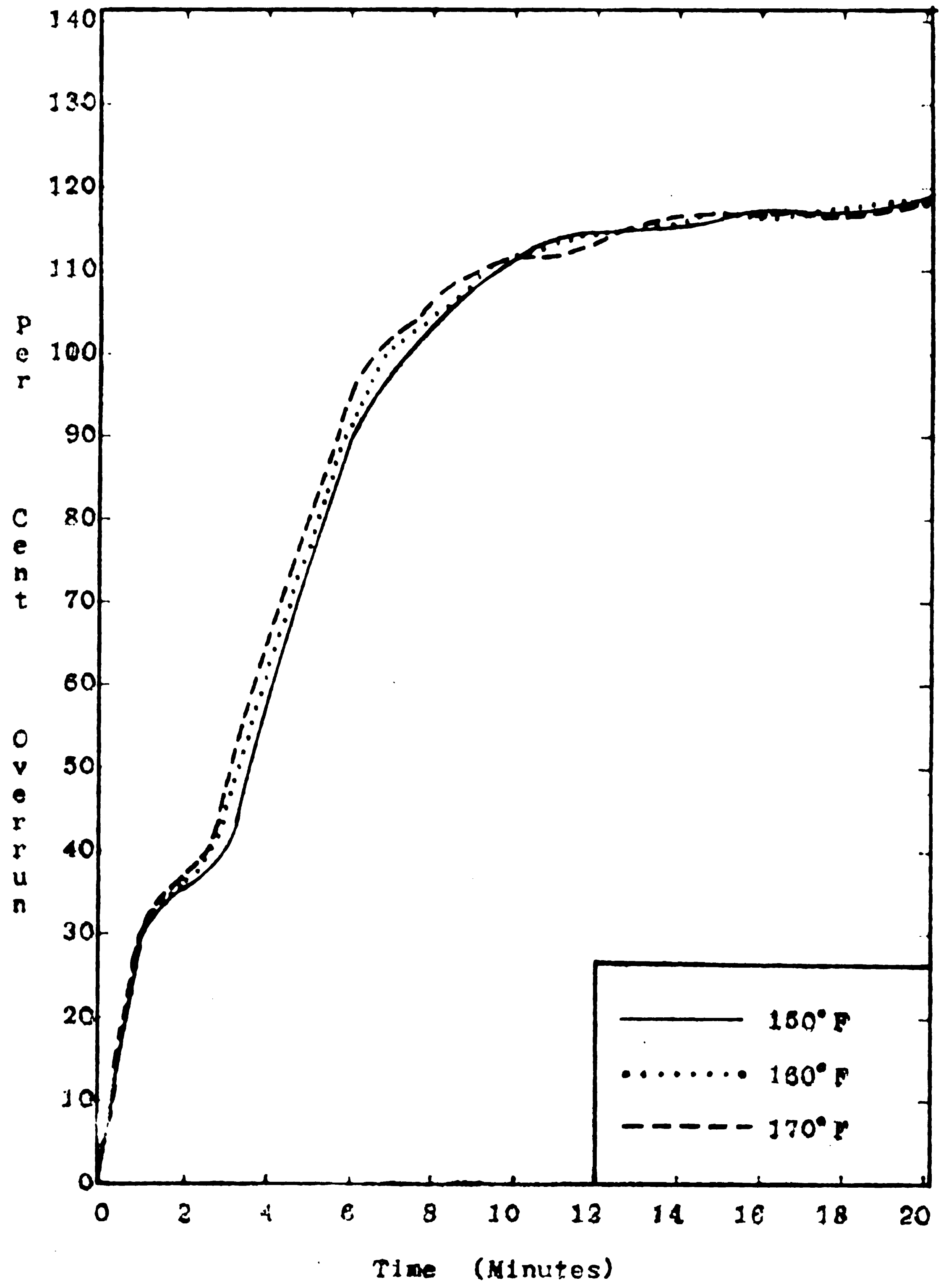
BATCH M



THE EFFECT OF VARYING THE PASTEURIZATION TEMPERATURE

ON OVERRUN CHARACTERISTICS

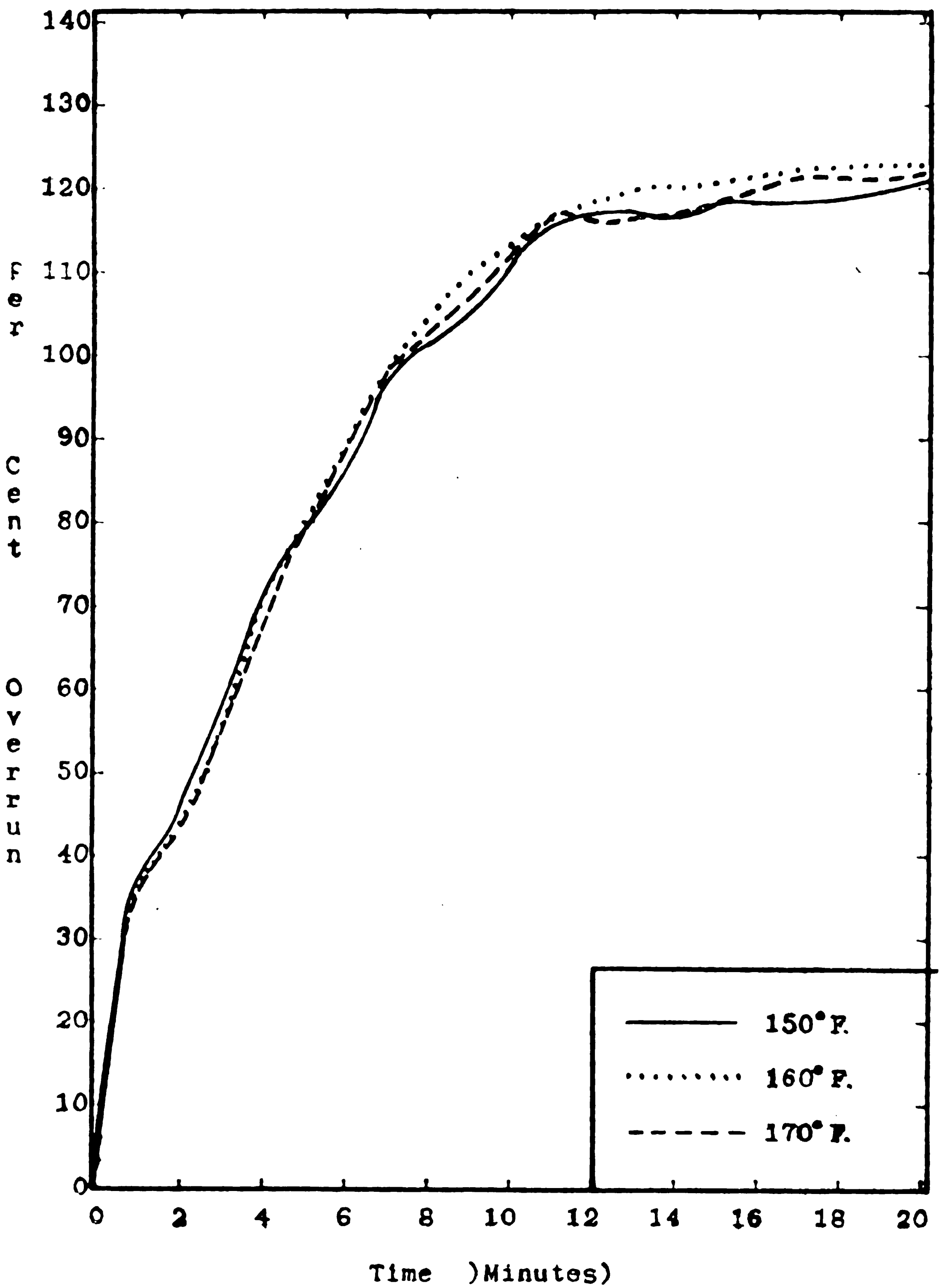
BATCH R



THE EFFECT OF VARYING THE PASTEURIZATION TEMPERATURE

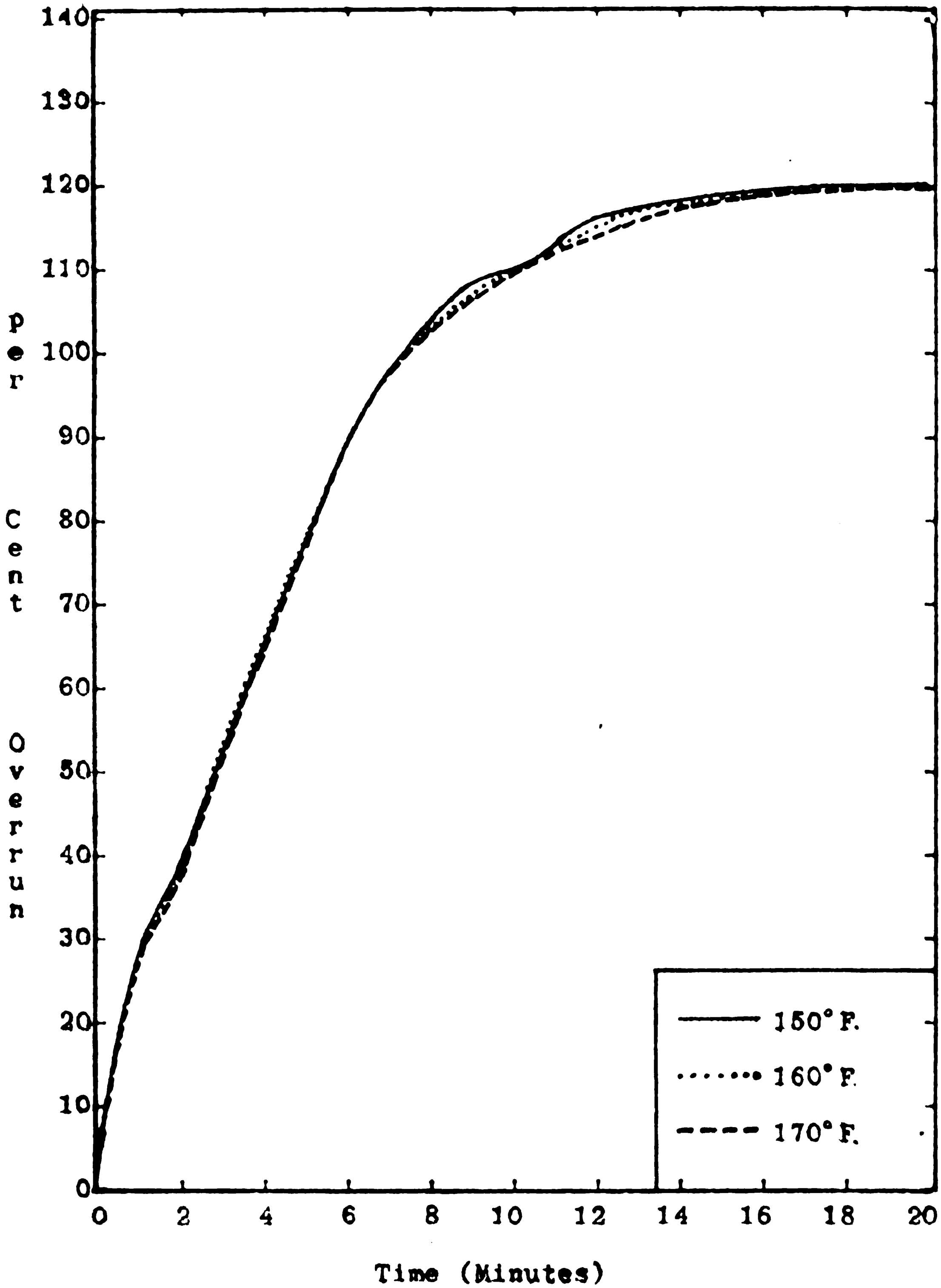
ON OVERRUN CHARACTERISTICS

BATCH U



THE EFFECT OF VARYING THE PASTEURIZATION TEMPERATURE ON OVERRUN CHARACTERISTICS

AVERAGE OF BATCHES G, J, M, R, and U



Discussion of Results

The results of these experiments showed that the pasteurization temperatures used had little if any effect on the quality of the ice cream as determined by the tests for quality used in this problem. The fact that pH or acidity was not materially altered by different pasteurization temperatures is in agreement with results obtained by Martin, Swope, and Knapp (69).

The viscosity tests showed conflicting results. As the pasteurization temperature was increased, the viscosity in batch G decreased while the viscosity in batches J and R increased. The viscosity in batches M and U did not exhibit any constant change. Gregory and Manhart (45) have reported that pasteurization reduces the viscosity. Dahle and Barnhart (20) found that pasteurizing at the higher temperatures of 170°F. to 180°F. reduced the viscosity. However, the data here failed to show that the pasteurization temperatures used had any effect on the viscosity.

There was noted a decrease in the viscosity of the mix after it had been frozen and melted. Previous studies, (52), (79), (89), and (97) have reported that mechanical agitation of the mix resulted in a lowering of viscosity, thus the agitation during the freezing process with the accompanying reduction in fat globule clumping apparently brought about the decrease in viscosity observed in these results.

No reference in the literature could be found concerning the effect of pasteurization temperature on the surface tension of the mix. The results of the surface tension determinations in this problem lacked consistency, failing to show any consistent change with an increase in the pasteurization temperature. The surface tension values after freezing tended to be lower but were not uniform in the amount of reduction and in some cases actually showed an increase in value. The variations in the surface tension readings after freezing were probably due to the reduction of fat in suspension by the partial churning during freezing.

The results of the alcohol number determinations showed that within a batch the alcohol number tended to increase as the pasteurization temperature decreased. Dahle and Barnhart (20) have reported the protein stability of the mix to be increased by pasteurization temperatures of 170°F. to 180°F. The findings in this study do not agree with these results. The results showed the protein stability to be lowered slightly as the pasteurization temperature is increased from 150°F. to 170°F. Probably the reduction was associated with a denaturation of the protein by the additional heat at the higher pasteurization temperatures, thereby reducing the protein stability. There were no indications that the freezing process had any effect on the protein stability.

The clumping and size of the fat globules were determined at the same time in a sample of mix that had been diluted 1:100 with water. The observations failed to show any significant variation in the size of the fat globules as the pasteurization temperature increased. However, there was noted a marked decrease in the size of the globules due to processing. The homogenization during processing was responsible for this decrease in fat globule size. An increase in the size of the fat globules was noted as a result of the freezing process, but there was no uniformity observed in the amount of increase.

Examination of the mix showed a lack of clumping of the fat globules before processing, but clumping was observed in all of the processed samples. There was no apparent relation between the amount of clumping and the temperature of pasteurization. The freezing process resulted in a decrease in the amount of clumping. However, the reduction was not uniform with all of the mixes. The clumping was associated with the change on the fat globules; however, the mechanical agitation during freezing apparently was sufficient to overcome this attraction. This observation is in agreement with earlier results of Hening (50).

The results of the body and texture scores, rate of melt down, and ice crystal size determinations showed only slight variation and with no consistent trends. The uniformity of the results indicated that the pasteurization temperature had no appreciable effect upon the body and texture score, rate of melt down, or ice crystal size.

The graphs of the overrun tests failed to show any appreciable difference in the overrun characteristics due to the pasteurization temperature. Dahle, Keith, and McCullough (21) and Dahle and Barnhart (20) have reported that higher pasteurization temperatures reduced the freezing time. Gregory and Manhart (45) reported pasteurization resulted in lesser overrun unless the viscosity was restored. On the other hand, Martin, Swope, and Knapp (69) have reported that the pasteurization temperature had no appreciable effect upon the amount of overrun obtained or the time required for freezing. The findings of this study indicated that the temperature of pasteurization used resulted in no significant difference in either the rate or amount of overrun obtained.

II. THE EFFECT OF VARYING THE HOMOGENIZATION PRESSURE ON THE QUALITY OF ICE CREAM

In this portion of the experiment, homogenization pressure was the only variable. Pressures of 1500 to 3500 pounds per square inch increasing in 500 pound increments were used. The product was then tested to see how the variation in the homogenization pressure affected the quality of the resulting ice cream.

Procedure

The procedure used in this study was the same as that used in the study of pasteurization temperatures with a few exceptions that will be enumerated below. In all cases, the ingredients, composition of the mix, tests, and testing methods used were the same as thoselisted previously on pages 19 to 25 .

Following pasteurization at 150°F. for 30 minutes, the mix was homogenized at a temperature of 150°F. using a Cherry-Burrell Model 238 Viscolizer with a capacity of 200 gallons per hours. Pressures of 1500, 2000, 2500, 3000, and 3500 pounds per square inch were used on the machine which had a breaker ring around the single-stage homogenizing valve. Immediately after processing, the mix was collected in 10 gallon milk cans, and cooled by placing the cans in a 50°F. water bath. As in the previous section, the mix was aged for 24 hours in a 40°F. cold storage room before it was frozen. All of the other steps in the preparation and handling excepting those listed above were the same as those in the preceding section pertaining to pasteurization temperatures.

Experimental Results

Effect of Homogenization Pressure on Acidity. The titratable acidity of each of the mixes was obtained to determine if the pressure of homogenization had any effect on the acidity of the mix. Mix samples were secured before and after the processing. Also portions of frozen ice cream from their respective mixes were melted and samples taken for analysis. The acidity tests were made following the procedure given in the section on testing the mix and the results recorded in the following table.

Table 12. The Effect of Varying the Homogenization Pressure on the Acidity of the Mix.

Homogenization Pressure	Per Cent Acidity				
	Batch X	Batch A	Batch F	Batch K	Batch P
	Before Processing				
0 lbs.	0.225 %	0.240 %	0.235 %	0.230 %	0.216%
	After Processing				
1500	0.222	0.235	0.220	0.232	0.211
2000	0.218	0.240	0.212	0.224	0.215
2500	0.218	0.238	0.205	0.220	0.208
3000	0.220	0.240	0.210	0.224	0.208
3500	0.217	0.237	0.215	0.218	0.213
	After Freezing				
1500	0.220	0.228	0.224	0.213	0.220
2000	0.222	0.230	0.220	0.215	0.215
2500	0.220	0.223	0.225	0.214	0.212
3000	0.220	0.230	0.220	0.221	0.213
3500	0.220	0.220	0.220	0.220	0.212

The results of the acidity tests varied appreciably between samples. However, there was noted a tendency for the acidity to be decreased by the processing of the mix. Contributing factors to this decrease could be the loss of carbon dioxide due to the heat treatment and a finer dispersion of the mix constituents. Considering these facts, the pressure of homogenization apparently had little or no effect on the acidity of the samples.

Effect of Homogenization Pressure on pH. To observe the effect of homogenization pressure on pH, electrometric determinations were run on the samples for each of the homogenization pressures. Samples were obtained before and after processing, and after freezing and melting. The results of the pH determinations are recorded in the following table.

Table 13. The Effect of Varying the Homogenization Pressure on the pH of the Mix.

Homogenization Pressure	pH Readings				
	Batch X	Batch A	Batch F	Batch K	Batch P
		Before Processing			
0 lbs.	6.36	6.32	6.35	6.36	6.36
		After Processing			
1500	6.37	6.33	6.34	6.35	6.34
2000	6.37	6.36	6.36	6.34	6.35
2500	6.37	6.35	6.36	6.36	6.35
3000	6.37	6.35	6.36	6.34	6.34
2500	6.36	6.35	6.35	6.35	6.35
		After Freezing			
1500	6.35	6.35	6.36	6.34	6.36
2000	6.36	6.33	6.36	6.35	6.35
2500	6.36	6.34	6.37	6.35	6.35
3000	6.35	6.33	6.36	6.35	6.35
3500	6.35	6.33	6.35	6.34	6.35

The results of the pH determinations show the pH to be remarkably constant. The small variation indicated that the homgenization pressures used had little if any effect upon the pH of the mix.

Effect of Homogenization Pressure on Viscosity. The viscosity of the samples at each of the homgenization pressures used was determined before and after processing, and after freezing and melting. The viscosity determinations were made on a MacMichaels viscosimeter following the procedure given previously. The results of the viscosity determinations are given in the following table.

Table 14. The Effect of Varying the Homogenization Pressure on the Viscosity of the Mix.

Homogenization Pressure	Centipoise Batch X	Batch A	Batch F	Batch K	Batch P
			Before Processing		
0 lbs.	95.9	120.9	105.3	130.7	49.8
			After Processing		
1500	159.8	141.7	123.7	183.2	78.9
2000	222.0	163.6	144.0	205.7	92.5
2500	248.9	205.3	162.1	225.6	114.4
3000	291.4	267.0	178.0	261.3	132.0
3500	322.0	310.6	193.8	318.8	163.0
			After Freezing		
1500	115.4	70.5	42.9	70.5	52.6
2000	126.0	83.3	41.4	69.2	56.4
2500	120.3	100.0	42.9	65.2	59.2
3000	120.5	120.5	41.0	67.7	62.2
3500	124.1	105.8	40.4	73.7	62.6

Processing the mix resulted in an increase in the viscosity, however the increase was not uniform in all cases. The viscosity in the processed samples increased as the pressure of homogenization was made higher. Finer dispersion of the mix ingredients coupled with a clumping of the fat globules induced by homogenization are thought to be responsible for increase in viscosity. There was a close correlation between the viscosity readings and the clumping of the fat globules. Conversely, the freezing process brought about a decrease in viscosity.

Effect of Homogenization Pressure on Surface Tension. The surface tension of each of the samples was determined following the procedure outlined previously. Tests were made on each of the samples and compiled in the table on the following page.

The variation in the results of these tests were not great; however a tendency for the surface tension to increase slightly as the homogenization pressure increased was noted, but there were several irregularities and exceptions to this. Apparently the higher homogenization pressure brought about a finer dispersion of the mix constituents, thereby producing a more closely knit surface. Freezing, however, resulted in a lowering of the surface tension. The probable cause of this reduction was thought to be a lack of homogeneity of the samples due to the partial churning of the fat during freezing with an accompanying reduction in the amount of fat in suspension.

Table 15. The Effect of Varying the Homogenization Pressure on the Surface Tension of the Mix.

Homogenization Pressure	Dynes Per cm. Batch X	Batch A	Batch F	Batch K	Batch P
		Before Processing			
0 lbs.	47.5	48.3	47.4	47.8	46.6
		After Processing			
1500	48.2	48.4	48.5	48.9	48.2
2000	48.8	47.6	48.3	49.2	49.0
2500	48.0	47.9	48.7	49.7	49.1
3000	48.9	47.4	49.0	49.5	49.5
3500	48.6	47.9	48.8	51.5	49.8
		After Freezing			
1500	47.8	47.7	44.2	46.5	47.4
2000	46.7	47.3	44.8	46.2	47.4
2500	47.4	47.2	43.5	46.9	47.9
3000	47.5	46.9	42.0	47.4	47.7
3500	471.	47.8	46.5	47.5	48.5

Effect of Homogenization Pressure on Protein Stability. The protein stability as indicated by the alcohol number was determined on each of the samples for each of the pressures used. Tests were made before processing, after processing, and after freezing and melting by following the procedure previously given. The resulting values are given in the table on the following page.

The outcome of the tests show that in all of the batches except batch A the alcohol number had a tendency to decrease slightly as the homogenization pressure increased. The higher pressure of homogenization apparently resulted in a slight destabilization of the proteins. The freezing process, however, produced no marked trends to indicate that it had any appreciable effect on the protein stability.

Table 16. The Effect of Varying the Homogenization Pressure on the Alcohol Number of the Mix.

Homogenization Pressure	Stability: Alcohol Number Batch X	Batch A	Batch F	Batch K	Batch P
		Before Processing			
0 lbs.	7.2	7.2	7.4	7.4	7.4
		After Processing			
1500	7.2	7.1	7.4	7.4	7.4
2000	7.2	7.1	7.4	7.4	7.4
2500	7.2	7.2	7.4	7.3	7.3
3000	7.1	7.2	7.3	7.2	7.3
3500	7.1	7.2	7.3	7.1	7.3
		After Freezing			
1500	7.4	7.4	7.4	7.3	7.5
2000	7.4	7.4	7.3	7.3	7.4
2500	7.4	7.3	7.3	7.2	7.4
3000	7.4	7.4	7.3	7.1	7.3
3500	7.3	7.4	7.3	7.0	7.3

Effect of Homogenization Pressure on Fat Globule Size. Direct microscopic examinations of diluted samples of the mix were made. The average size of the globules was determined by examining five random fields and measuring the size of the globules with an ocular micrometer. Results of the observations are recorded in the table on the following page.

In all cases, the average diameter of the fat globules was 4.0 microns in the unprocessed mix, but in the homogenized mix it was 1.25 to 2.25 microns, decreasing in size as the homogenization pressure increased. In the samples homogenized at the lower pressures of 1500 and 2000 pounds, a number of globules over 4 microns in diameter were observed, while in the samples homogenized at 2500 pounds and above, few globules over 3 microns in diameter were observed. The increased shearing action in the homogenization valve at the higher pressures was thought to be the reason for this reduction.

Table 17. The Effect of Varying the Homogenization Pressure on the Fat Globule Size in the Mix.

Homogenization Pressure	Size of Fat Globules in Microns				
	Batch X	Batch A	Batch F	Batch K	Batch P
	Before Processing				
0 lbs.	4.0	4.0	4.0	4.0	4.0
	After Processing				
1500	2.0	2.0	2.25	2.0	2.25
2000	1.75	2.0	2.0	1.75	2.0
2500	1.5	1.75	2.0	1.75	2.0
3000	1.5	1.5	1.75	1.5	2.0
3500	1.25	1.25	1.5	1.5	1.75
	After Freezing				
1500	4.0	4.0	4.5	3.5	3.5
2000	3.0	3.0	3.0	3.0	3.5
2500	3.0	2.5	3.0	3.0	3.0
3000	2.5	2.5	3.0	2.5	3.0
3500	2.0	2.5	2.5	2.5	2.75

The average size of the fat globules in the mix after freezing was 2.0 to 4.5 microns in diameter, decreasing in size as the homogenization pressure used increased. The increase in the size of the fat globules due to the freezing process was directly related to the size of the fat globules before freezing.

__Effect of Homogenization Pressure on Fat Clumping.__ The effect of homogenization pressure on the fat globule clumping in the mix was determined by direct microscopic examination at the same time the fat globules were observed. The results of these observations are recorded in the table on the following page.

The results showed that there was no observable clumping of the fat globules in the unprocessed mix. However, clumping did exist in all of the mixes that had been homogenized. The extent of clumping varied from slight to very pronounced clumping. The degree of clumping varied directly with the homogenization pressure, increasing as the homogenization pressure increased. The freezing process resulted in a reduction in the

Table 18. The Effect of Varying the Homogenization Pressure on the Fat Clumping in the Mix.

Homogenization Pressure	Extent of Clumping Batch X	Batch A	Batch F	Batch K	Batch P
		Before Processing			
0 lbs.	0	0	0	0	0
		After Processing			
1500	+	+	+	+	+
2000	++	+	+	+	+
2500	++	++	++	++	++
3000	+++	+++	+++	+++	++
3500	++++	+++	+++	+++	+++
		After Freezing			
1500	0	+	0	0	+
2000	+	+	+	+	+
2500	+	+	+	+	+
3000	+	+	+	+	+
3500	+	+	+	+	+

extent of clumping in the mix as there was slight or no clumping observed in all of the batches after freezing. The agitation of the mix in the freezer apparently was sufficient to effectively reduce the size of the clumps of fat globules.

<u>Effect of Homogenization Pressure on Body and Texture Score.</u> Each of the samples, processed at each of the homogenization pressures used, was scored organoleptically for body and texture. The scores for the various batches are given in the following table.

Table 19. The Effect of Varying the Homogenization Pressure on the Body and Texture Score of the Ice Cream.

Homogenization Pressure	Body and Texture Score Batch X	Batch A	Batch F	Batch K	Batch P
1500 lbs.	28.25	28.00	27.75	27.50	27.75
2000	28.50	28.25	28.00	28.00	28.00
2500	28.50	28.25	28.00	28.25	28.00
3000	28.50	28.25	28.25	28.25	28.00
3500	28.50	28.25	28.25	28.25	28.00

The body and texture scores did not exhibit wide variation. The maximum difference between the scores was .75 points, while the maximum difference between socres within a batch was only .50 points. The body and texture scores for each batch showed a tendency to increase as the pressure of homogenization increased. At the lower pressures, the samples were observed to have a slightly coarse texture, but as the homogenization pressure was increased the ice cream became smoother and more chewy. Insofar as the body and texture score was affected, the higher homogenization pressures used in this study resulted in a smoother and slightly better product.

Effect of Homogenization Pressure on Rate of Melt Down. A sample of each batch of ice cream was permitted to melt to determine the rate and manner of melt down. The volume of mix obtained was used as in indication of the rate at which the ice cream melted. These amounts are given in the following table.

Table 20. The Effect of Varying the Homogenization Pressure on the Rate of Melt Down of the Ice Cream

Homogenization Pressure	Melt Down in ml.				
	Batch X	Batch A	Batch F	Batch K	Batch P
1500	18	26	16	19	18
2000	27	34	21	28	29
2500	35	40	38	39	43
3000	52	59	42	51	47
3500	67	64	57	62	51

The pressure of homogenization had a significant effect upon the melting characteristics of the ice cream. In all of the batches, the rate of melt down increased as the homogenization pressure increased. The samples homogenized at the lower pressures had a slightly coarse manner of melt down. It also was observed that the higher the homogenization pressure used the smoother was the melt down of the resulting ice cream.

Effect of Homogenization Pressure on Ice Crystal Size. The size of the ice crystals in each of the samples was determined by direct microscopic examination of the ice cream. The results of the examinations are given in the following table.

Table 21. The Effect of Varying the Homogenization Pressure on the Size of the Ice Crystals in the Frozen Ice Cream.

Homogenization Pressure	Size of Ice Crystals in Microns				
	Batch X	Batch A	Batch F	Batch K	Batch P
1500 lbs.	35	40	40	40	30
2000	35	40	40	40	35
2500	40	40	40	35	35
3000	40	40	35	35	35
3500	40	40	35	35	30

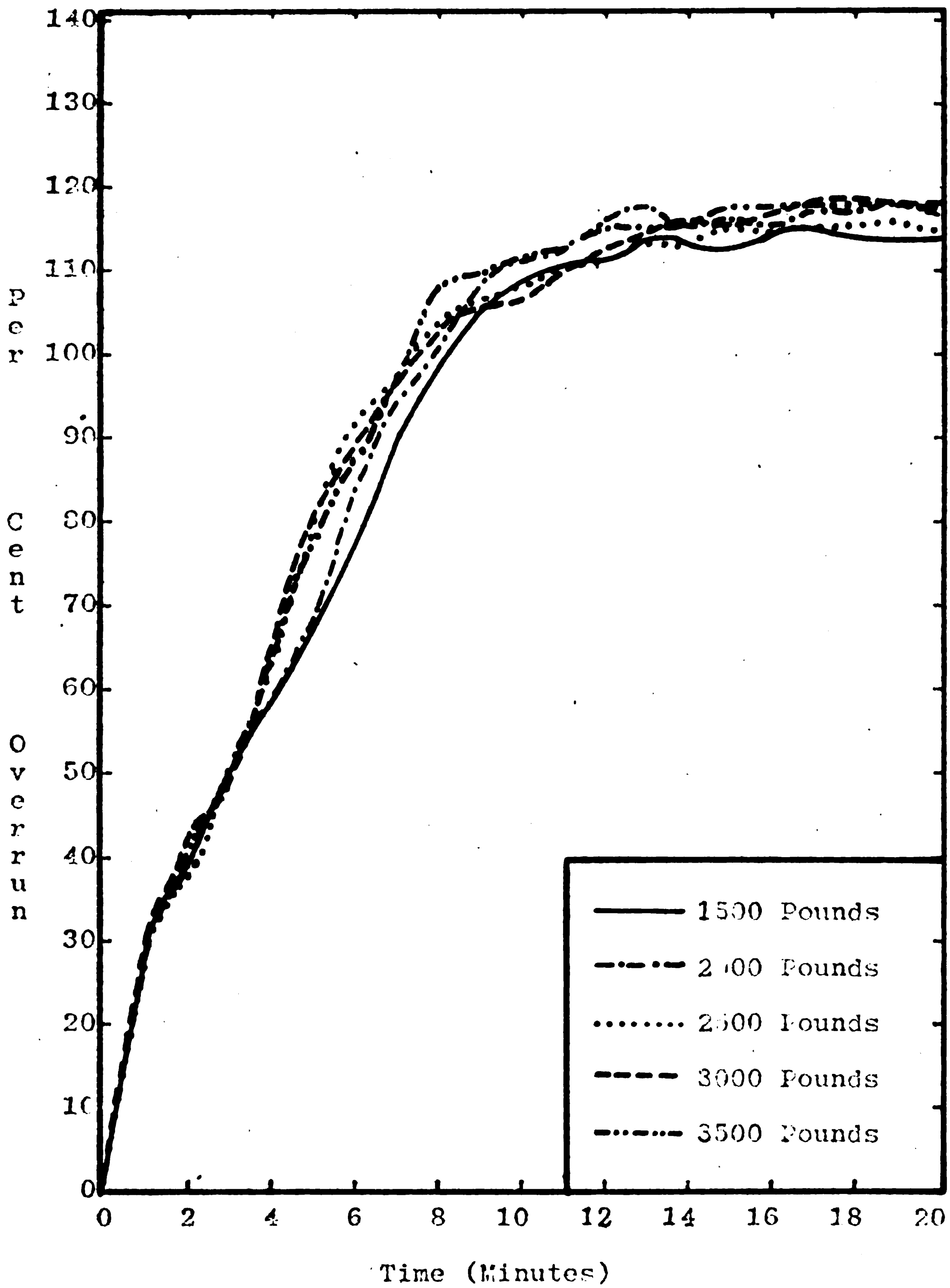
The variations in the size of the ice crystals were relatively small. The maximum variation noted was only 10 microns, while the variation within the batches was only 5 microns. There were no consistent trends to indicate that the homogenization pressures studied had any effect on the ice crystal size.

Effect of Homogenization Pressure on Whipping Characteristics. Overrun readings were made on each of the batches for a period of twenty minutes from the time freezing started. Graphs of these overrun readings are given on the following six pages. Inspection of the graphs reveal that there was no significant difference attributable to the homogenization pressure in the rate of whipping until 100 per cent overrun was reached. However, the whipping capacity of the ice cream mix was slightly increased by an increase in the homogenization pressure. A theory has been advanced that the size of the fat masses limited the whipping capacity of any mix and in these results a decrease in the size of the fat globules was noted. Consequently, the improved whipping capacity was attributed to the smaller fat globules in the mixes homogenized at the higher pressures.

THE EFFECT OF VARYING THE HOMOGENIZATION PRESSURE

ON OVERRUN CHARACTERISTICS

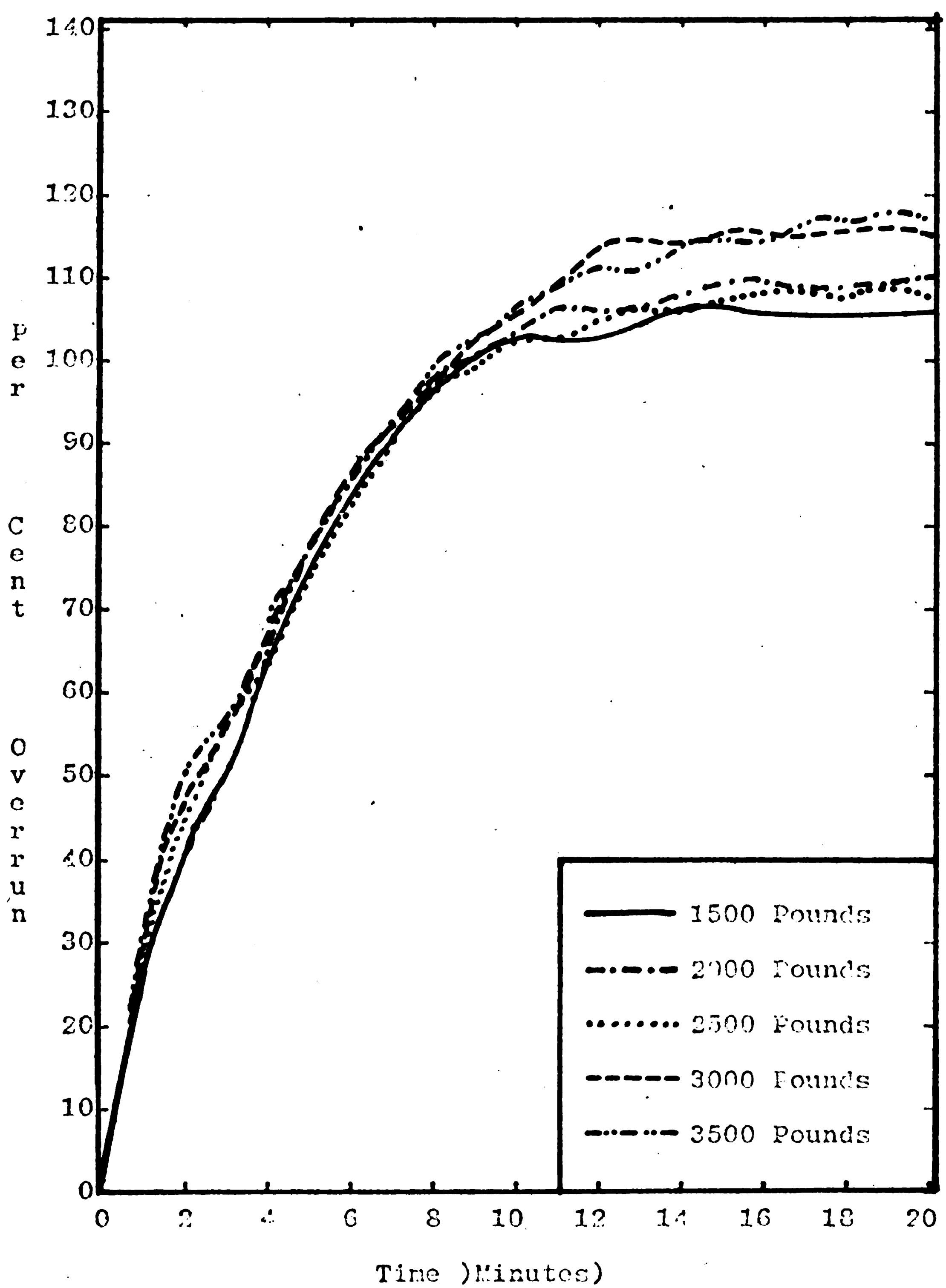
BATCH X



THE EFFECT OF VARYING THE HOMOGENIZATION PRESSURE

ON OVERRUN CHARACTERISTICS

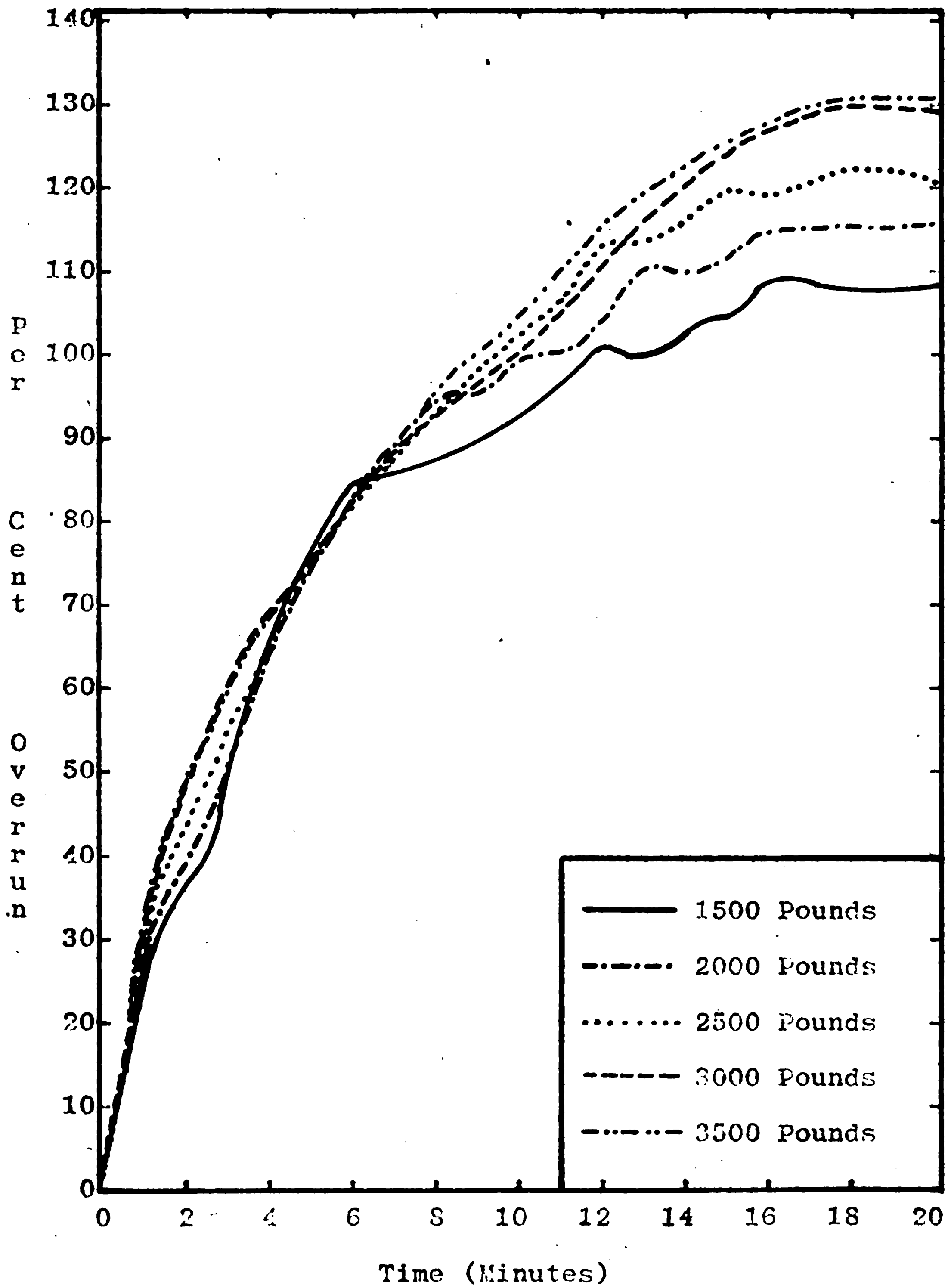
BATCH A



THE EFFECT OF VARYING THE HOMOGENIZATION PRESSURE

ON OVERRUN CHARACTERISTICS

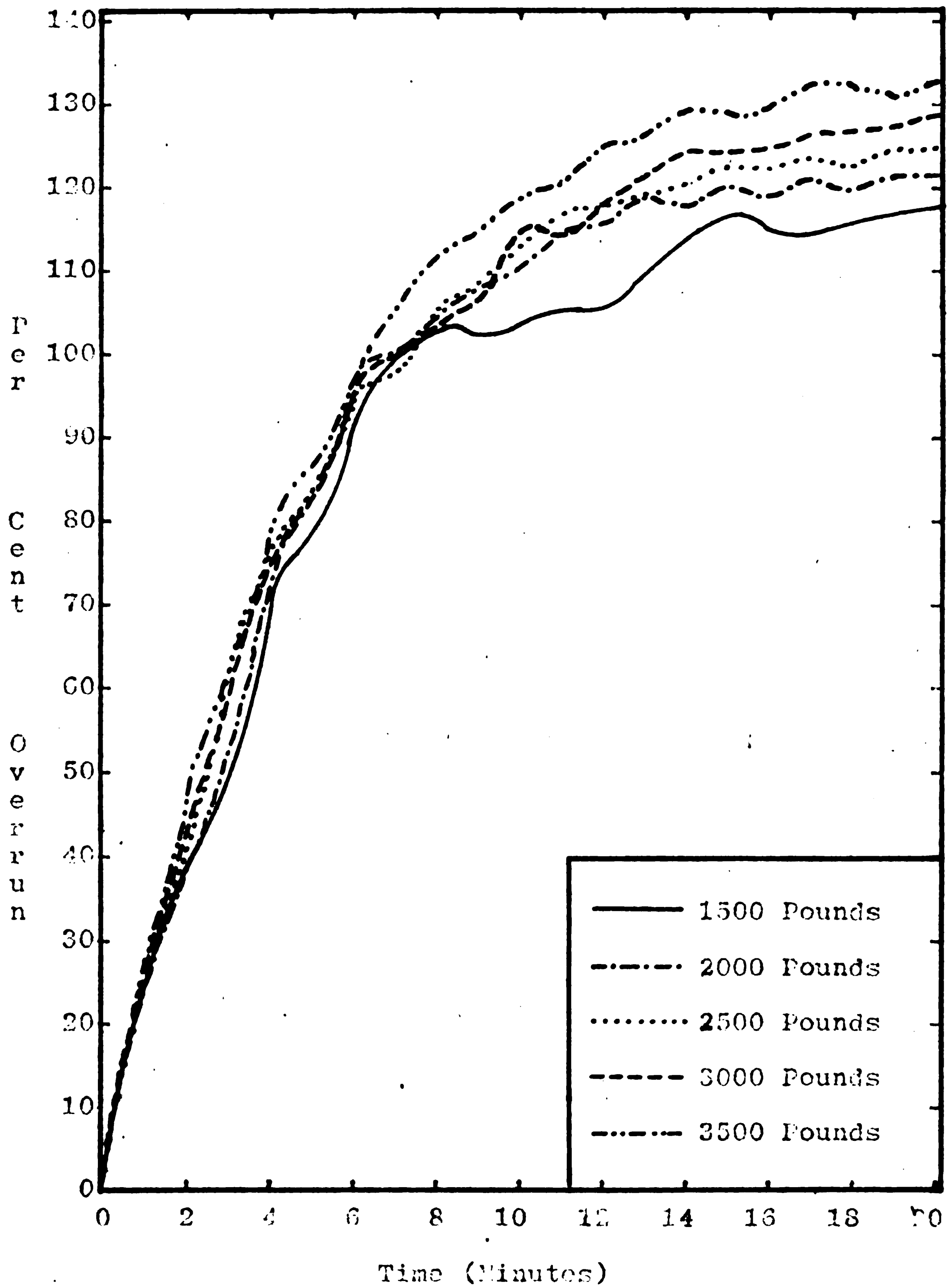
BATCH F



THE EFFECT OF VARYING THE HOMOGENIZATION PRESSURE

ON OVERRUN CHARACTERISTICS

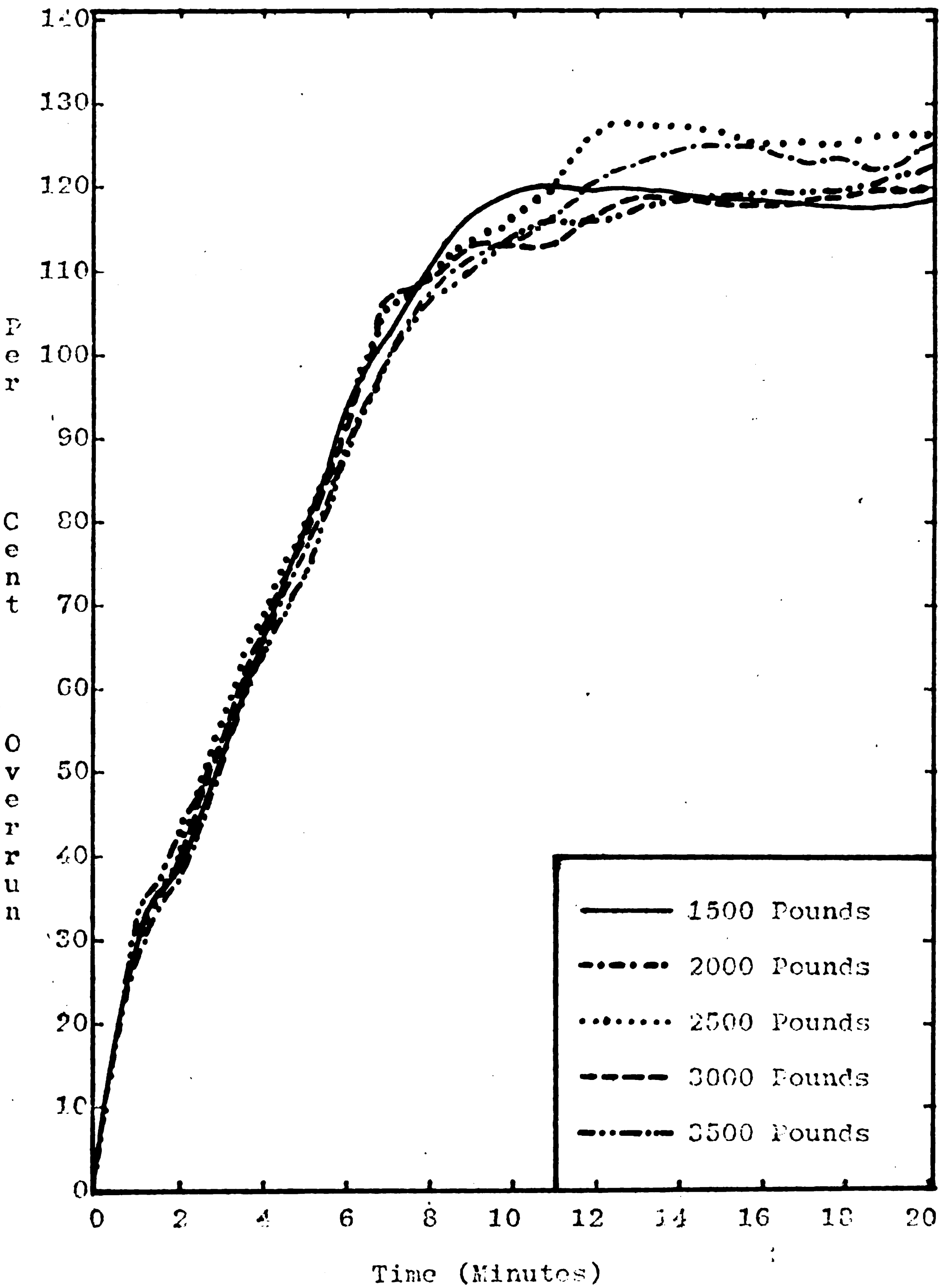
BATCH K



THE EFFECT OF VARYING THE HOMOGENIZATION PRESSURE

ON OVERRUN CHARACTERISTICS

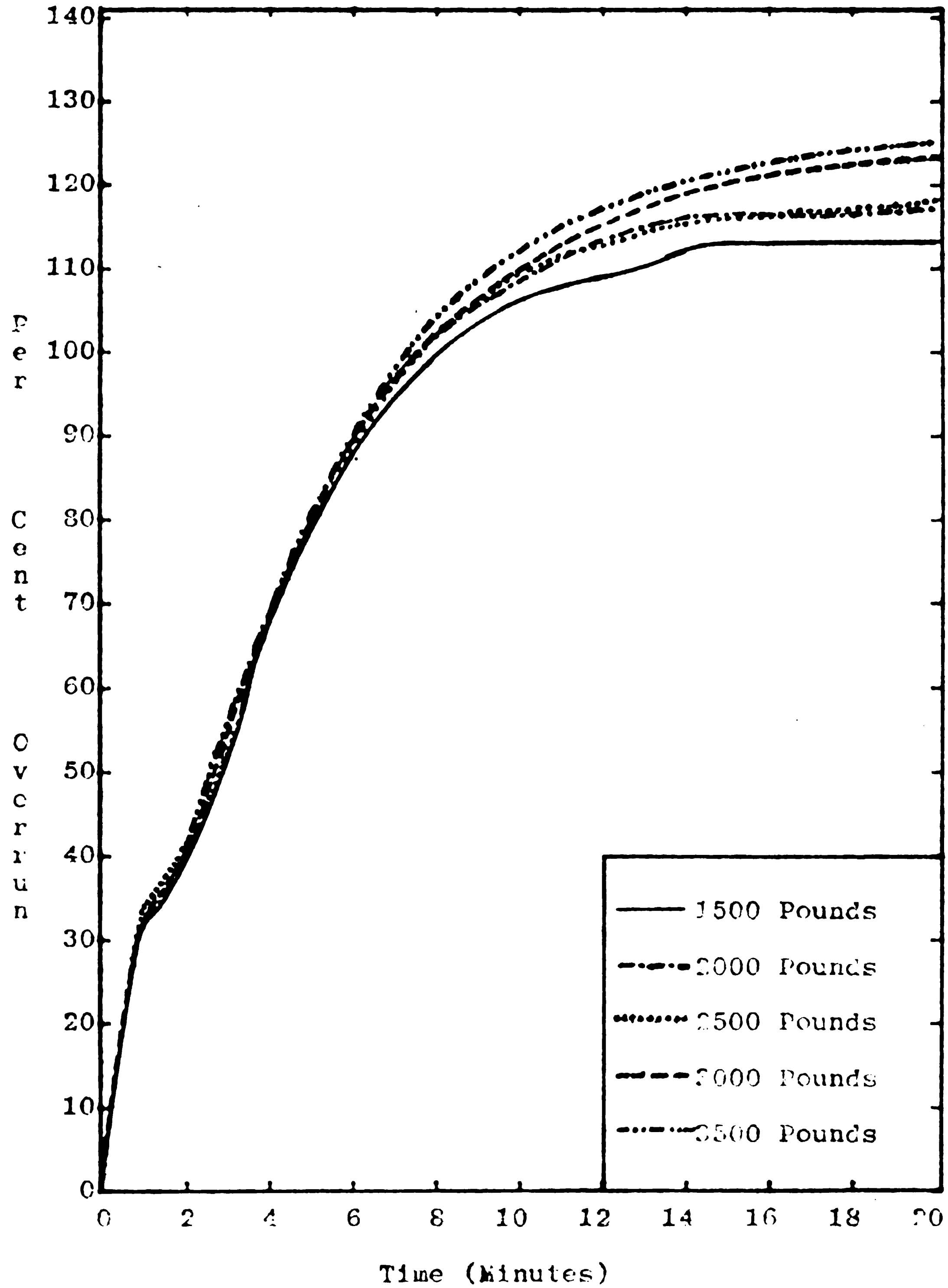
BATCH P



THE EFFECT OF VARYING THE HOMOGENIZATION PRESSURE

ON OVERRUN CHARACTERISTICS

AVERAGE OF BATCHES A, F, K, P, and X



Discussion of Results

The results of the analyses show that the pressure of homogenization was influential in determing the quality of the resulting ice cream. It will be noted that the most desirable homogenization pressure is influenced by a number of factors and must be determined individually for each case. This discussion will point out how the various factors governing quality are affected by the homogenization pressure.

The results of the examination of the mix indicated that the size of the fat globules was reduced as the homogenization pressure was increased. The reduction in size was probably due to the increased shearing action brought about by reducing the clearance in the homogenization valve. The freezing process resulted in an increase in the size of the fat globules. The agitation during the freezing process a parently brought about collision and coalesence of the fat globules. Although the size was not exactly doubled in all cases, it was noted that the increase in size was proportional to the size of the fat globules before freezing.

The clumping of the fat globules was observed to be increased by an increase in the homogenization pressure. This phenomenon has been noted by several investigators, (25), (26), and (96). The increased charge on the fat globules caused by the adsorpted protein layer has been advanced as an explanation of the reason clumping occurs. The freezing process reduced the clumping of the fat globules. The agitation of freezing apparently was sufficient to separate mechanically the fat agregates until slight or no clumping was observed.

Attempts were made to prepare photomicrographs showing the degree of clumping. The brownian movement, depth of the samples, and rising of the samples, and rising of the fat globules prevented the obtaining of

a clear representative photomicrograph of the samples, thus they were not included because they failed to give representative pictures of the samples.

In all of the cases, the viscosity of the mix increased as the homogenization pressure increased. Several investigators (25), (52), (84), and (89) have noted a direct relationship between the viscosity and the fat clumping. This study showed that both the viscosity and fat clumping were increased by an increase in homogenization pressure. Although the viscosity is greatly influenced by the degree of fat clumping, other factors also affect the viscosity. This is born out by the fact that after freezing the viscosity tended to vary directly with the homogenization pressure while the fat clumping was reduced to a minimum. Nevertheless, the main factor in determing the viscosity of the mix appears to be the degree of internal friction of the solid phase due to the clumping of fat globules. Several studies, (50), (63), (67), and (86), have shown that the fat clumping and accompanying viscosity were reduced by rehomogenization or multiple stage homogenization.

The results of the alcohol number determinations show that there was a tendency for the stability of the proteins to be decreased as the pressure of homogenization was increased. Doan (27) reported that homogenization lowered the pH which in turn brought the system closer to the iso-electric point of casein. In this study the pH readings failed to show any significant difference thereby offering no explanation regarding the change in protein stability.

The melt down characteristics were materially influenced by the homogenization pressure. The rate of melt down and the smoothness of melt down were observed to increase as the homogenization pressure increased.

Other investigators, (34), (84), (85), and (100), have reported similar findings. The reason for the faster and smoother melt down has been advanced and involves the finer dispersion of the mix constituents at the higher homogenization pressure and a corresponding effect on the gel formation.

A tendency for the body and texture scores to increase as the homogenization pressure increased was observed. The differences in the scores recorded primarily at the lower level were not large, thus the homogenization pressure apparently does not greatly affect the body and texture score. It was noted during the scoring of the samples that the body of the ice cream became more resistant and chewy at the higher homogenization pressures. The literature of approximately twenty years ago reports marked improvements in body and texture as the homogenization pressure was increased. However, with the present mix composition and freezing methods, the benefits brought about by higher homogenization pressures are not as significant.

The whipping capacity of the mix was increased by an increase in the homogenization pressure, but the rate of whipping was not noticeably affected by the pressure of homogenization. Here again the literature of a decade ago has reported marked increases in the whipping properties as the homogenization pressure increased, but the present manufacturing practices have reduced the importance of the pressure of homogenization, providing the fat globules have been sufficiently reduced. Among the factors that tend to reduce the importance of homogenization are the present ingredients, stabilizers, whipping aids, homogenizer efficiency, and freezers.

III. THE EFFECT OF VARYING THE HOMOGENIZATION TEMPERATURE ON THE QUALITY OF ICE CREAM

The process of homogenization has become an indispensible step in the preparation of ice cream mix. Various temperatures of homogenization have been recommended and many different practices are being followed. In this portion of the experiment, homogenization pressures of 110°F., 130°F., 150°F., and 170°F., respectively, were used and the resulting product tested to see how variations in the pressure of homogenization would affect the quality.

Procedure

In this portion of the experiment homogenization temperature was the variable. In all cases the ingredients in the mix, the composition of the mix, the methods of testing, and the tests to determine quality were the same as those listed on 19 to 25.

In this study, the ingredients were combined and pasteurized at a temperature of 150°F. for 30 minutes. At the end of the pasteurization period, four representative batches of mix were removed and placed in 10 gallon milk cans. The batches were heated or cooled in water baths, as was necessary to temperatures of 110°F., 130°F., 150°F., and 170°F., and then homogenized with a Manton-Gaulin laboratory homogenizer using a pressure of 2500 pounds per square inch on a single stage valve with a breaker ring. The homogenized batches were placed into milk cans and immediately cooled to 50°F. in a cold water bath, and then aged for 24 hours in a 40°F. cold storage room before freezing.

Experimental Results

Effect of Homogenization Temperature on Acidity. Each of the batches of mix was titrated with 0.1 N NaOH to see how the temperature of homogenization affected the acidity. Acidity determinations were made at various stages in the processing and the results are given in the following table.

Table 22. The Effect of Varying the Homogenization Temperature on the Acidity of the Mix.

Homogenization Temperature	Per Cent Acidity Batch D	Batch H	Batch I	Batch L	Batch V
			Before Processing		
100°F.	0.235 %	0.225 %	0.230 %	0.230 %	0.230 %
			After Processing		
110°F.	0.240	0.232	0.232	0.220	0.235
130°F.	0.240	0.235	0.232	0.222	0.231
150°F.	0.245	0.230	0.235	0.225	0.232
170°F.	0.238	0.232	0.235	0.224	0.232
			After Freezing		
110°F.	0.245	0.236	0.228	0.223	0.235
130°F.	0.240	0.240	0.226	0.220	0.232
150°F.	0.242	0.238	0.232	0.221	0.232
170°F.	0.240	0.242	0.228	0.225	0.232

The results of the acidity tests show that the variations were inconsistent and failed to show any tendency to increase or decrease with the homogenization temperature. The temperature at which the mix was homogenized apparently did not affect the acidity of the mix.

Effect of Homogenization Temperature on pH. The pH of each of the samples was determined to observe the influence of homogenization temperature on the pH. The results of the potentiometeric readings are given in the following table.

Table 23. The Effect of Varying the Homogenization Temperature on the pH of the Mix.

Homogenization Temperature	pH Readings Batch D	Batch H	Batch I	Batch L	Batch V
		Before	Processing		
100°F.	6.33	6.37	6.36	6.37	6.35
		After	Processing		
110°F.	6.35	6.36	6.35	6.34	6.37
130°F.	6.33	6.35	6.36	6.34	6.37
150°F.	6.34	6.37	6.35	6.36	6.36
170°F.	6.34	6.36	6.35	6.37	6.36
		After	Freezing		
110°F.	6.34	6.37	6.36	6.35	6.35
130°F.	6.35	6.36	6.35	6.36	6.36
150°F.	6.35	6.35	6.35	6.36	6.37
170°F.	6.33	6.35	6.37	6.36	6.35

The results of the pH readings showed very little variation with no tendency to increase or decrease as the homogenization temperature was changed. It is evident that the temperature at which the mix was homogenized had little effect on the pH of the resulting product.

Effect of Homogenization Temperature on Viscosity. Viscosity determinations on each batch of mix were made on a MacMichael viscosimeter following the procedure given earlier. The results of these tests are given in the following table.

Table 24. The Effect of Varying the Homogenization Temperature on the Viscosity of the Mix.

Homogeniation Temperature	Centipoise Batch D	Batch H	Batch I	Batch L	Batch V
		Before	Processing		
100°F.	35.7	76.1	102.3	243.5	36.8
		After	Processing		
110°F.	251.4	492.6	554.6	492.6	319.6
130°F.	248.9	329.4	508.5	463.4	177.1
150°F.	232.2	214.7	223.2	391.0	125.2
170°F.	230.3	188.6	207.2	316.8	110.9
		After	Freezing		
110°F.	54.9	85.0	88.0	93.1	53.0
130°F.	53.0	82.7	86.5	92.1	52.8
150°F.	54.5	92.5	93.1	81.2	48.7
170°F.	52.2	94.6	85.7	74.6	53.6

The viscosity of the mix was greatly influenced by the temperature of homogenization. Some variation is noted in the viscosity of the mix before processing; however, the viscosity of the mix in all cases was found to increase as the temperature of homogenization decreased. The increase in viscosity is probably associated with the increased clumping noted at the lower homogenization temperatures. The freezing process resulted in a decrease in the viscosity of the mix. Mechanical agitation during freezing apparently broke up the fat clusters, thereby reducing the amount of internal friction of the solid phase. The viscosity of the mix after freezing varied moderately but did not exhibit any consistency in variation.

Effect of Homogenization Temperature on Surface Tension. Surface tension determinations were made on each of the batches of mix homogenized at each of the temperatures used. Results of the tests showing the effect of homogenization temperatures on surface tension are given in the following table.

Table 25. The Effect of Varying the Homogenization Temperature on the Surface Tension of the Mix.

Homogenization Temperature	Dynes per cm. Batch D	Batch H	Batch I	Batch L	Batch V
		Before Processing			
100°F.	46.3	45.3	46.4	47.8	45.4
		After Processing			
110°F.	48.1	46.0	48.3	49.9	48.3
130°F.	48.0	46.4	48.2	49.9	48.3
150°F.	47.7	46.3	48.4	50.2	48.3
170°F.	47.5	46.7	48.5	50.2	48.5
		After Freezing			
110°F.	43.5	41.2	48.3	48.6	45.5
130°F.	44.6	49.0	49.2	45.5	47.2
150°F.	46.0	45.2	47.8	40.2	46.8
170°F.	45.5	42.5	47.8	48.1	45.8

In all of the batches, processing of the mix resulted in an increase in the surface tension. It was thought that a finer dispersion of the mix ingredients by homogenization brought about a closer, molecular structure and an accompanying higher surface tension. However, there were no trends to indicate that the temperature at which the mix was homogenized had any influence on the surface tension. There were a few irregularities; however, it was observed that the surface tension of the mix was reduced by the freezing process. Probably accountable for this decrease was the reduction in the amount of fat in suspension as a result of a partial churning by the freezer.

Effect of Homogenization Temperature on Protein Stability. Alcohol number determinations, as an indication of protein stability, were made on each of the batches of mix homogenized at each of the temperatures used. Results showing the effect of homogenization temperature on protein stability are given in the following table.

Table 26. The Effect of Varying the Homogenization Tenperature on the Alcohol Number of the Mix.

Homogenization Temperature	Stability: Alcohol Number				
	Batch D	Batch H	Batch I	Batch L	Batch V
		Before Processing			
100°F.	7.4	7.3	7.4	7.5	7.4
		After Processing			
110°F.	7.4	7.5	7.5	7.5	7.4
130°F.	7.2	7.5	7.5	7.7	7.4
150oF.	7.4	7.4	7.5	7.6	7.4
170°F.	7.4	7.4	7.5	7.6	7.4
		After Freezing			
110°F.	7.5	7.4	7.5	7.7	7.7
130°F.	7.5	7.4	7.5	7.7	7.7
150°F.	7.7	7.4	7.5	7.6	7.7
170°F.	7.5	7.4	7.5	7.7	7.6

The results of the tests showed little variation in the alcohol numbers. The similarity and lack of trends in the results indicate that the protein stability of the mix is not affected by the homogenization temperature or freezing process.

Effect of Homogenization Temperature on Fat Globule Size. A direct microscopic examination was made on each batch of mix to observe the effect of homogenization temperature on the size of the fat globules. The results of the microscopic examinations are given in the following table.

Table 27. The Effect of Varying the Homogenization Temperature on the Fat Globule Size in the Mix.

Homogenization Temperature	Size of Fat Globules in Microns				
	Batch D	Batch H	Batch I	Batch L	Batch V
			Before Processing		
100°F.	4.0	4.0	4.0	4.0	3.5
			After Processing		
110°F.	2.0	1.5	2.0	1.75	2.0
130°F.	1.75	1.5	1.75	1.75	2.0
150°F.	1.75	1.75	1.75	1.75	2.0
170°F.	1.5	2.0	1.75	2.0	1.5
			After Freezing		
110°F.	4.0	3.5	3.0	5.0	4.0
130°F.	4.0	3.5	3.0	4.0	3.5
150°F.	2.5	3.0	2.5	4.0	4.0
170°F.	2.0	3.0	3.0	3.0	4.5

The size of the fat globules before processing was relatively uniform. Observations of the proceeded mix were conflicting. In batches D, I, and V the average size of the fat globules decreased as the homogenization temperature increased while in batches H and L the average size of the fat globules increased as the homogenization temperature increased. The variation in the average size of the fat globules was not extensive and apparently the size of the fat globules was not significantly affected by the homogenization temperature. The freezing

process, as noted in previous sections, resulted in an increase in the average size of the fat globules. This increase was attributed to the coalescence of the fat globules by the mechanical agitation during freezing.

Effect of Homogenization Temperature on Fat Globule Clumping. Each batch of mix homogenized at each of the temperatures used was examined directly with a microscope to determine the degree of clumping. Observations showing the effect of homogenization temperature on the extent of clumping are given in the following table.

Table 28. The Effect of Varying the Homogenization Temperature on the Fat Globule Clumping in the Mix.

Homogenization Temperature	Degree of Fat Clumping				
	Batch D	Batch H	Batch I	Batch L	Batch V
		Before Processing			
100°F.	0	0	0	0	0
		After Processing			
110°F.	+++	++++	+++++	++++	+++++
130°F.	++	+++	++++	+++	+++
150°F.	+	+	++	++	++
170°F.	+	+	+	+	+
		After Freezing			
110°F.	+	+	+	+	+
130°F.	+	+	+	+	+
150°F.	+	+	+	0	+
170°F.	+	0	+	+	+

No fat globule clumping was reported in the unprocessed mix. Clumping, however, was observed in all of the batches of mix that had been processed. The clumping of the fat globules was influenced greatly by the homogenization temperature, increasing as the temperature of homogenization was decreased. Clumping in the samples homogenized at 110°F. was very pronounced particularly in batches I and V. The freezing process resulted in a reduction in extent of clumping. This reduction,

noted previously, was probably a result of the mechanical agitation during the freezing process.

Effect of Homogenization Temperature on Body and Texture Score. The body and texture score was determined organoleptically for each sample processed at each of the homogenization temperatures. Results showing how the homogenization temperatures affected the body and texture score are given in the following table.

Table 29. The Effect of Varying the Homogenization Temperature on the Body and Texture Score of the Ice Cream.

Homogenization Temperature	Body and Texture Score				
	Batch D	Batch H	Batch I	Batch L	Batch V
110°F.	27.75	28.50	28.25	28.50	28.25
130°F.	27.75	28.50	28.25	28.25	28.25
150°F.	28.00	28.50	28.25	28.25	28.25
170°F.	27.75	28.25	28.25	28.25	28.25

The body and texture scores exhibited only slight variations as a result of change in the temperature of homogenization. The maximum variation in score within a batch was only 0.25 points with no consistent change reported; therefore, the body and texture of the ice cream was not significantly affected by homogenization temperature.

Effect of Homogenization Temperature on Rate of Melt Down. Samples of each batch of ice cream, homogenized at the varied temperatures, were permitted to melt for 1.5 hours. The amount of the liquid obtained was recorded as an indication of the rate of melt down. Results of the determinations are given in the table on the following page.

The degree of melt down obtained from these samples showed little variation . In some instances slightly higher values were obtained from the ice cream homogenized at the increased temperatures, but the increase was not significant. The manner of melt down differed very little between samples, being judged smooth for all of the samples. Therefore, it was concluded that the temperature of homogenization did not materially affect the rate or manner of melt down.

<u>Effect of Homogenization Temperature on Ice Crystal Size</u>. The size of the ice crystals was determined by direct microscopic examinations of each of the samples homogenized at the different temperatures.. Results of the examinations showing the effect of the homogenization temperature on the ice crystals in the frozen ice cream are given in the following table.

Table 31. The Effect of Varying the Homogeniation Temperature on the Size of the Ice Crystals in the Frozen Ice Cream.

Homogenization Temperature	Size of Ice Crystals in Microns				
	Batch D	Batch H	Batch I	Batch L	Batch V
110°F.	45	40	45	35	45
130°F.	45	45	40	40	40
150°F.	40	45	45	35	45
170°F.	45	45	45	40	45

The average size of the ice crystals ranged from 35 to 45 microns. This variation was relatively small with no tendency toward an increase or decrease in size. These results would indicate that the temperature of homogenization did not influence the ice crystal size.

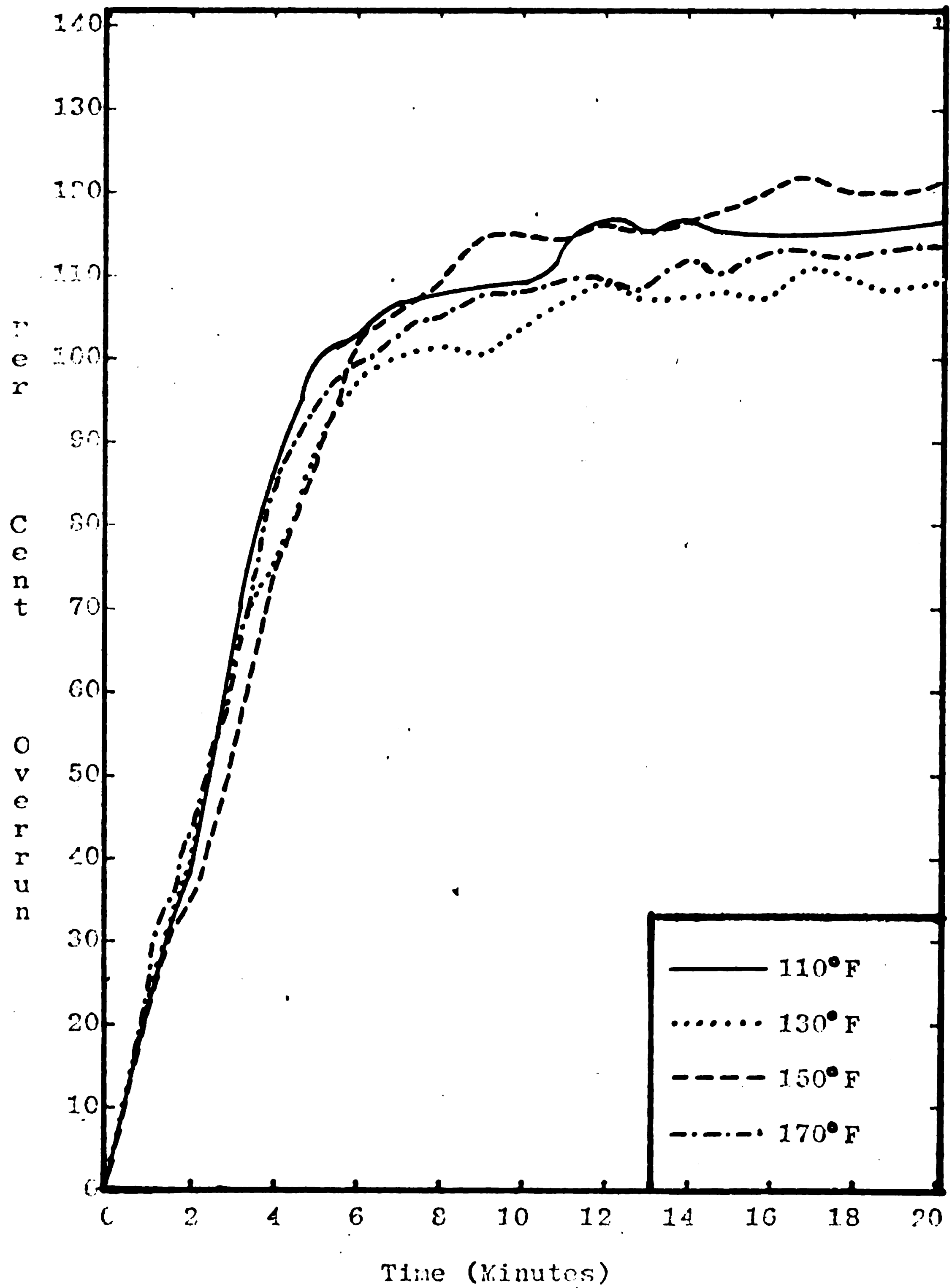
<u>Effect of Homogenization Temperature on Whipping Characteristics</u>. The overrun percentages were taken for a period of twenty minutes from the time freezing started for each batch of ice cream. Graphs showing the overrun pattern for each batch and for the average of all the batches

homogenized at the various temperatures are given on the following six pages. There was but slight variation in the overrun characteristics of the different mixes. Although a slight improvement was noted in the rate of whipping and the whipping capacity of the mixes homogenized at the higher temperatures, the difference is so small that it is probably of little commercial significance.

THE EFFECT OF VARYING THE HOMOGENIZATION TEMPERATURE

ON OVERRUN CHARACTERISTICS

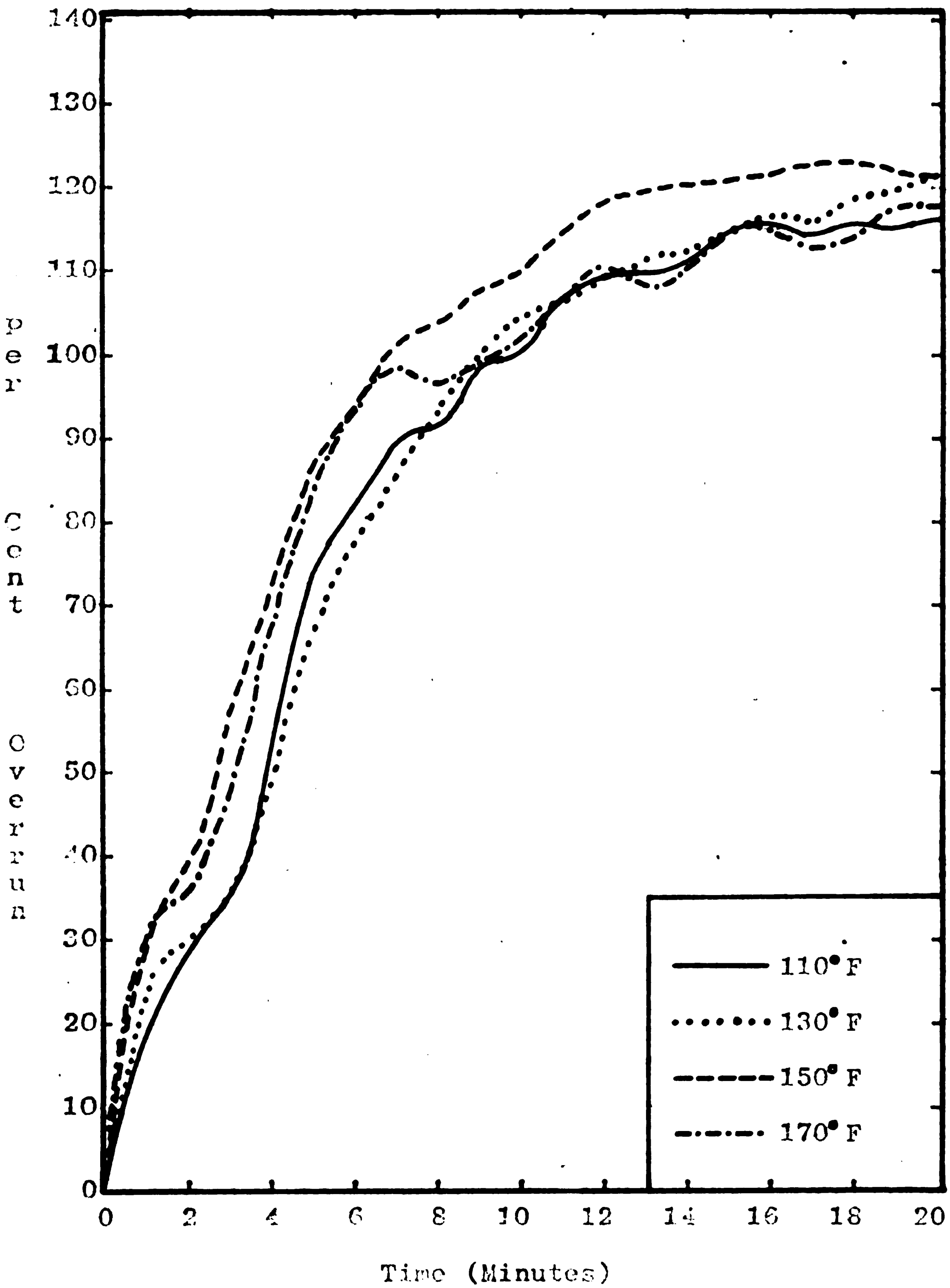
BATCH D



THE EFFECT OF VARYING THE HOMOGENIZATION TEMPERATURE

ON OVERRUN CHARACTERISTICS

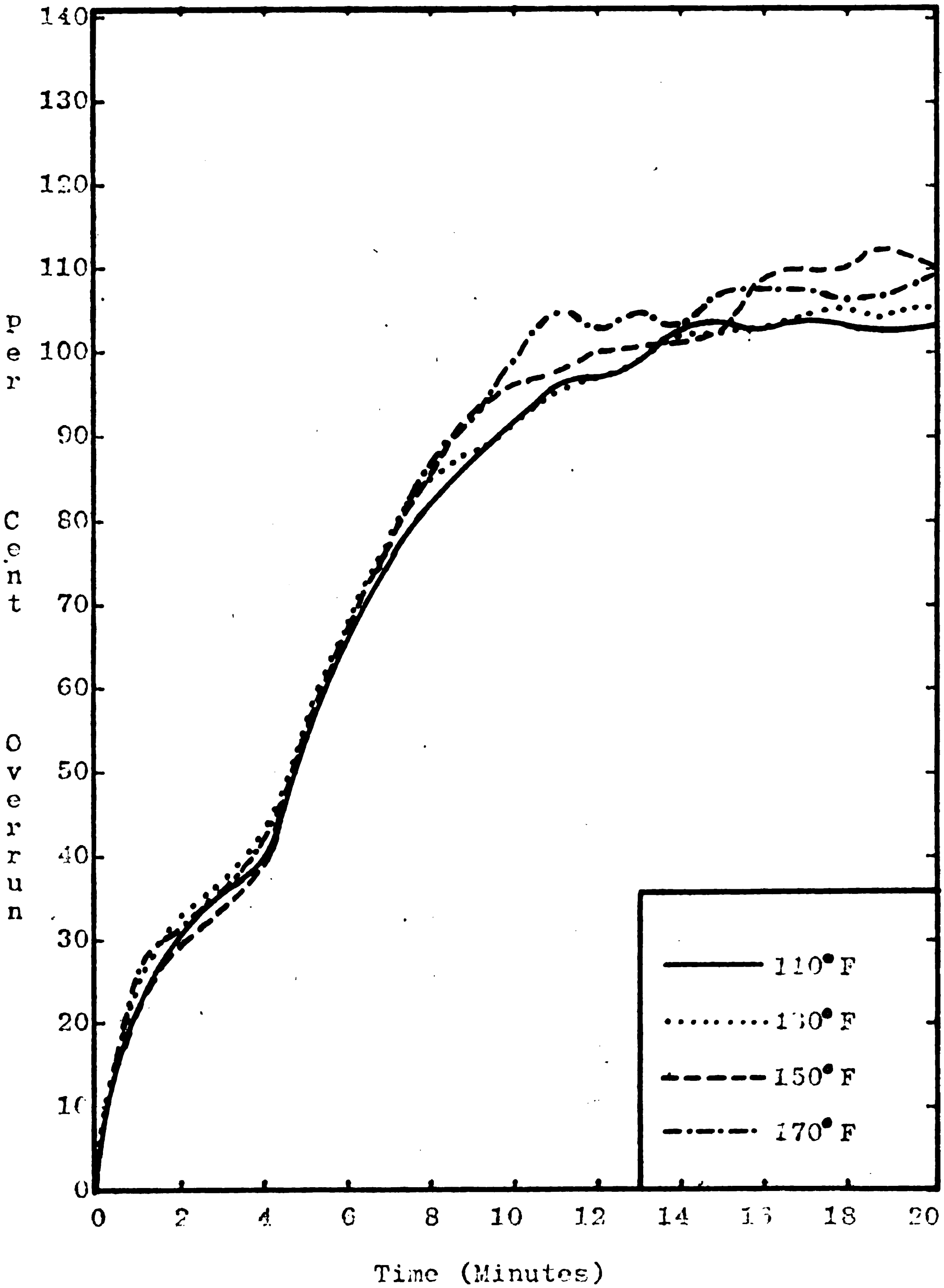
BATCH II



THE EFFECT OF VARYING THE HOMOGENIZATION TEMPERATURE

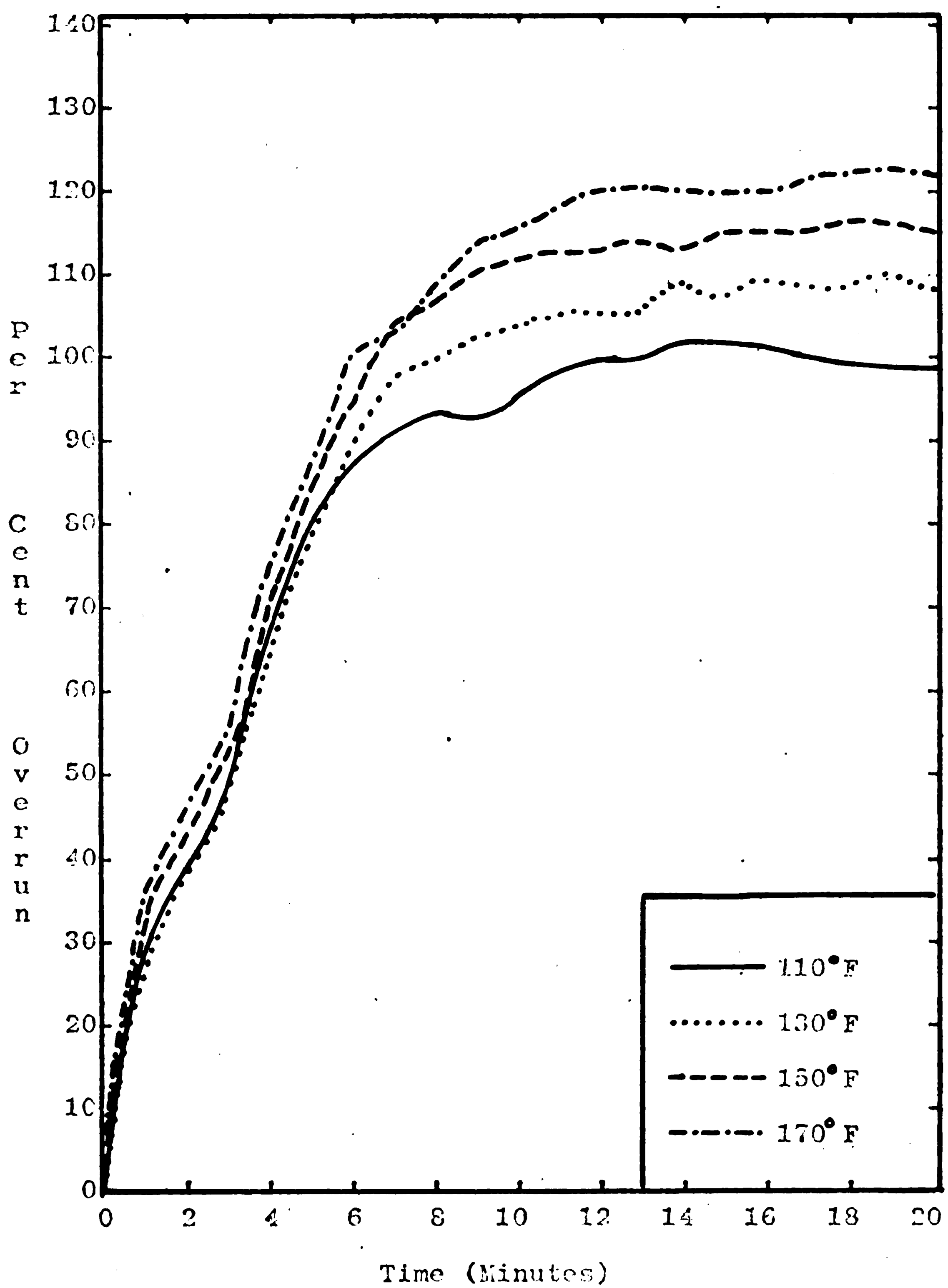
ON OVERRUN CHARACTERISTICS

BATCH I



THE EFFECT OF VARYING THE HOMOGENIZATION TEMPERATURE ON OVERRUN CHARACTERISTICS

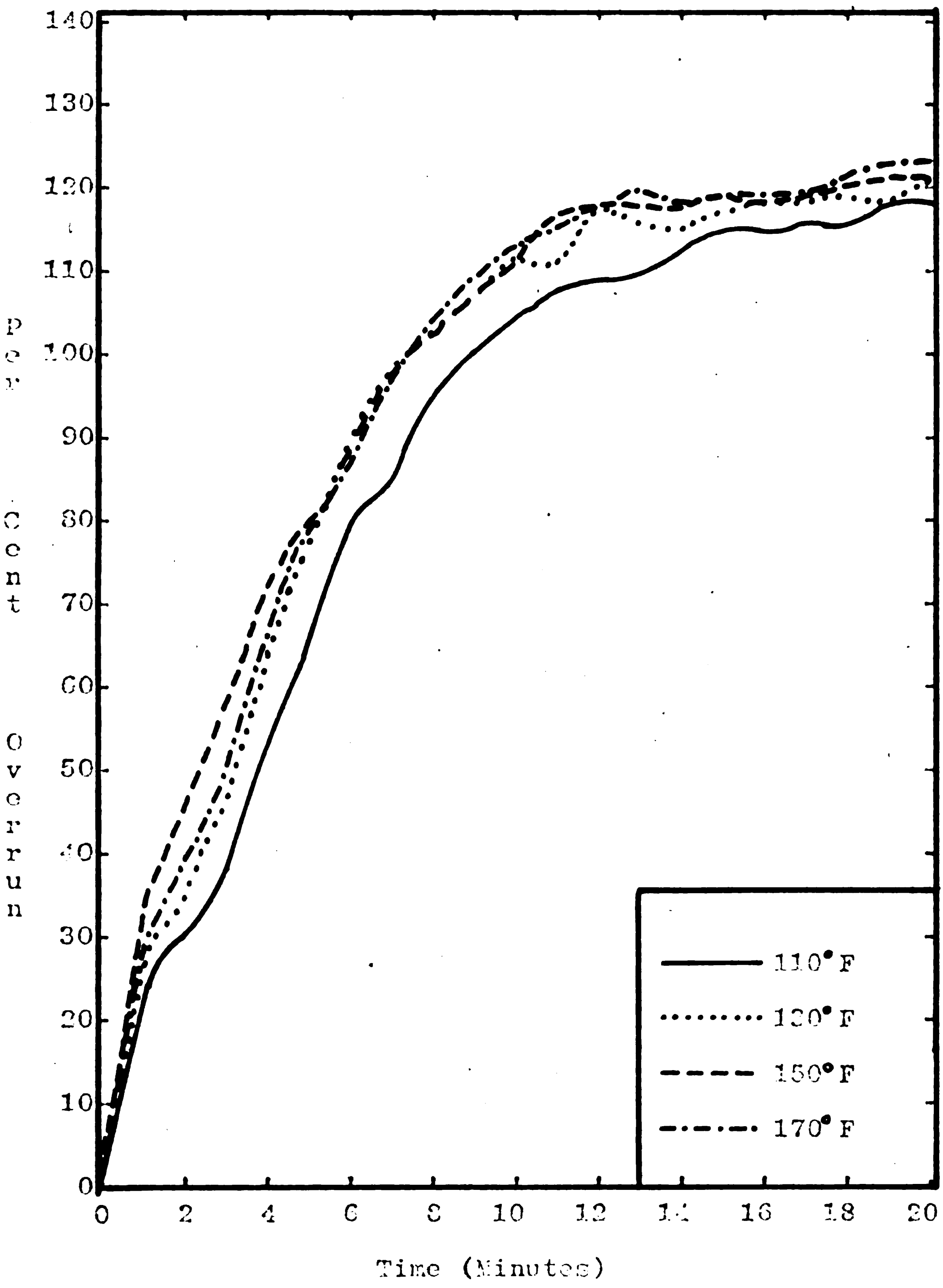
BATCH L



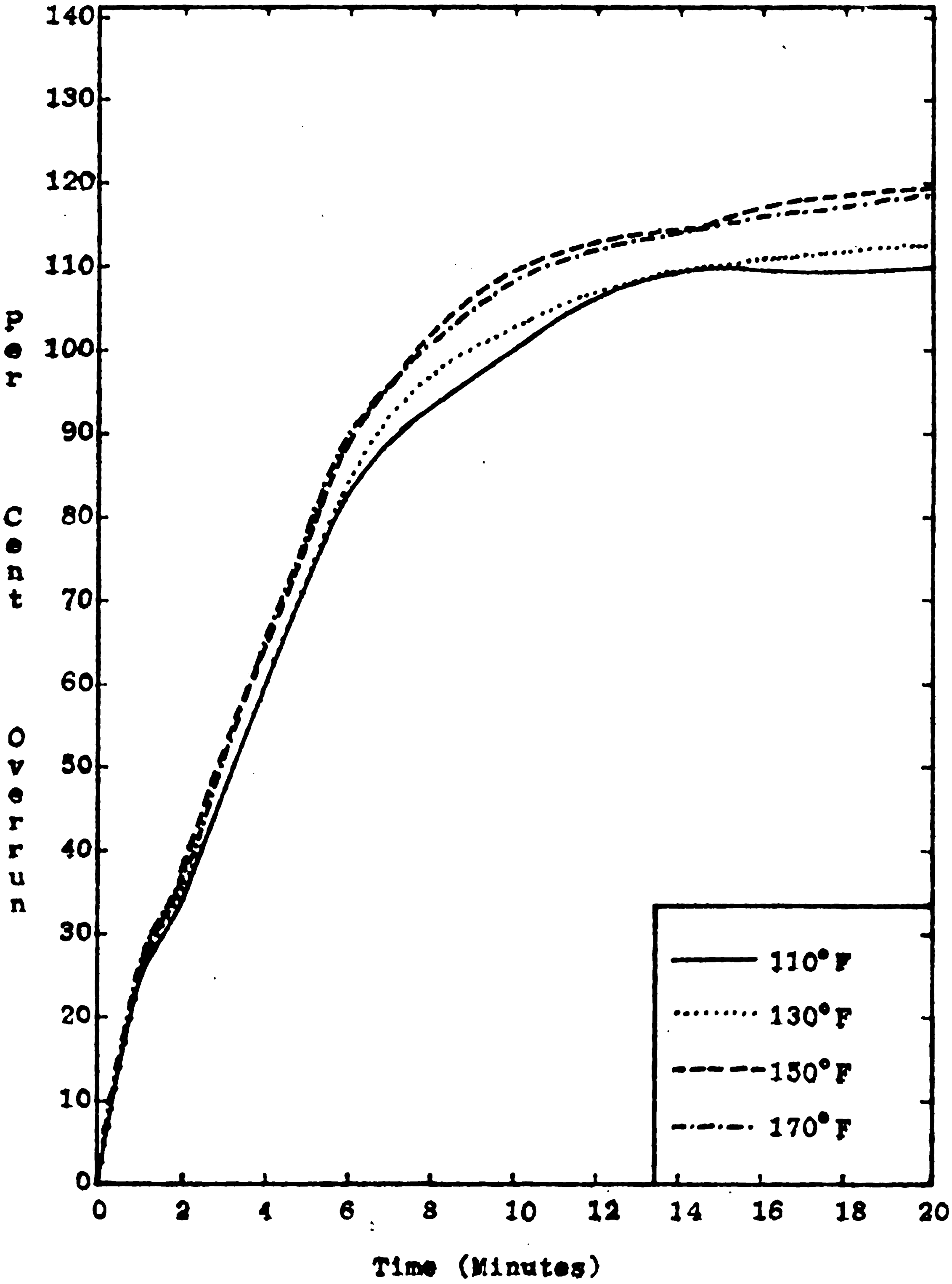
THE EFFECT OF VARYING THE HOMOGENIZATION TEMPERATURE

ON OVERRUN CHARACTERISTICS

BATCH V



THE EFFECT OF VARYING THE HOMOGENIZATION TEMPERATURE
ON OVERRUN CHARACTERISTICS
AVERAGE OF BATCHES D, H, I, L, and V



Discussion of Results

The results of these experiments showed that the temperature of homogenization had a significant importance on some of the factors affecting quality. Although the optimum temperature of homogenization will vary between mixes, the following observations should aid in determining the optimum homogenization temperature.

Viscosity of the mix was affected most by homogenization temperature. As the homogenization temperature was decreased there was a marked increase in the viscosity of the mix, this being particularly true at a temperature of 110°F. This increase in viscosity has been noted by several investigators (26), (60), (90), and (96). Since viscosity of the mix is closely associated with the fat clumping of the mix, the internal friction of the solid phase due to the clumps of fat globules was probably the main factor affecting the viscosity. In all of the batches, the viscosity of the mix was reduced by the freezing process. The mechanical agitation of the freezing process resulted in a reduction of the fat clumping and a corresponding reduction in viscosity.

The clumping of the fat globules was affected by the homogenization temperature, increasing as the temperature decreased. The reason for the clumping of the fat globules has been attributed to the increase in charge on the globule due to the adsorpted protein layer. The higher homogenization temperature probably resulted in a more highly charged particles which were capable of repelling the other globules.

The rate of melt down tended to be slightly higher in the ice cream that had been homogenized at the higher temperatures. The increased rate was not great or consistent in any of the batches. The more rapid melt down was probably due to a finer dispersion of the mix ingredients homogenized at the higher temperatures. Since there was no difference in the smoothness of melt down noted between the samples, the significance of the differences in body and texture scores probably has no commercial value.

The rate and capacity of whipping were increased slightly by an increase in the homogenization temperature. This increase was noted by other investigators (25), (55), and (100). The mix apparently was more receptive to the incorporation of air when the viscosity was lower; however, the improvement in the capacity and rate of whipping due to a change in homogenization temperature was not of great practical significance.

Homogenization resulted in a slight increase in the surface tension of the mix. The increase was probably due to the finer dispersion of the ingredients in the homogenized mix. There were no trends to indicate that the temperature at which the mix was homogenized had any effect on the surface tension. The variation in surface tension after the mix was frozen may have been affected by the reduction in the amount of fat in suspension as a result of a partial churning of the fat globules by the agitation during freezing.

The fat globule size was decreased by homogenization and increased by freezing, but was not appreciably affected by the homogenization temperature. Variation in the size of the fat globules in the processed mix indicated that the temperature of homogenization was not of major importance in the division of the fat globules.

The homogenization temperature had no perceptible effect on the acidity, pH, protein stability, ice crystal size, or body and texture score.

IV. THE EFFECT OF VARYING THE AGING PERIOD ON THE QUALITY OF ICE CREAM

The practice of aging the mix has been long regarded as an aid in improving the quality of ice cream, particularly the whipping ability body, and texture. Aging the mix one or two days has been generally adopted in the ice cream industry. In this section, aging periods of 0, 4, 24, and 48 hours were used and the resulting product was tested to determine if the quality was affected.

Procedure

The procedure used in this portion of the study was similar to that given in the section on pasteurization temperature on pages 19 to 25, with some exceptions that will be pointed out below. However, the mix ingredients and compositions, and the quality tests and testing methods were the same as those previously given.

The mix ingredients were assembled and pasteurized at a temperature of 150°F. for 30 minutes. Coming from the pasteurizer at 150°F., the mix was homogenized at 2500 pounds pressure on the Cherry-Burrell Model 238 Viscolizer. The mix was immediately cooled on a surface cooler to 50°F. and representative samples placed in 10 gallon milk cans and stored in a 40°F. storage room. After aging for periods of 0, 4, 24, and 48 hours, the mixes were frozen as previously outlined, and samples to be tested were secured. Samples of the frozen product were hardened at a temperature of -10°F. under still air conditions.

Experimental Results

Effect of Aging on Acidity. Samples of mix obtained at the various stages of processing were tested to determine if the aging periods had any effect on the acidity. Following the procedure given previously, the acidity tests were performed on the samples and the results recorded on the following table.

Table 32. The Effect of Varying the Aging Period on the Acidity of the Mix.

Aging Period	Per Cent Acidity				
	Batch C	Batch E	Batch N	Batch O	Batch T
		Before Processing			
0 Hrs.	0.242%	0.235%	0.240%	0.216%	0.230%
		After Processing			
0	0.245	0.238	0.243	0.218	0.234
4	0.242	0.238	0.242	0.222	0.235
24	0.247	0.225	0.240	0.218	0.233
48	0.245	0.230	0.240	0.220	0.235
		After Freezing			
0	0.240	0.235	0.238	0.222	0.235
4	0.245	0.233	0.240	0.230	0.234
24	0.245	0.225	0.240	0.225	0.232
48	0.247	0.230	0.244	0.220	0.227

In all of the batches, it will be noted that the processing of the mix resulted in a slight increase in the titratable acidity. The only plausible explanation of this would be the increased perceptibility of color change in the processed samples. Tests on the aged mixes exhibited some variation but failed to show any consistent trend to increase or decrease. Also freezing apparently had no appreciable effect on the acidity. The temperatures used in the handling of the mix were not high enough to permit bacterial growth and an accompanying increase in acidity. Under the conditions of this experiment, the length of the aging period had no significant effect on the acidity.

Effect of Aging on pH. Potentiometric determinations of the hydrogen ion concentration were made on the samples of the mix obtained at the various aging periods. The results of the tests showing the effect of aging on the pH are given in the following table.

Table 33. The Effect of Varying the Aging Period on the pH of the Mix.

Aging Period	pH Readings				
	Batch C	Batch E	Batch N	Batch O	Batch T
	Before Processing				
0 Hrs.	6.33	6.36	6.36	6.37	6.35
	After Processing				
0	6.34	6.36	6.37	6.35	6.35
4	6.34	6.36	6.38	6.36	6.36
24	6.35	6.36	6.36	6.35	6.36
48	6.33	6.35	6.36	6.36	6.35
	After Freezing				
0	6.34	6.37	6.33	6.38	6.36
4	6.33	6.37	6.34	6.33	6.35
24	6.34	6.38	6.36	6.35	6.35
48	6.35	6.35	6.33	6.33	6.33

The results of the determinations showed some variation in the pH of the mix, but there were no trends indicating that the aging period had a significant effect on the pH. The variations noted were not great and were within the limits of accuracy of the potentiometer.

Effect of Aging on Viscosity. Mix samples were obtained from each of the batches and tested for viscosity by the procedure given. Results of the viscosity determinations showing the effects of aging are given in the table on the following page.

Numerous investigators, (21), (25), (47), (62), (69), (87), and (89), have observed an increase in the viscosity of the mix as the aging time increased. Data obtained in this study did not show the large increases previously noted, but it did confirm the earlier observations. The increase in viscosity in this experiment where gelatin was used as a stabilizer, was due probably to the formation of a gel structure which increased the amount of bound water. As a result of the freezing process the viscosity of the mix was reduced, but the reduction was not uniform in all cases. The reduction in viscosity by freezing has been attributed to the mechanical separation of the fat globule clumps, but the breaking down of the gel structure must also be considered as a contributing factor.

Table 34. The Effect of Varying the Aging Period on the Viscosity of the Mix.

Aging Period	Centipoise Batch C	Batch E	Batch N	Batch O	Batch T
		Before Processing			
0 Hrs.	35.7	100.8	46.2	49.8	36.8
		After Processing			
0	58.3	196.6	102.5	105.7	78.0
4	60.5	210.6	119.2	112.0	88.4
24	60.2	253.8	115.8	108.7	93.3
48	58.3	275.4	127.8	111.3	97.6
		After Freezing			
0	42.1	63.0	90.4	67.7	64.7
4	44.7	57.5	90.6	72.2	61.1
24	79.3	73.9	89.7	73.3	61.1
48	89.5	88.6	91.4	62.0	59.0

<u>Effect of Aging on Surface Tension</u>. Samples of the mix removed at various stages of preparation were tested to learn the effect of aging on surface tension. The tensiometric readings were made according to the procedure outlined earlier. Results of the determinations are given in the table on the following page.

In all of the cases, the surface tension of the mix was increased by processing. This increase probably resulted in a finer dispersion of the mix components and an increased uniformity of the mixture due to homogenization. Results indicated that surface tension was not affected by the aging period. Since samples of the melted ice cream were noted to have some free fat rising to the surface, the lack of homogeneity of of the samples may have been the reason for the decreased surface tension following freezing.

Table 35. The Effect of Varying the Aging Period on the Surface Tension of the Mix.

Aging Period	Dynes per cm. Batch C	Batch E	Batch N	Batch O	Batch T
		Before Processing			
0 Hrs.	46.3	47.3	46.2	46.6	45.4
		After Processing			
0	47.4	48.3	48.5	50.2	48.5
4	47.1	48.0	48.7	50.4	48.4
24	47.4	46.8	48.8	50.5	48.0
48	47.5	46.2	47.8	49.5	48.0
		After Freezing			
0	47.0	48.0	47.7	47.2	46.8
4	46.0	48.5	47.5	47.8	47.0
24	46.6	48.3	47.8	47.8	47.4
48	47.8	48.7	47.9	47.4	46.9

<u>The Effect of Aging on Protein Stability</u>. Samples of each of the batches were tested to determine their alcohol numbers which were used as an indication of protein stability. The results of the determinations showing the effect of aging on alcohol numbers are given in following table.

Table 36. The Effect of Varying the Aging Period on the Alcohol Number of the Mix.

Aging Period	Stability: Alcohol Number Batch C	Batch E	Batch N	Batch O	Batch T
		Before Processing			
0 Hrs.	7.2	7.6	7.4	7.4	7.4
		After Processing			
0	7.3	7.6	7.3	7.4	7.4
4	7.3	7.7	7.4	7.3	7.3
24	7.2	7.7	7.3	7.4	7.4
48	7.2	7.6	7.3	7.4	7.4
		After Freezing			
0	7.3	7.3	7.2	7.5	7.6
4	7.7	7.6	7.3	7.4	7.7
24	7.5	7.6	7.3	7.3	7.7
48	7.5	7.7	7.3	7.5	7.7

There was some variation in the protein stability of the mixes, but the differences were not large and failed to show a consistent increase or decrease. Also, processing and freezing of the mix did not result in significant differences. These data would indicate that the protein stability was not affected appreciably by the aging period, processing, or freezing.

Effect of Aging on Fat Globule Size. The average size of the fat globules was determined by direct microscopic examination of the samples of each of the batches. The procedure outlined earlier was used to obtain the average size of the globules in the samples taken in the various stages. These data are summarized in the following table.

Table 37. The Effect of Varying the Aging Period on the Fat Globule Size in the Mix.

Aging Period	Size of Fat Globules in Microns				
	Batch C	Batch E	Batch N	Batch O	Batch T
		Before Processing			
0 Hrs.	3.5	4.0	3.5	4.0	3.5
		After Processing			
0	1.75	2.0	1.5	1.75	1.75
4	1.75	2.0	1.5	2.0	1.75
24	1.50	2.0	1.5	2.0	1.75
48	1.50	2.0	1.5	1.75	1.75
		After Freezing			
0	3.0	3.0	4.0	3.5	3.0
4	2.75	3.0	4.0	3.5	3.0
24	2.5	3.0	4.0	3.0	2.75
48	2.5	3.0	4.0	3.0	2.5

The average size of the fat globules was reduced approximately one-half by the processing of the mix, although the reduction was not uniform for each of the mixes. Since there was inconsistency in the results of the examination of the aged mixes, indications are that fat globule size was not affected significantly by the length of the aging period. Collision and coalescence during the freezing process brought about an

increase in the fat globule size with a tendency for a greater increase to occur in the samples aged for the shortest period. Solidification and crystalization of the fat in the globules in the batches aged for longer period were the likely cause of the resistance of the globules to coalesce during freezing.

Effect of Aging on Fat Globule Clumping. The extent of clumping was noted at the same time the size of the globules was determined. Results showing the effect of aging on the fat globule clumping are given in the following table.

Table 38. The Effect of Varying the Aging Period on the Fat Globule Clumping in the Mix.

Aging Period	Degree of Fat Clumping				
	Batch C	Batch E	Batch N	Batch O	Batch T
	Before Processing				
0 Hrs.	0	0	0	0	0
	After Processing				
0	++	++	+	+	+
4	++	++	+	++	+
24	++	+++	+	++	+
48	++	++	+	+	+
	After Freezing				
0	+	+	+	+	+
4	+	+	+	+	+
24	+	+	+	+	+
48	+	+	+	+	+

There was no clumping of the fat globules in the unprocessed mixes; however, clumping was observed in all of the batches that had been homogenized. The extent of clumping varied between batches, but was relatively uniform within the batches, exhibiting no trends toward an increase or decrease. The length of the aging period was not instrumental in determining the degree of clumping. Clumps of fat globules were broken up by the agitation during the freezing process with only slight clumping noted in the samples after freezing.

Effect of Aging on Body and Texture Score. Organoleptic observations of body and texture were made on each of the samples of ice cream. The body and texture scores of these determinations are given in the following table.

Table 39. The Effect of Varying the Aging Period on the Body and Texture Score of the Ice Cream.

Aging Period	Body and Texture Score				
	Batch C	Batch E	Batch N	Batch O	Batch T
0 Hrs.	27.50	27.50	28.00	28.00	28.00
4	27.75	27.50	28.00	28.00	28.00
24	28.25	27.50	28.00	28.00	28.00
48	28.50	27.75	28.25	28.00	28.25

Results of this study showed that the body and texture were slightly improved by aging but the improvement was relatively small. The body and texture benefits of aging high solids mixes, as pointed out by Martin (64), were not of practical value. There appeared to be justification in some aging of low solids mixes to permit form tion of a gel structure and hydration of the proteins.

Effect of Aging on the Rate of Melt Down. Representative portions of the ice cream were permitted to melt in order that the rate and manner of melt down could be noted. Volumes of melt down obtained in the determinations are listed in the following table.

Table 40. The Effect of Varying the Aging Period on the Melt Down of the Ice Cream.

Aging Period	Melt Down in ml.				
	Batch C	Batch E	Batch N	Batch O	Batch T
0 Hrs.	21	23	39	26	63
4	32	50	44	41	64
24	52	65	48	42	68
48	63	77	54	46	67

It was noted that the rate of melt down increased as the length of the aging period was increased. This was recorded in all of the batches; however the increase was not uniform in each case. The greatest benefits were obtained during the first four hours of aging. In addition to the increased rate of melting, it was observed that the smoothness of melt down increased as the length of the aging period was increased. Hydration of the proteins during the storage period resulting in an increased amount of bound water, probably was the reason for the aged mixes melting slower and smoother.

Effect of Aging on the Ice Crystal Size. Direct microscopic examinations of the frozen ice cream were made to determine the average size of the ice crystals. Results of the observations are given in the following table.

Table 41. The Effect of Varying the Aging Period on the Ice Crystals in the Frozen Ice Cream.

Aging Period	Size of Ice Crystals in Microns				
	Batch C	Batch E	Batch N	Batch O	Batch T
0 Hrs.	45	40	30	35	30
4	40	40	30	35	35
24	40	35	40	35	35
48	40	40	40	30	35

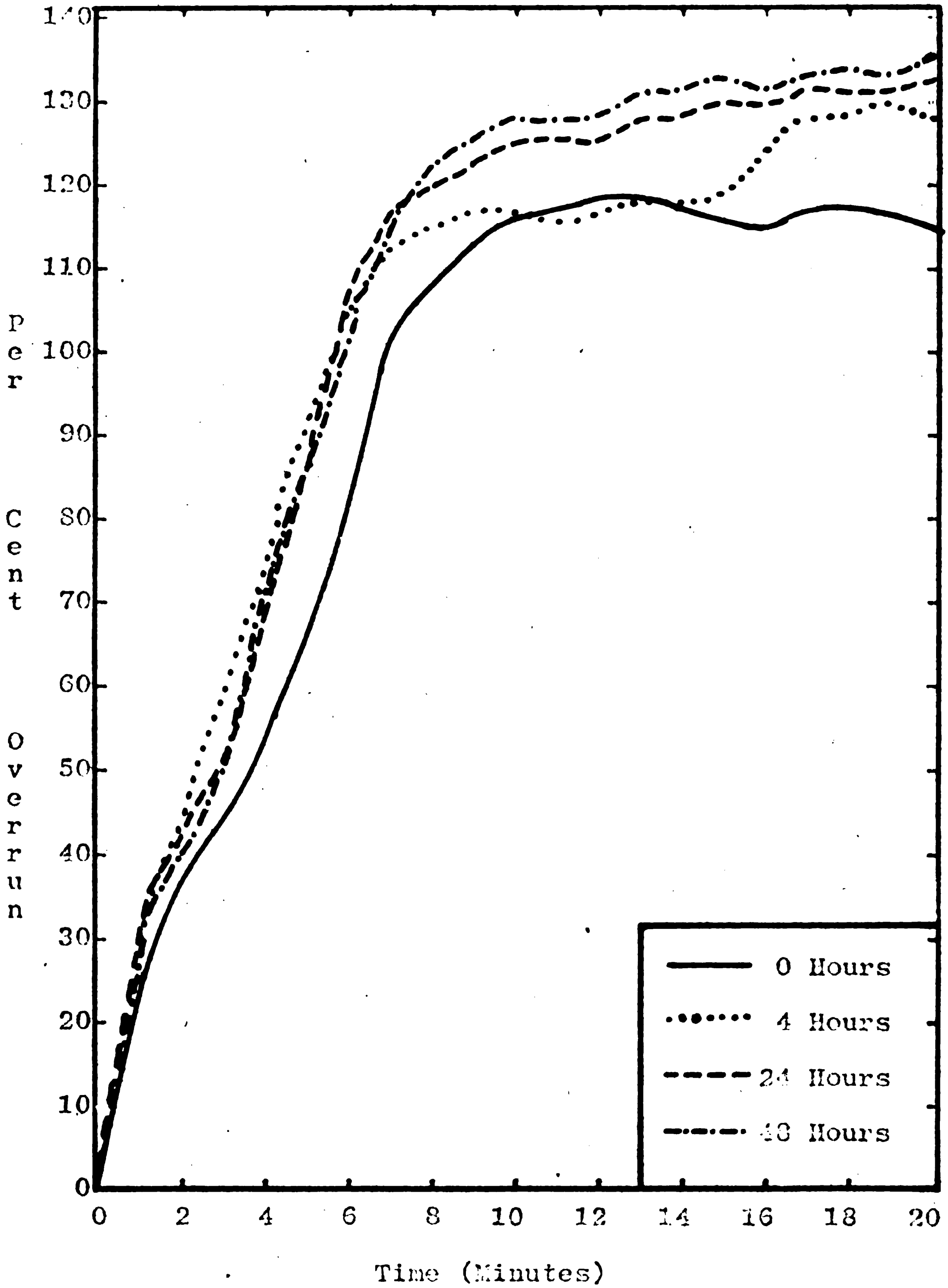
Ice crystal size did not vary widely within the various batches of mix; since trends were not distinguishable, it indicated that the length of the aging period had little effect on the size of the ice crystals. The ice crystal size appeared to be more dependent on the freezing and subsequent handling than on the processing of the mix.

Effect of Aging on the Whipping Characteristics. Overrun readings were made at one minute intervals from the time freezing began and the readings compiled in the graphs fround on the next six pages. Inspection of the overrun patterns indicated that both the rate and capacity of whipping was increased by an increase in the aging period. The improvements to the whipping characteristics were particularly beneficial when the aging period was at least 24 hours in length. Studies of higher aging temperatures (74) showed that the whipping characteristics were associated closely with the gelatin content and the formation of a more extensive gel structure.

THE EFFECT OF VARYING THE AGING PERIOD ON

OVERRUN CHARACTERISTICS

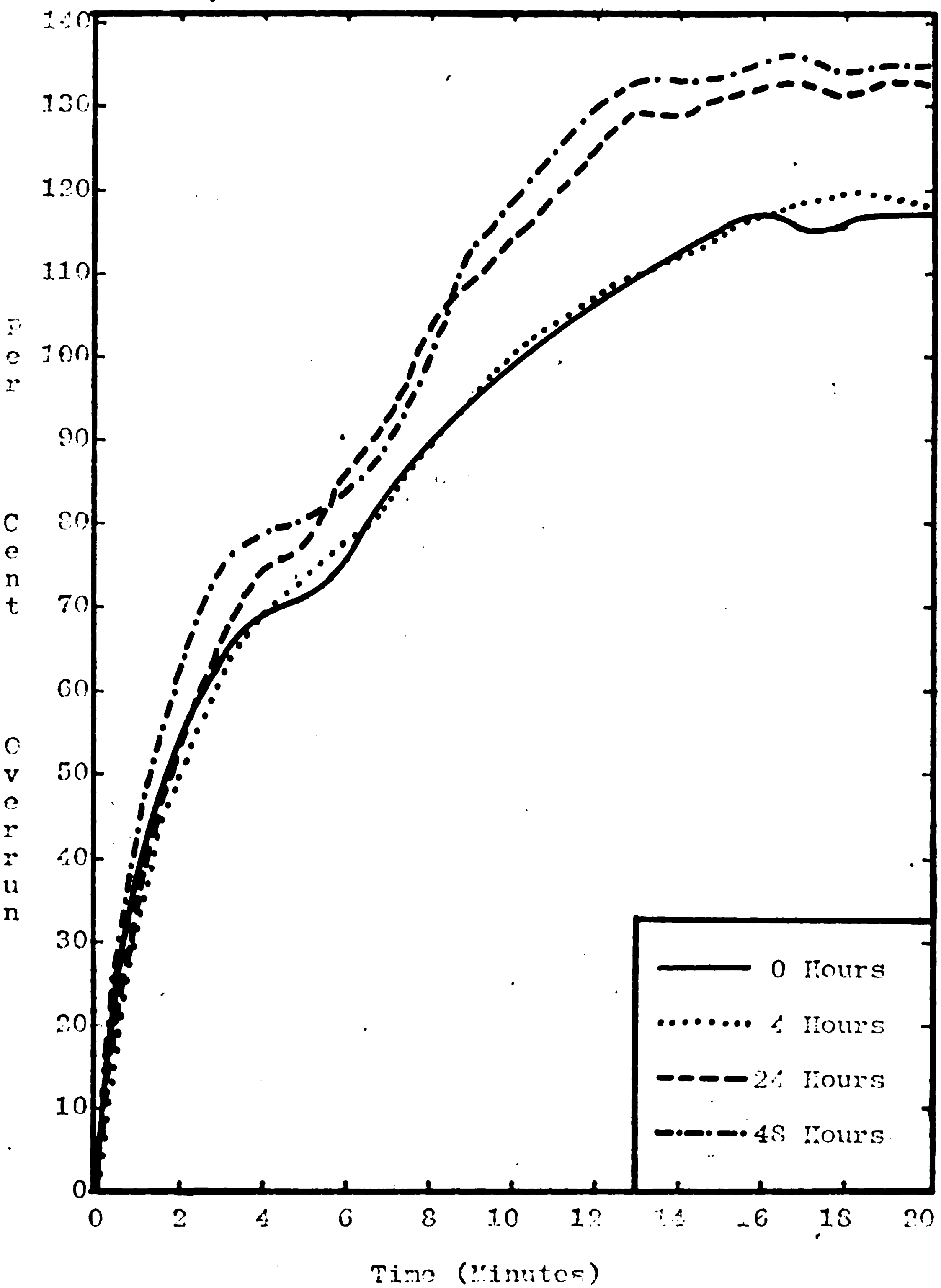
BATCH C



THE EFFECT OF VARYING THE AGING PERIOD ON

OVERRUN CHARACTERISTICS

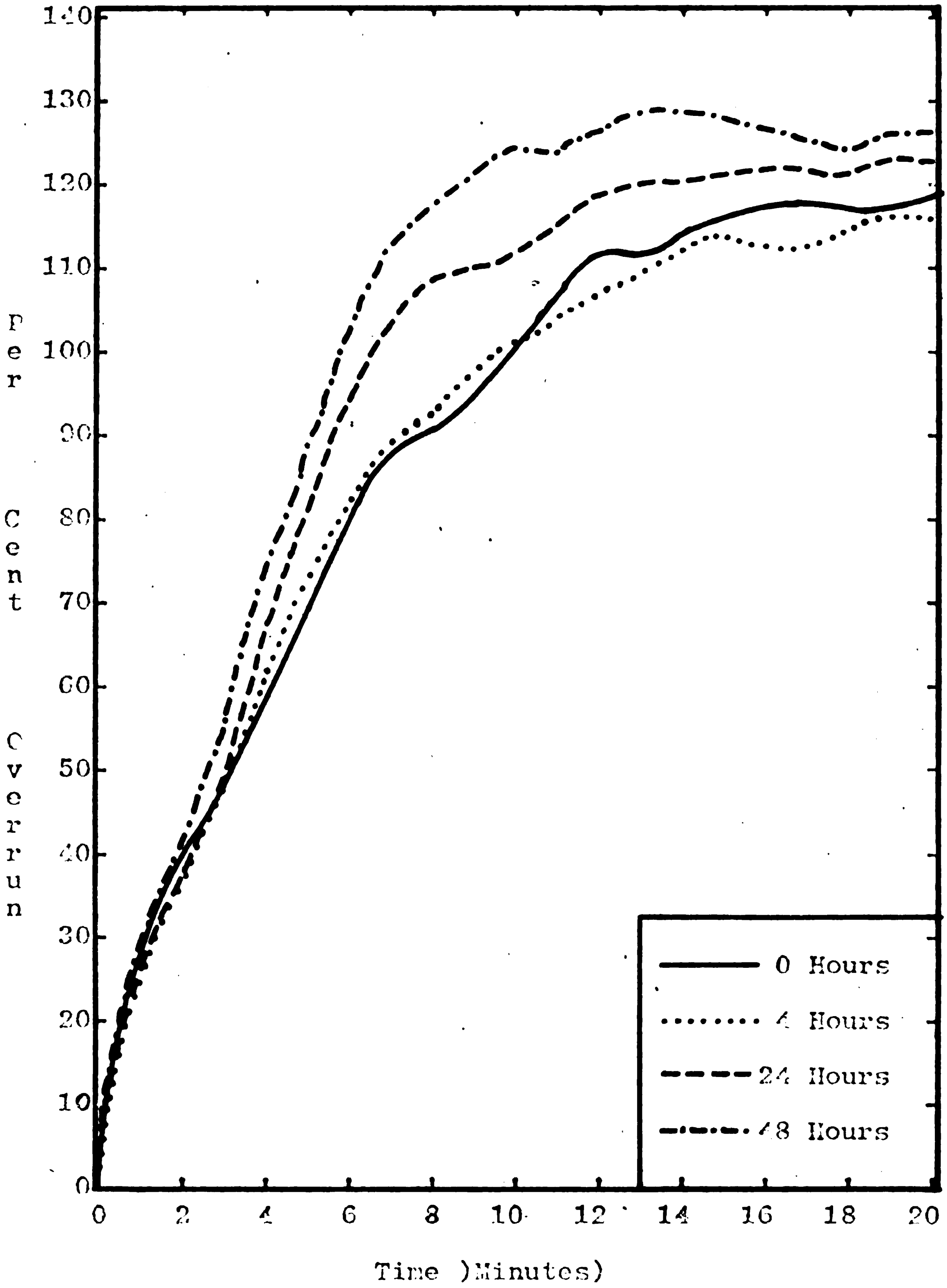
BATCH E



THE EFFECT OF VARYING THE AGING PERIOD ON

OVERRUN CHARACTERISTICS

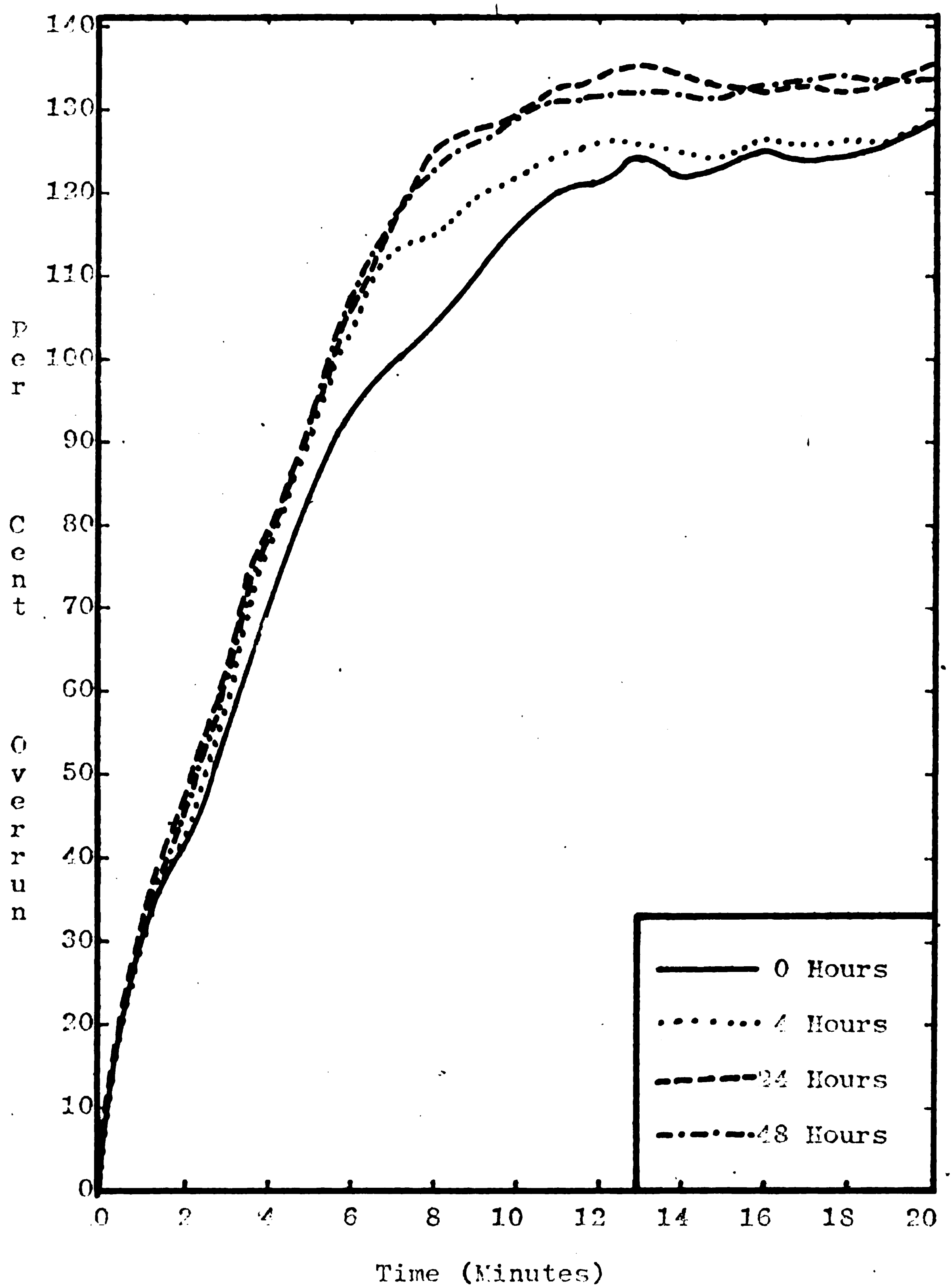
BATCH N



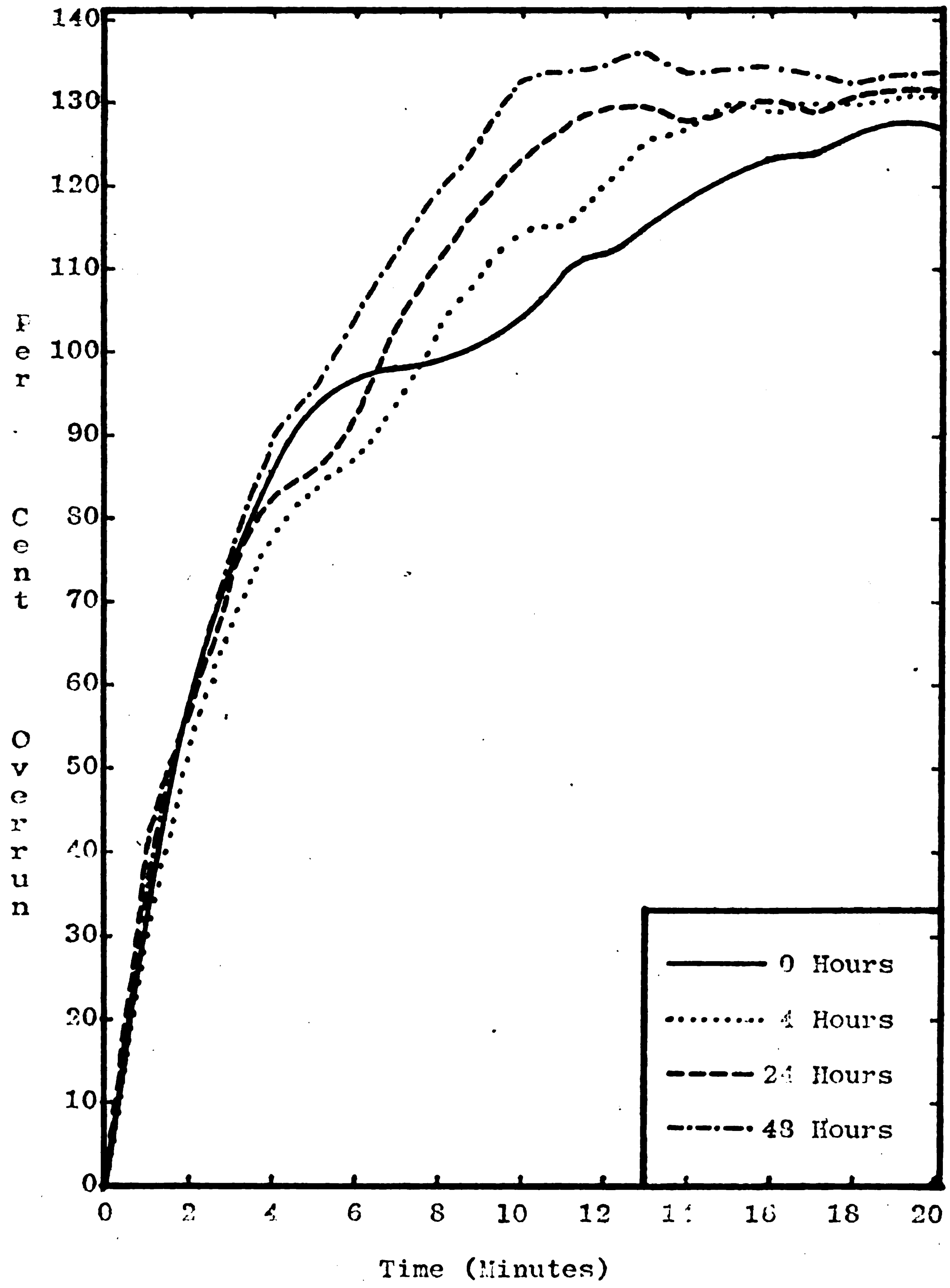
THE EFFECT OF VARYING THE AGING PERIOD ON

OVERRUN CHARACTERISTICS

BATCH O



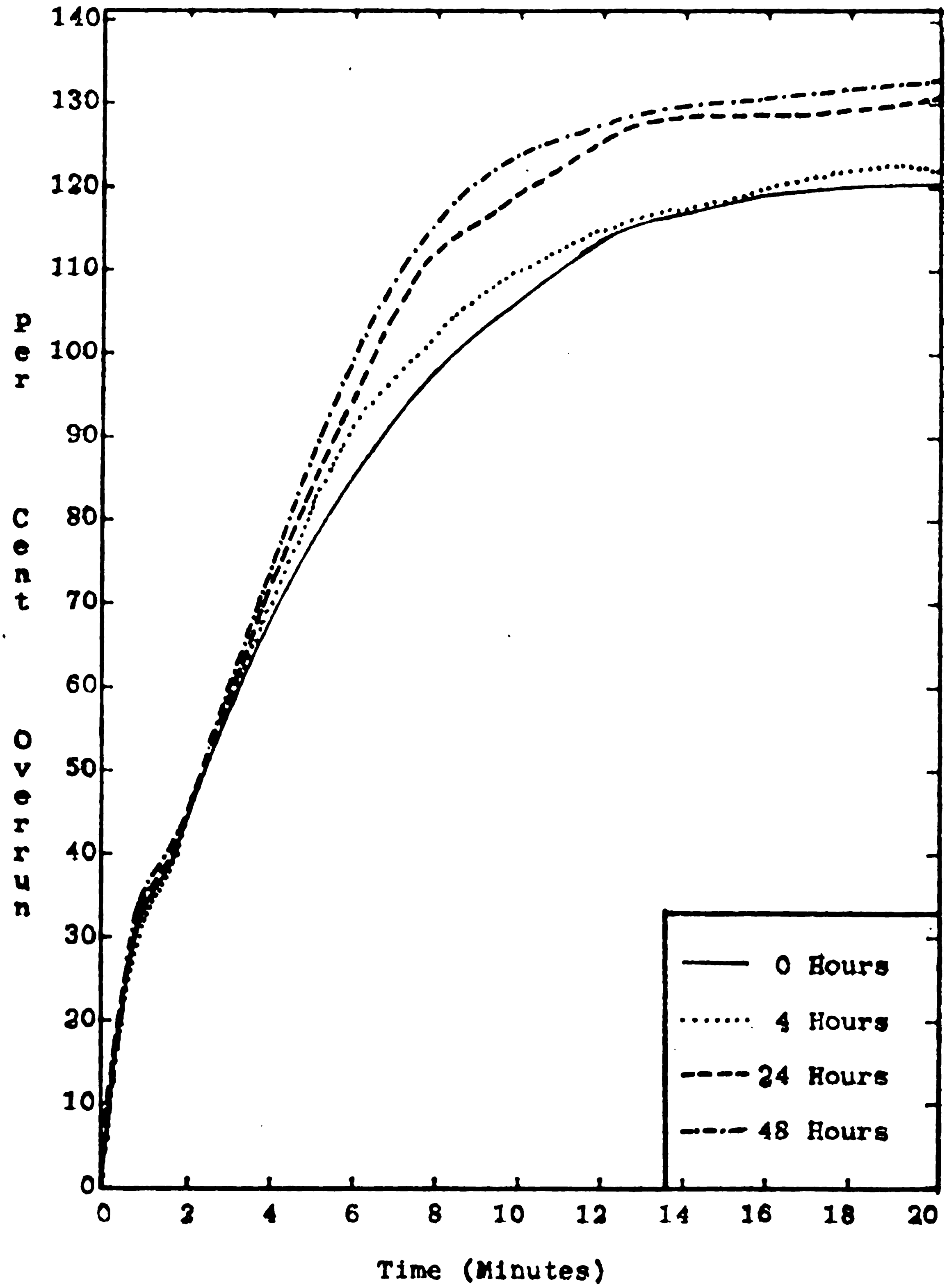
THE EFFECT OF VARYING THE AGING PERIOD ON
OVERRUN CHARACTERISTICS
BATCH T



THE EFFECT OF VARYING THE AGING PERIOD ON

OVERRUN CHARACTERISTICS

AVERAGE OF BATCHES C, E, N, O, and T



Discussion of Results

Aging brings about some very complex changes in the mix which include the hydration of the stabilizer and milk proteins, adsorption of materials on the surface of the fat globules, formation of a gel structure in the mix, and redissolving of some of the tri-calcium phosphate. It is difficult to attribute a change in quality due to aging to any one of these phenomenon. Nevertheless, aging is influential on some of the factors that affect quality in ice cream.

Probably the most significant effect of aging was on the viscosity of the mix. As the aging period increased the viscosity of the mix is increased. Several investigators, (21), (25), (47) (62), (69), (87), and (89) have noted this condition. This was true only where gelatin or some similar stabilizer was used, for there are some stabilizers that produce almost their final viscosity immediately upon cooling. Data indicated that where gelatin was used as the stabilizer, the increased viscosity was due to the formation of a more extensive gel structure. The mechanical agitation during the freezing process probably altered the gel structure thereby lowering the viscosity.

Aging the mix was observed to improve the rate and capacity of whipping. Although the increase in whipping ability was not great, it was significant. Results of this study indicated that four hours of aging was benficial to whipping rate and that twenty-four hours of aging gave some additional benefits in obtaining a maximum overrun. This is in keeping with the conclusions of Dahle, Keith, and McCullough (21), Hening (51), and Sommer (90), who stated that aging the mix four hours gave some improvements, but little additional benefits were attained by longer aging periods. The benefits due to the aging period probably were brought about by the formation of a gel structure which aided in the incorporation of air.

As the aging period was lengthened, the rate and smoothness of melt down was noted to increase. The literature failed to show any similar observations. The benefits in melt down characteristics due to the increased aging period possibly are associated with both the hydration of the proteins and the formation of a gel structure.

Body and texture scores of the ice cream aged for the various periods increased slightly as the aging period increased. However, the improvements in body and texture were small and not of important commercial value. Dahle, Keith, and McCullough (21) and Martin (64) reported some body and texture benefits as a result of aging. This should suppress the common misconception that aging is of great benefit to the body and texture. The benefits attributable to aging are thought to be associated with the hydration of the proteins and to the gel formation.

A slight increase in the surface tension was noted as a result of processing, and a decrease was noted in the samples after freezing. The length of the aging period had no apparent effect on the surface tension. No similar observations were reported in the literature, and it was reasoned that the mix increased its uniformity and that the lower surface tension values noted in the unprocessed and frozen mixes were due to a lack of homogeneity.

The fat globule size was significantly affected by the length of the aging period. As in the previous sections, a decrease in size of the globules resulted from the processing and an increase was brought about by the freezing. These changes were attributable to the mechanical handling of the mix and were not influenced by the aging period.

The acidity of the mix was observed to be increased by processing the mix. The dissipation of carbon dioxide by heating the mix has been noted as a reason for a decrease in acidity. The only plausible explanation of an increase in the acidity due to processing was that the end point color was detected more easily when titrating an unprocessed mix. The aging period had no significant effect on the acidity, since conditions in this study were not favorable for bacterial growth and an accompanying increase in acidity.

V. THE EFFECT OF VARYING THE HARDENING TEMPERATURE ON THE QUALITY OF BATCH AND CONTINUOUSLY FROZEN ICE CREAM

This portion of the study was devoted to studying the effect of varying the hardening temperature. Ice cream samples from both batch and continuous freezers were placed in rooms at 0°F., -10°F., and -20°F. and permitted to harden. The resulting product was tested to see if the quality of the ice cream was affected by the temperature at which it was hardened.

Procedure

The ingredients and composition of the mix were the same as those used throughout the study. The ingredients were assembled in a Creamery Package Series B 300 gallon steam vapor pasteurizing vat and pasteurized at 150°F. for 30 minutes. Following pasteurization, the mix was homogenized in a Cherry-Burrell Series C 350 gallon per hour super homogenizer at a pressure of 2000-500 pounds on a two-stage homogenization valve. After processing, the mix was immediately cooled on a surface cooler to 50°F. and stored in a 40°F. cooler for 24 hours. A representative batch of the ice cream was frozen in either a Creamery Package Fort Atkinson direct expansion 40 quart batch freezer or a Cherry-Burrell Model VS - 200 Vogt continuous ice cream freezer. The ice cream was frozen in the normal fashion on each freezer and samples containing 90 per cent overrun were secured. Average drawing temperatures of 23.5°F. and 22.5°F. were obtained on the batch and continuous freezer respectively.

One gallon Sealright containers were used in determining the rate of hardening. Thermometers were inserted into the center of the samples

which were placed in hardening rooms at 0°F., -10°F., and -20°F. respectively and the ice cream was permitted to harden under still air conditions. The temperatures were recorded at hourly intervals for a period of 12 hours.

Other samples of the ice cream were secured and hardened at the various temperatures. After 24 hours, all of the samples were placed in a -10°F. hardening room and held for an additional 24 hours. The samples were then tested for melt down characteristics, ice crystal size, and body and texture score by following the procedure previously given.

Experimental Results

Effect of Hardening Temperature on Rate of Melt Down. Samples of the ice cream hardened at the various temperatures were tempered to -10°F. and then permitted to melt following the procedure given earlier. The volumes of mix collected indicating the rate of melt down for both the batch and continously frozen ice cream are recorded in the following table.

Table 42. The Effect of Varying the Hardening Temperature on Rate Rate of Melt Down of Batch and Continuously Frozen Ice Cream.

Hardening Temperature	Melt Down in ml.				
	Batch Frozen				
	Batch Z	Batch B	Batch E	Batch F	Batch H
0°F.	76	87	81	85	68
-10°F.	73	82	76	77	55
-20°F.	64	80	67	73	44
	Continuously Frozen				
	Batch Y	Batch A	Batch C	Batch D	Batch G
0°F.	52	41	69	67	52
-10°F.	53	30	68	64	45
-20°F.	41	29	65	65	40

Marked differences were noted in the above results. Probably the most significant difference was in the rate of melt down in the samples hardened at the various temperatures. The rate of melt down was decreased as the hardening temperature was increased. There have been no similar findings reported in the literature. The underlying reason for the decreased rate of melt down is thought to be associated with the decrease in ice crystal size as the result of fast hardening. It is possible that the smaller crystals were more effective in insulating the crystals toward the center, thus retarding the rate of melt down. Most of the samples had a smooth, creamy melt down; but there was noted a tendency for the batch frozen samples to be slightly coarse, especially those that had been hardened at the higher temperatures.

Another significant difference noted was that the batch frozen ice cream melted more rapidly than the continuously frozen ice cream. The smaller, more stable bubbles on the surface during melt down suggested that the air cells in the continuously frozen ice cream were smaller and offered a greater insulation. However, the irregularities in the size of the air cell prevented any general conclusions that the size of the air cell in continuously frozen ice cream was smaller. The ice crystals in the batch frozen ice cream were generally larger which may have been a factor in their more rapid melt down.

<u>Effect of Hardening Temperature in Ice Crystal Size</u>. Direct microscopic examinations of the ice cream were made on each of the samples to determine the average size of the ice crystals. Results of the observations are given in the following table.

Table 43. The Effect of Varying the Hardening Temperature on Ice Crystal Size in Batch and Continuously Frozen Ice Cream.

Hardening Temperature	Size of Ice Crystals in Microns				
	Batch Frozen				
	Batch Z	Batch B	Batch E	Batch F	Batch H
0°F.	45	55	55	55	50
-10°F.	35	45	45	45	45
-20°F.	30	35	40	45	40
	Continuously Frozen				
	Batch Y	Batch A	Batch C	Batch D	Batch G
0°F.	30	40	35	40	35
-10°F.	25	30	30	30	30
-20°F.	25	30	30	30	30

Average ice crystal size in the continuously frozen ice cream was observed to be significantly smaller than that in the batch frozen samples, the average difference being 13 microns. Apparently the lower freezing temperature and faster speed of the scrapers in the continuous freezer resulted in more ice crystal nuclei, reducing the size and increasing the number of ice crystals.

There was a significant decrease in the size of the ice crystals in both the batch and continuous ice cream as the hardening temperature was lowered. Undoubtedly this can be attributed to the melting of some of the ice crystal nuclei during the early stages of hardening and recrystalization on the large nuclei as the temperature was lowered.

Effect of Hardening Temperature on the Body and Texture Score. Each of the samples of ice cream was scored organoleptically for body and texture. A table in which these scores are combined follows immediately.

Table 44. The Effect of Varying the Hardening Temperature of Body and Texture scores of Batch and Continuously Frozen Ice Cream.

Hardening Temperature	Body and Texture Score				
	Batch Frozen				
	Batch Z	Batch B	Batch E	Batch F	Batch H
0°F.	27.75	27.50	27.50	27.75	28.00
-10°F.	28.00	28.50	28.00	28.00	28.25
-20°F.	28.25	28.75	28.25	28.25	28.25
	Continuously Frozen				
	Batch Y	Batch A	Batch C	Batch D	Batch G
0°F.	28.25	28.00	29.00	28.50	28.50
-10°F.	28.50	28.25	29.00	28.75	28.75
-20°F.	28.50	29.00	29.00	29.00	29.00

The body and texture scores varied inversely with the hardening temperature, increasing as the hardening temperature was lowered. Sommers (90) has pointed out that quick hardening produces smaller ice crystals and a smoother texture. The smoothness in the texture of the samples hardened at the lower temperatures is thought to have been due to the smaller ice crystals in those samples.

In general, the scores of the batch frozen samples were lower than comparable samples of continuously frozen ice cream. The lower drawing temperature, finer air incorporation, and smaller ice crystals are all thought to contribute to the improved body and texture score.

Effect of Hardening Temperature on the Ice Cream Temperature. The center temperature of the one gallon sealright containers was taken at hourly intervals for 12 hours. The results of these readings are plotted on the graphs found on the following pages.

Temperature changes in the ice cream hardened at the different

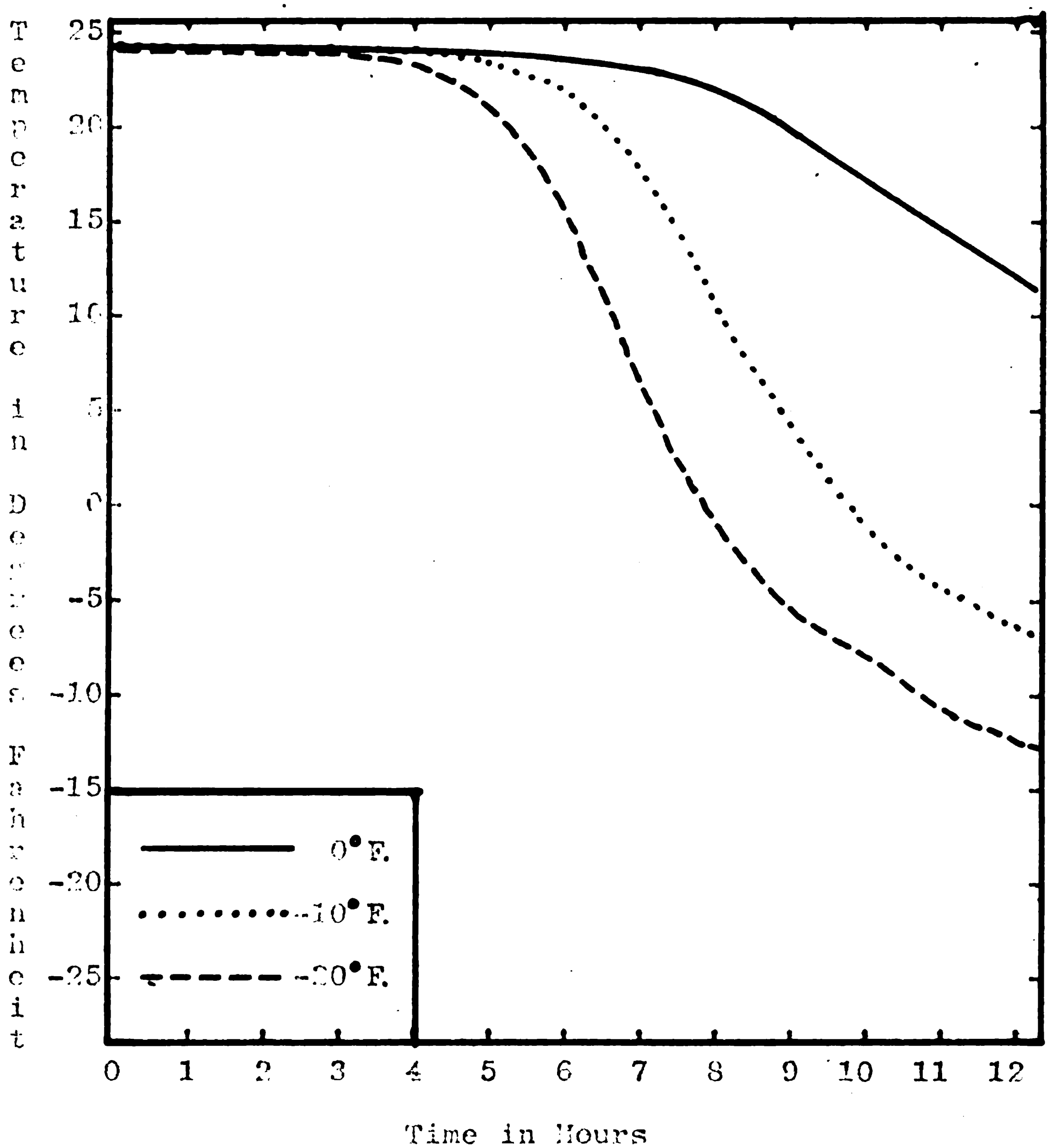
temperatures exhibited very similar drops. The continuously frozen ice cream averaged about one degree colder than the batch frozen samples. A lag period in which the temperature of the samples was relatively constant was noted after the samples were placed in the hardening room. After four to seven hours of relatively constant temperatures, there was a steady decline until the samples came into adjustment with the hardening room temperatures. It was noted that the decline in temperature came sooner and was faster as the hardening temperature declined.

Observations of the samples when drawn revealed that the lower the temperature at which the samples were drawn the drier appearing were the samples. The shiny appearance in freshly drawn ice cream was dependent upon the amount of unfrozen liquid; the more unfrozen water present the shinier was the appearance of the ice cream. Since the amount of unfrozen water was dependent upon the temperature, it was logical to assume that the wet appearance of the freshly drawn ice cream was dependent upon the drawing temperature.

THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF

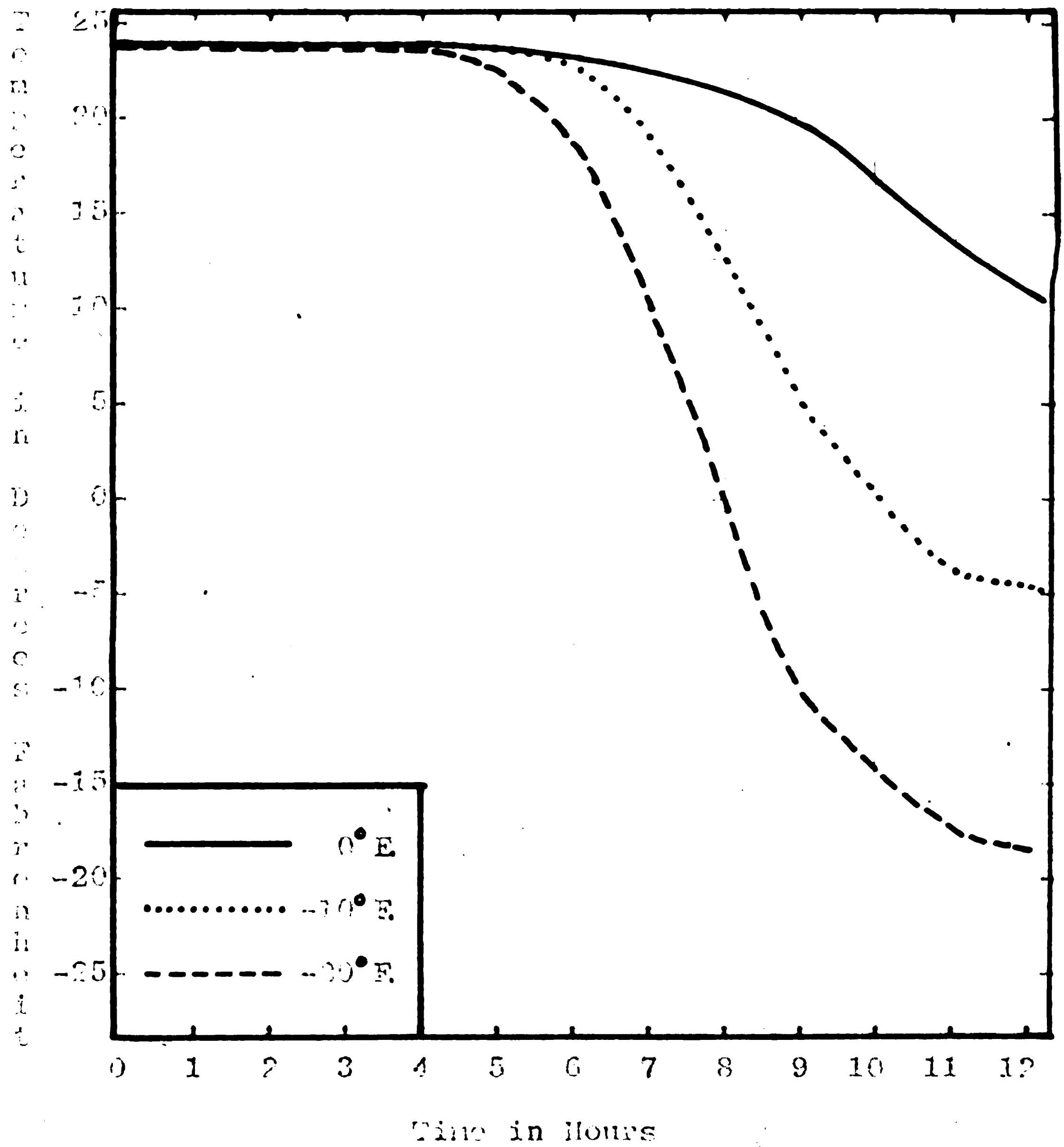
HARDENING OF BATCH FROZEN ICE CREAM

BATCH Z



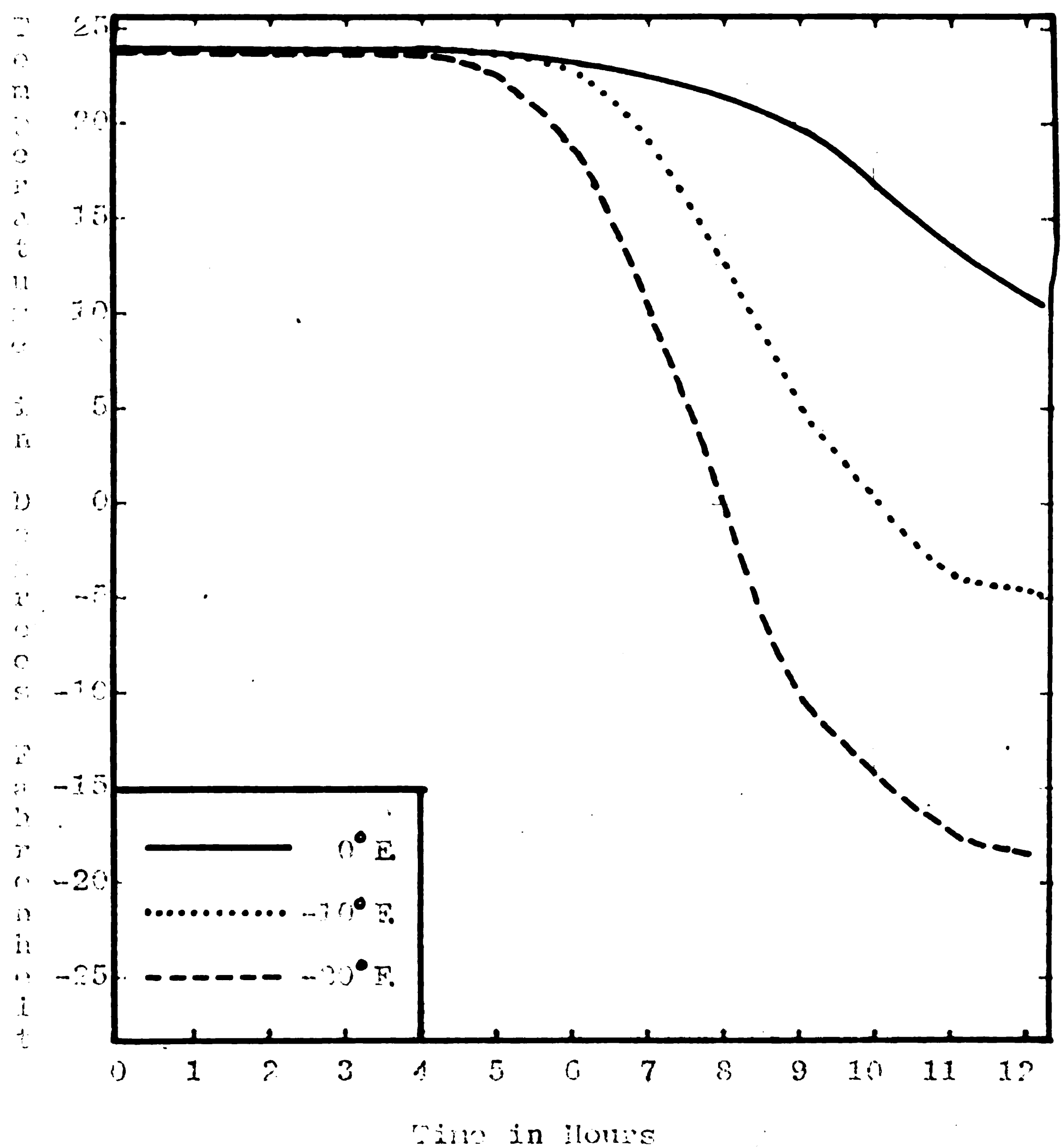
THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF BATCH FROZEN ICE CREAM

BATCH E



THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF BATCH FROZEN ICE CREAM

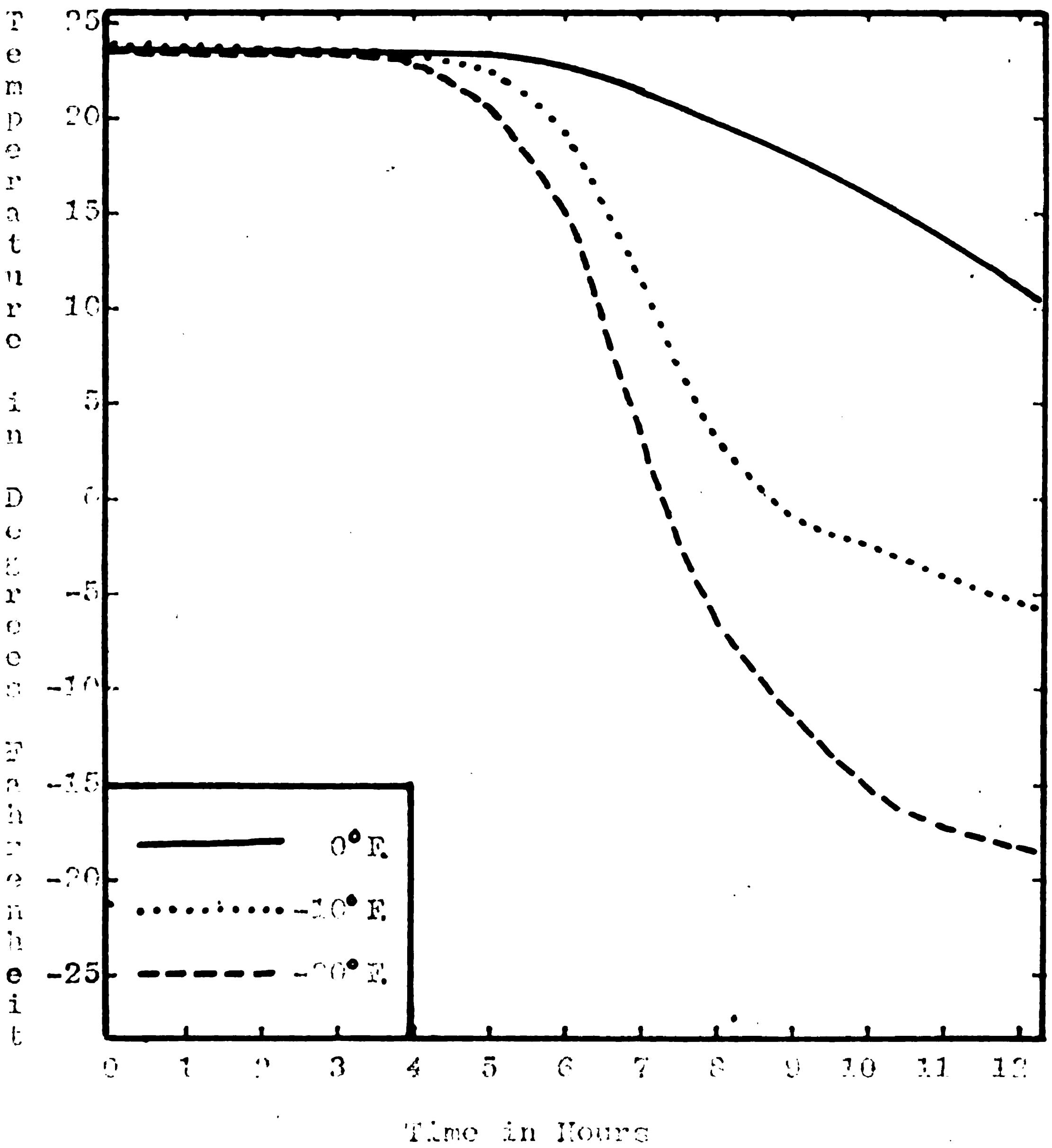
BATCH B



THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF

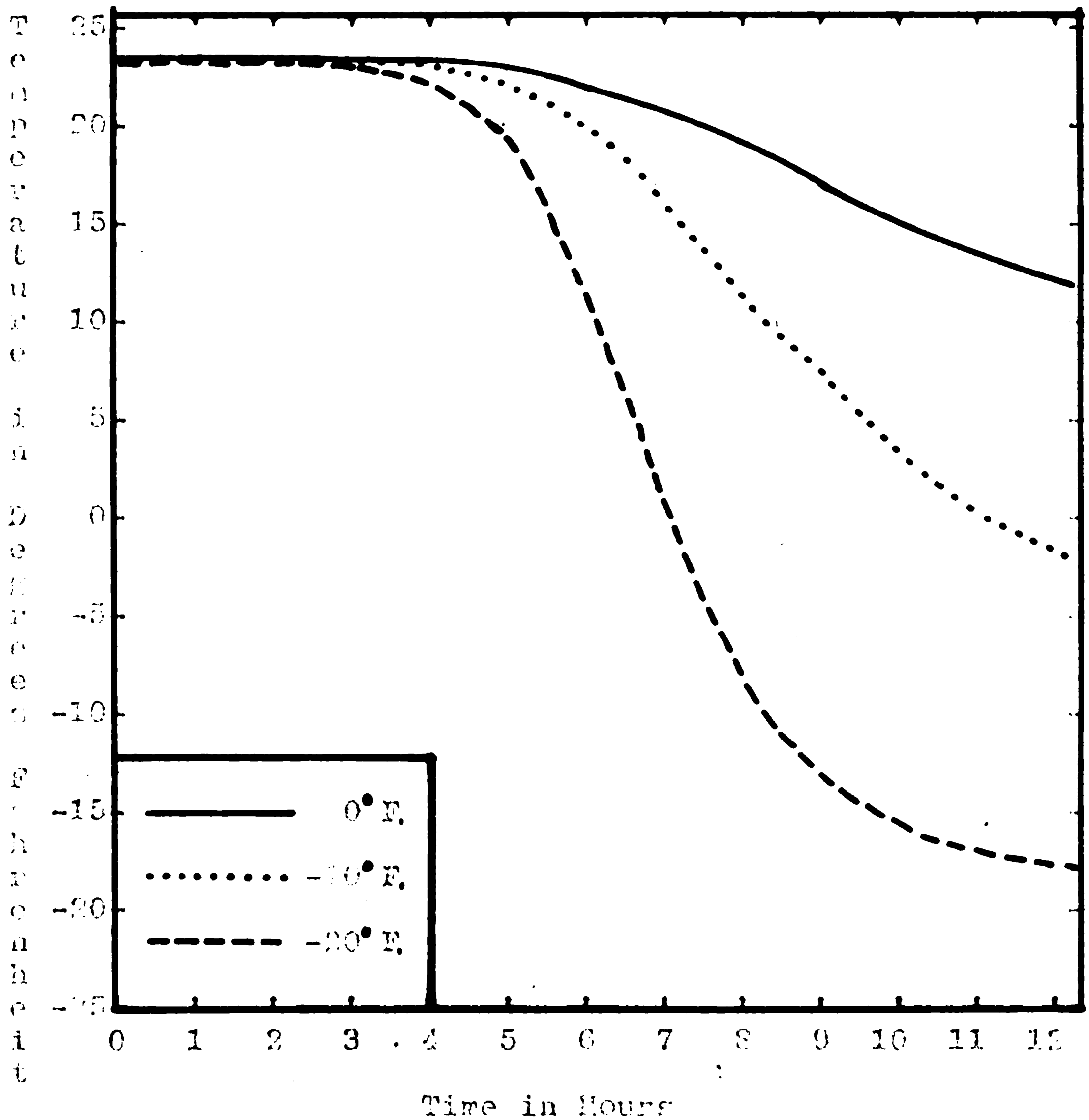
HARDENING OF BATCH FROZEN ICE CREAM

BATCH E



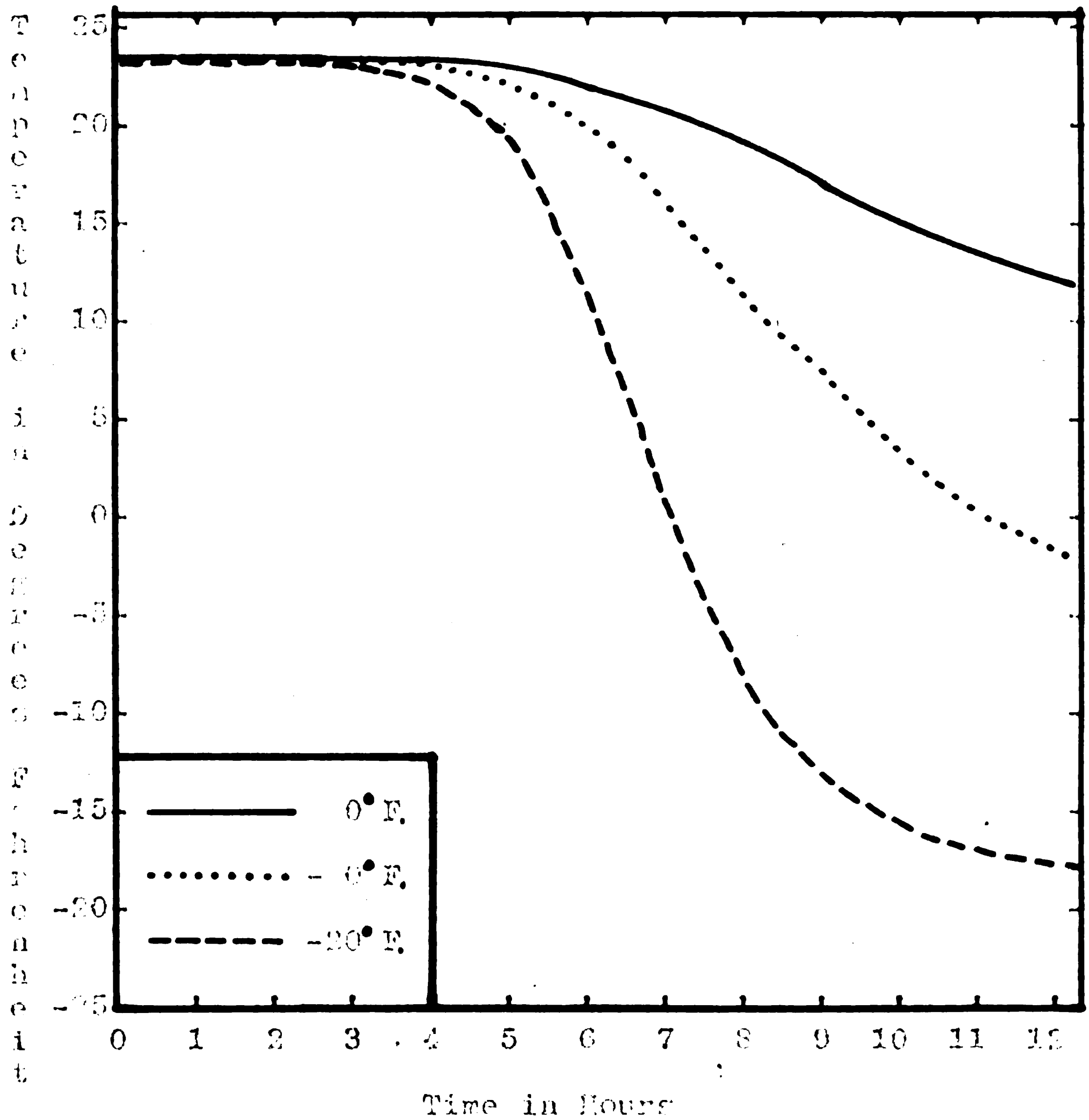
THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF BATCH FROZEN ICE CREAM

BATCH F



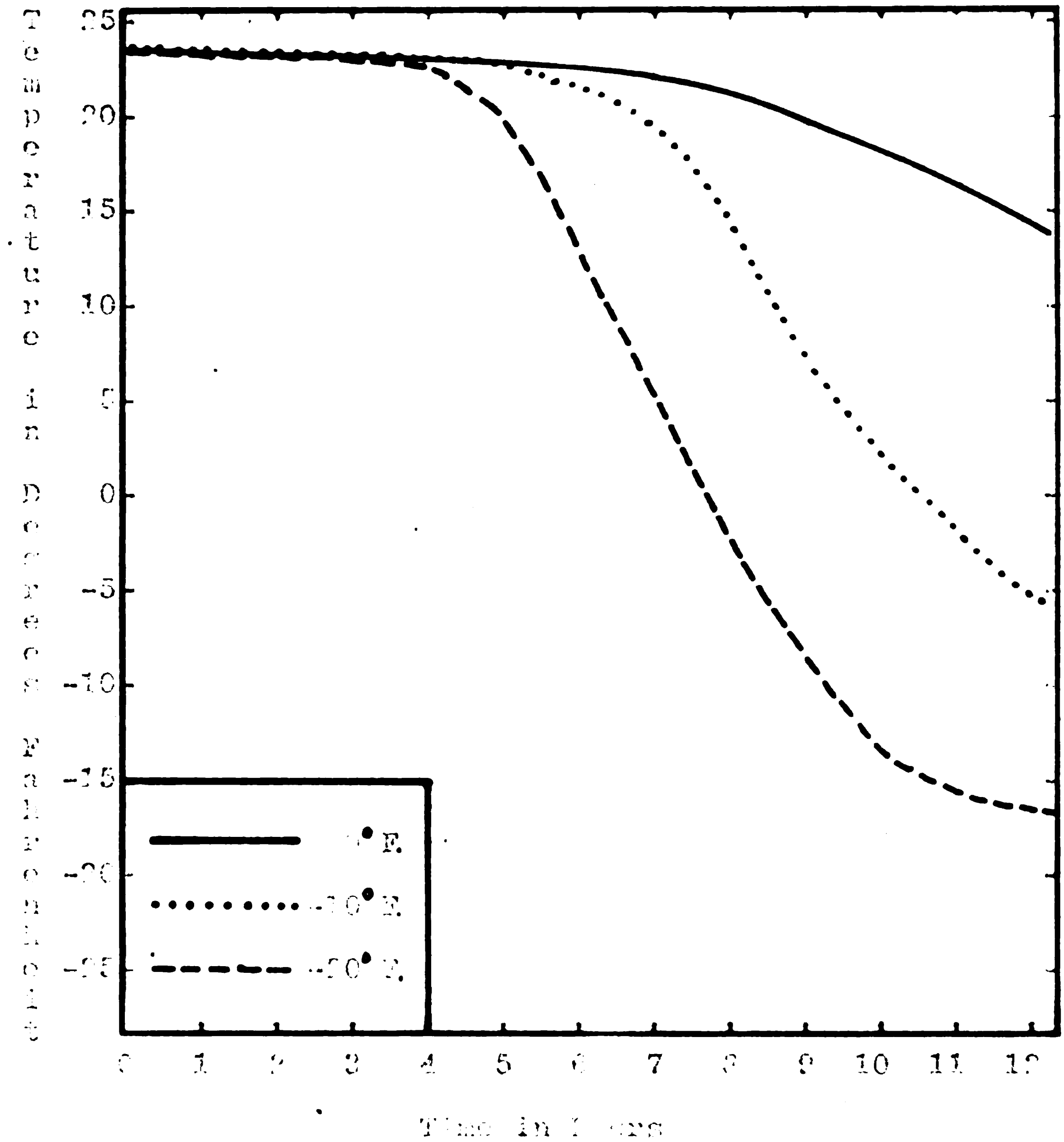
THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF BATCH FROZEN ICE CREAM

BATCH F



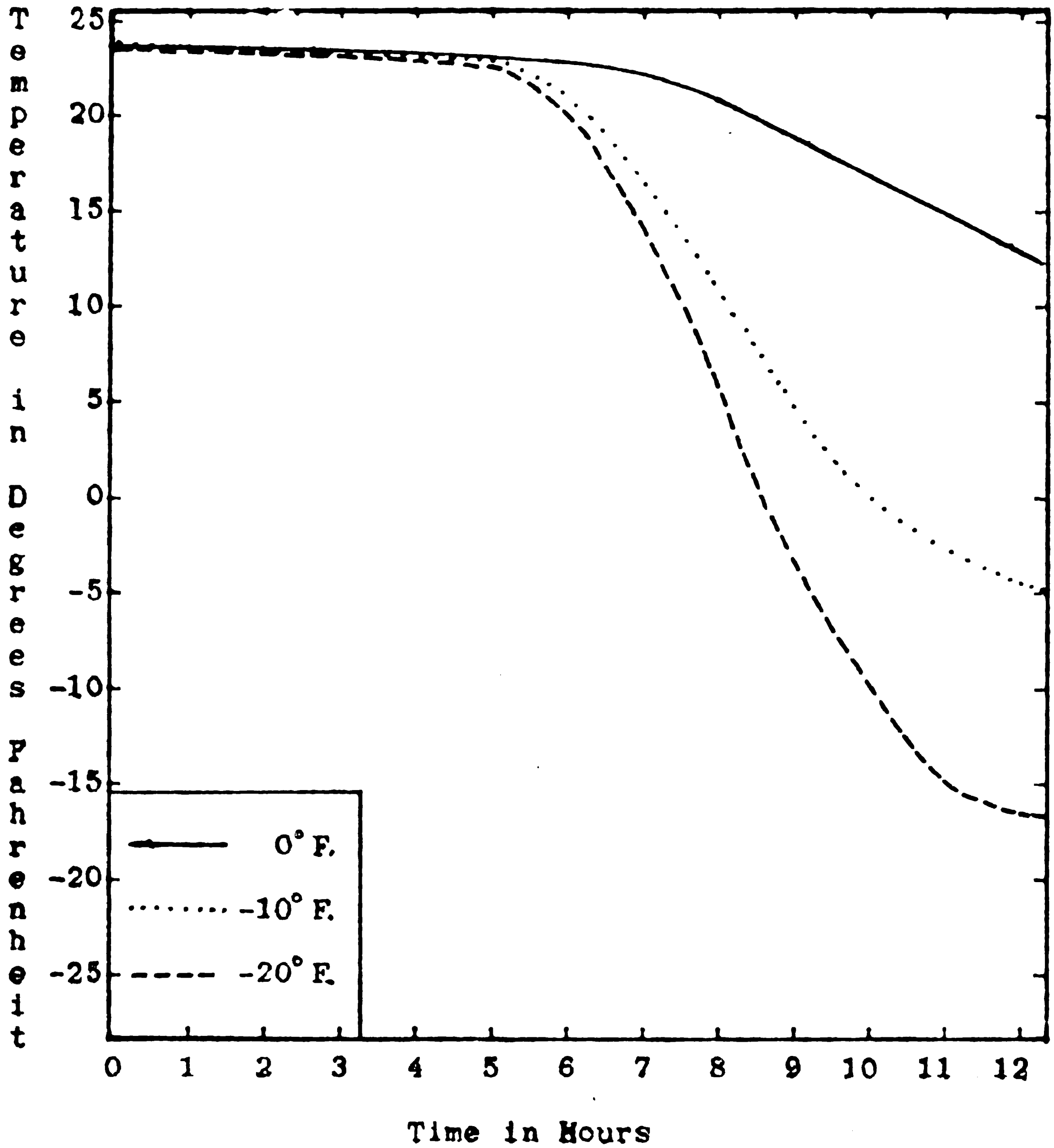
THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF BATCH FROZEN ICE CREAM

BATCH II



THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF BATCH FROZEN ICE CREAM

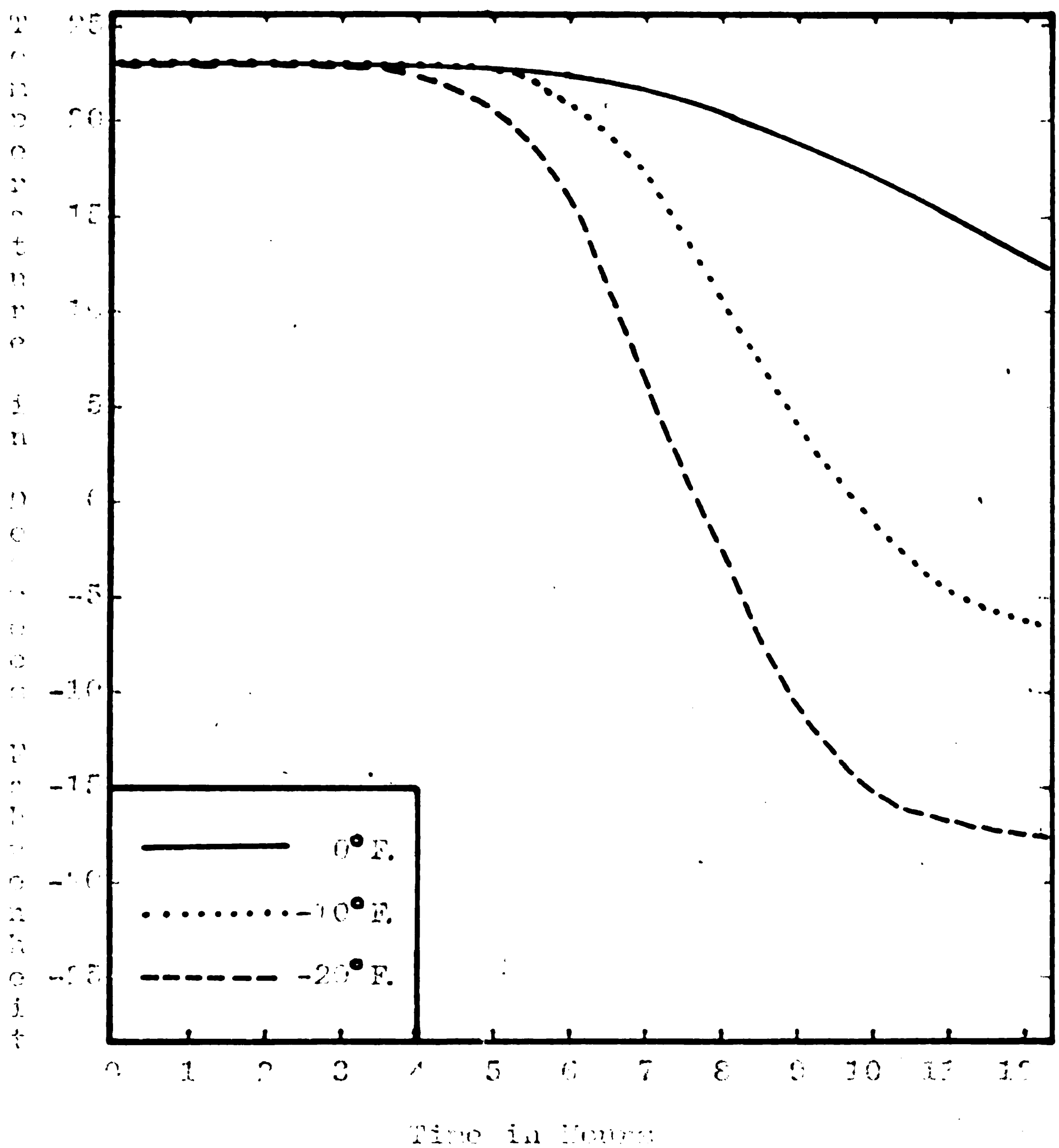
AVERAGE OF BATCHES B, E, F, H, and Z



THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF

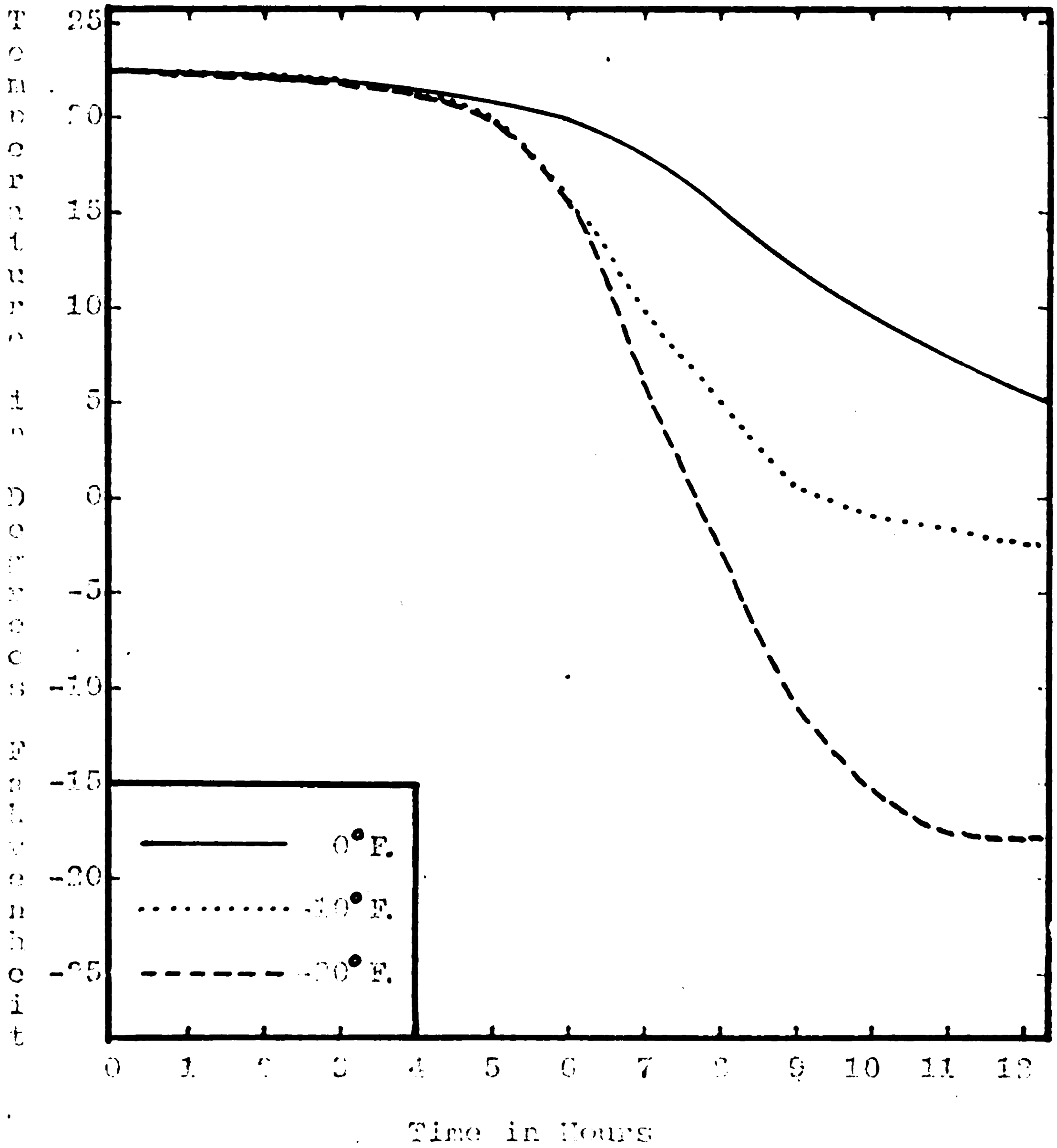
HARDENING OF CONTINUOUSLY FROZEN ICE CREAM

BATCH Y



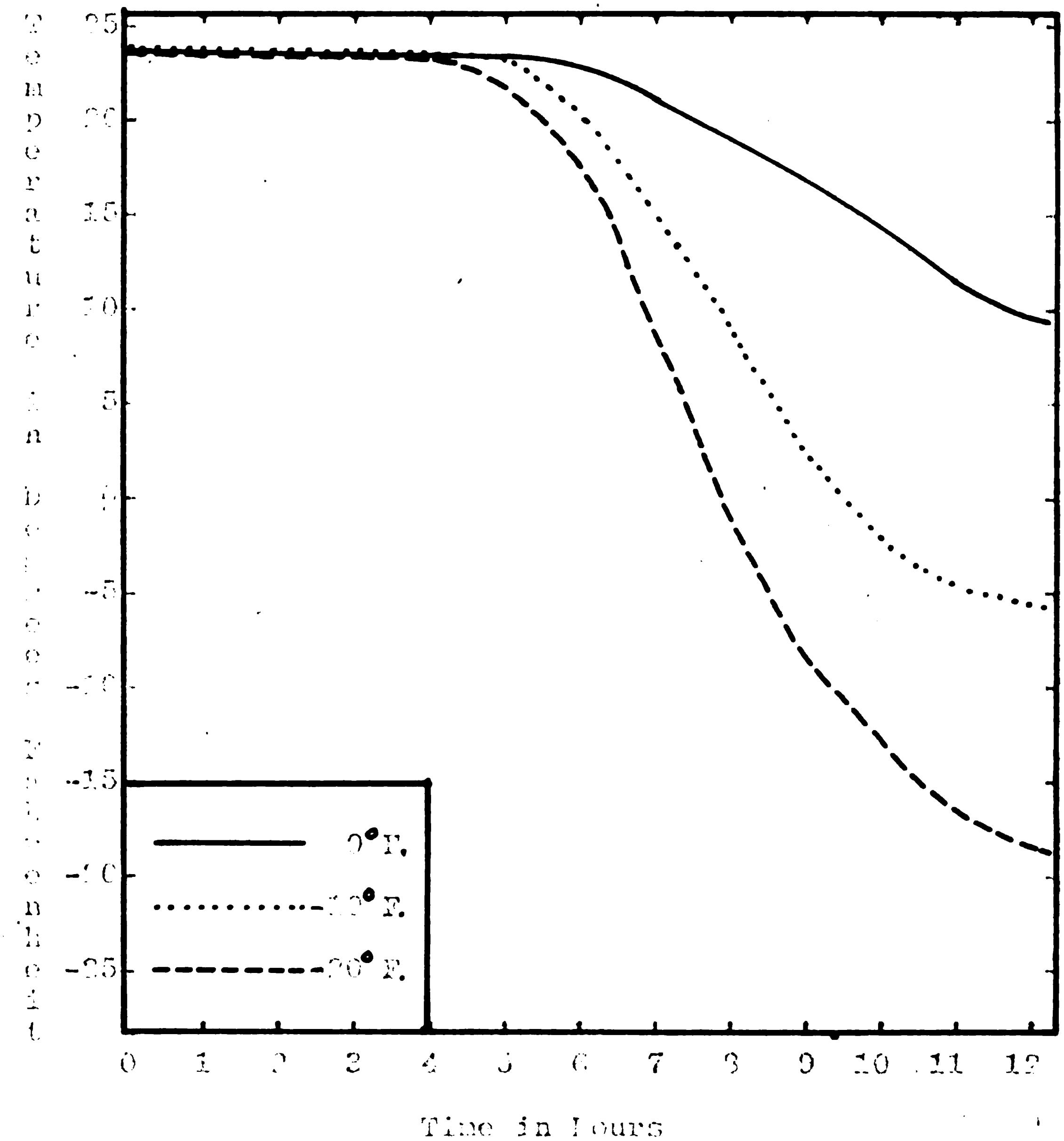
THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF CONTINUOUSLY FROZEN ICE CREAM

BATCH A



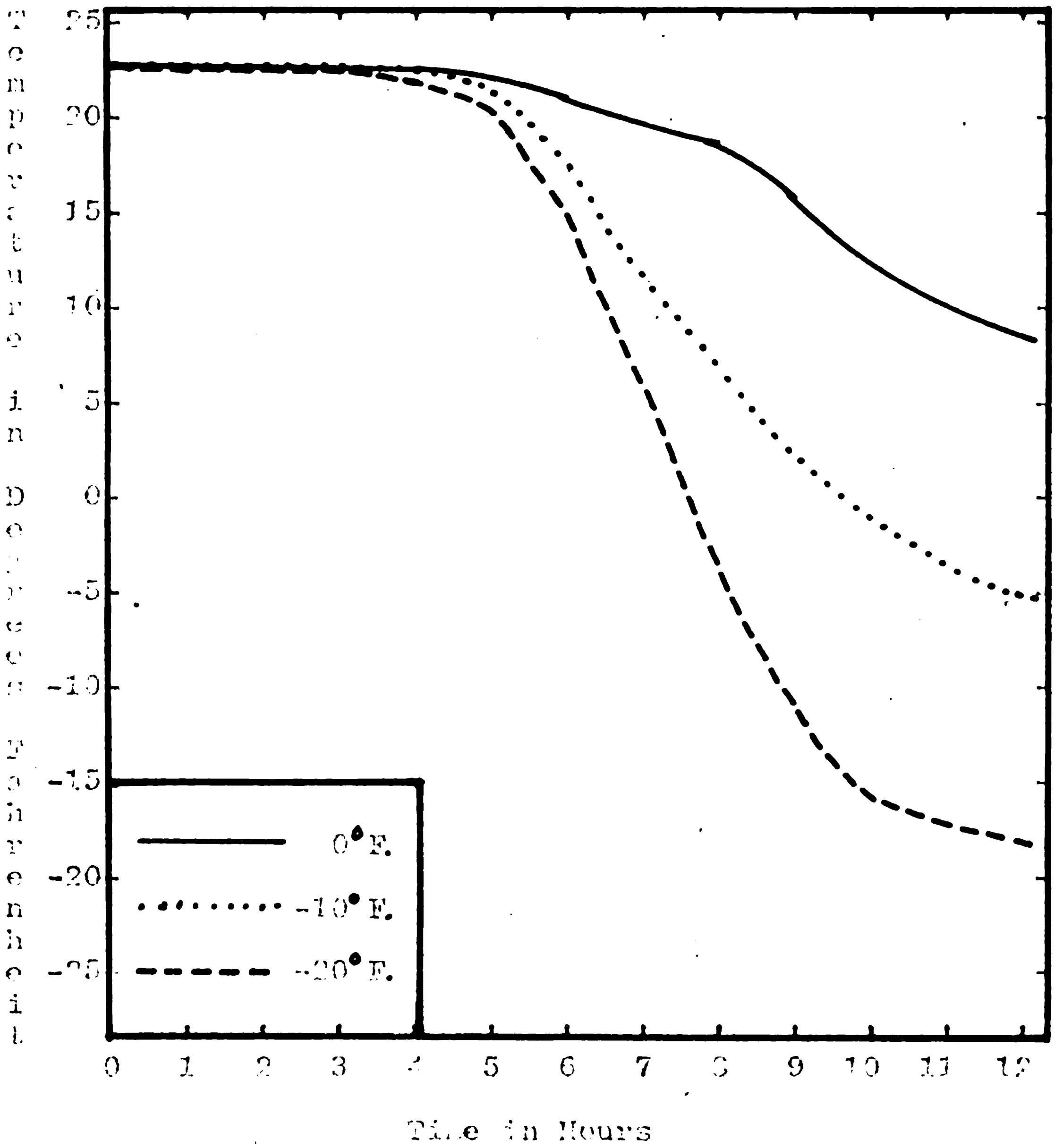
THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF CONTINUOUSLY FROZEN ICE CREAM

BATCH C



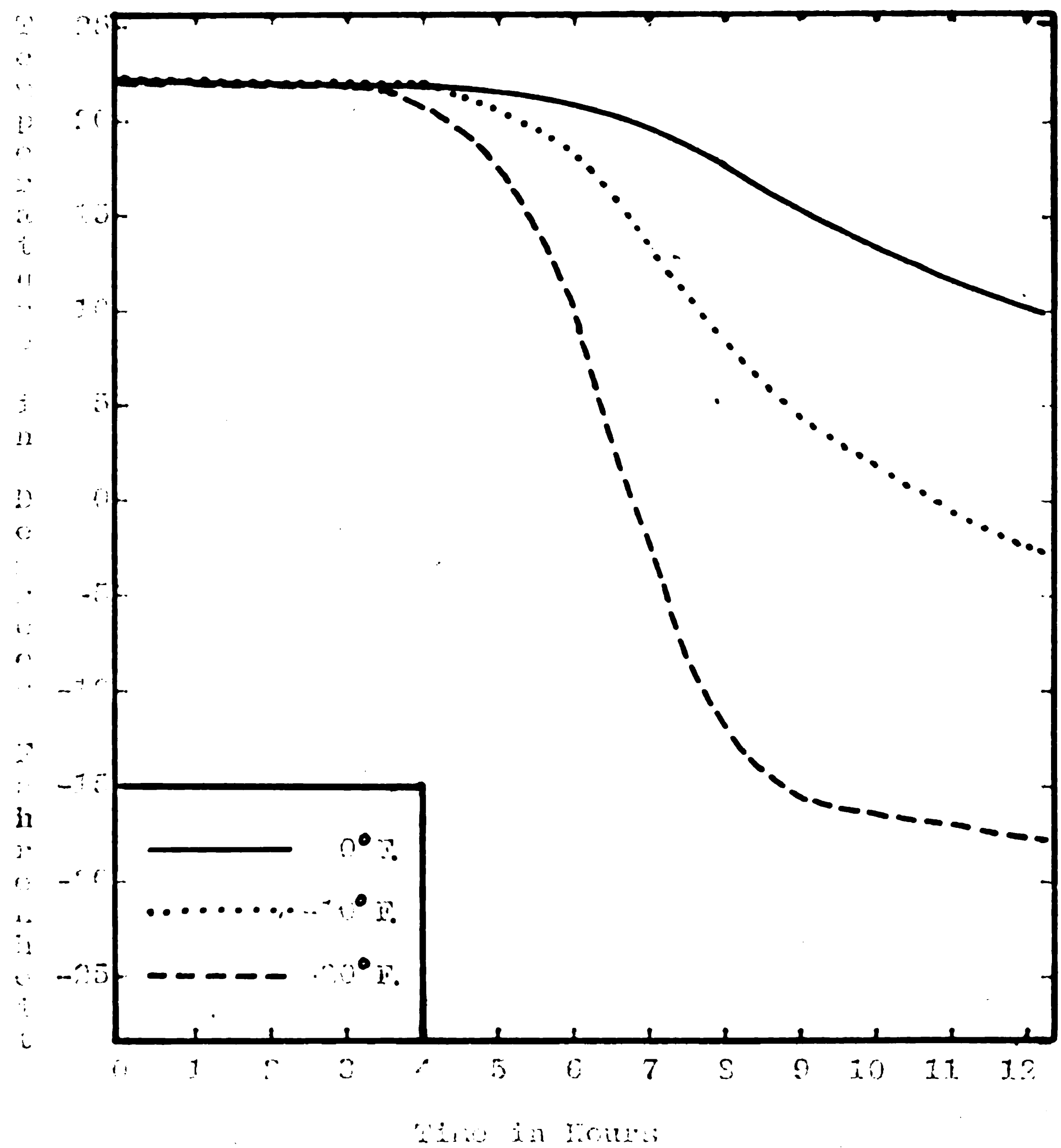
THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF HARDENING OF CONTINUOUSLY FROZEN ICE CREAM

BATCH D



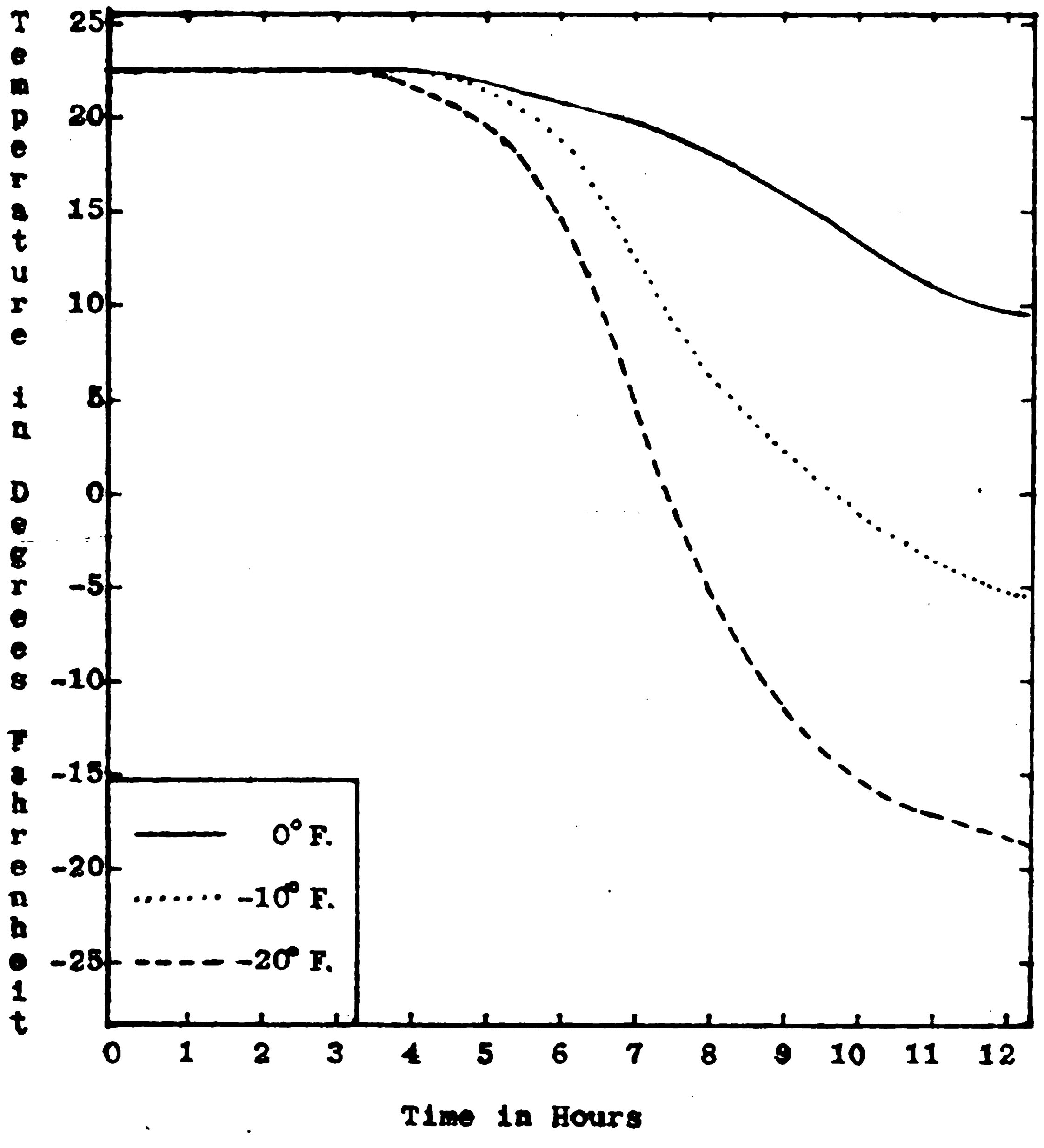
THE EFFECT OF VARYING TEMPERATURE ON THE RATE OF HARDENING OF CONTINUOUSLY FROZEN ICE CREAM

[illegible] G



THE EFFECT OF HARDENING TEMPERATURE ON THE RATE OF
HARDENING OF CONTINUOUSLY FROZEN ICE CREAM

AVERAGE OF BATCHES A, C, D, G, and Y



Discussion of Results

These experiments have shown that the hardening temperature of the ice cream was important in determining the quality of the resultant ice cream. The data obtained indicated that both the batch and continuously frozen ice cream were similarly affected by the different hardening temperatures. The body and texture, rate of melt down, ice crystal size, and rate of hardening were affected by the temperature of hardening.

Probably the most important effect of hardening temperature was on body and texture. The texture of the ice cream was increasingly smoother as the hardening temperature was lowered. Cole (13) was unable to correlate smoothness of texture as determined by ice crystal size with the size or value of the air cells. HOwever, in this study a close correlation between the organoleptic body and texture score and the size of the ice crystals was demonstrated. These findings are in keeping with later work by Cole and Boulware (16).

The body and texture of continuously frozen ice cream was consistently superior to the batch frozen samples. The lower drawing temperature of the continuous ice cream undoubtedly was responsible for the improved texture. Heyl and Tracy (64) reported that ice cream drawn at the same temperature on the counter, batch, and continuous freezer were equal in body. However, Erb (32) concluded that continuously frozen compared to batch frozen ice cream at the same drawing temperature had a better texture due to the finer air incorporation. The indications of this study are that under normal operations continuously frozen ice cream was superior to batch frozen ice cream.

Bradley and Dahle (7) have reported that the more rapid the

hardening the smaller the size of the ice crystals. Data obtained in this study are in agreement with these findings. A possible explanation of this observation is that there was some melting of the small ice crystals and subsequent refreezing onto larger crystals during delayed hardening. Therefore, the more rapid the rate of hardening, the more numerous and smaller will be the ice crystals.

Continuously frozen ice cream was observed to have smaller ice crystals than similarly handled batch ice cream. The lower drawing temperature and the more rapid scraping in the freezer were instrumental in giving many small crystal nuclei. The lower temperature of the continuously frozen ice cream retarded the melting and refreezing of the small ice crystals. The body and texture score of batch frozen ice cream that was hardened rapidly at -20°F. compared favorably to continuously frozen ice cream hardened slowly at 0°F. Any practice that would lower the freezing temperature or increase the hardening rate resulted in smaller ice crystals.

An attempt to prepare photomicrographs showing the ice crystal size was made. Condensation on the lenses of the microscope and camera at the lower temperatures of the hardening room was particularly problem-atical. The fields viewed in the microscope were clear, but difficulties in photographing technique prevented the duplication of these fields photographically. Therefore, because of the difficulty in securing a representative picture the photomicrographs were not considered satis-factory for use in this thesis.

The rate of melt down was found to be decreased by a decrease in the rate of hardening. In addition, the rate of melt down of batch frozen ice cream was noted to be higher than that of continuously frozen ice cream. No reference of this is reported in the literature. Smaller ice crystal size and possible smaller air cell size attributable to a lower drawing temperature and faster rate of hardening apparently offered some insulation effect to the unmelted portion.

A tendency for the manner of melt down to be smoother was noted in the samples hardened more rapidly. Batch frozen samples, hardened slowly, exhibited a slightly coarse melt down. On the other hand, melting resistance in some of the continuously frozen samples had the appearance of overstabilized mix.

The rate of hardening was shown to be closely correlated to the hardening temperatures. In both the batch and continuously frozen samples the rate of hardening was the same when hardened at similar temperatures. The rate of hardening apparently was dependent upon the the dissipation of the heat in the ice cream to the hardening room, rather than the ice cream's physical structure resulting from the type of freezer used. This observation is in agreement with conclusions of Tracy and McCown (95).

SUMMARY AND CONCLUSIONS

Results obtained in this study indicated that an increase in pasteurization temperature resulted in a slight decrease in the protein stability but had no appreciable effect on the other quality tests. These determinations included the acidity, pH, viscosity, surface tension, body and texture score, melt down characteristics, size and clumping of the fat globules, ice crystal size, and whipping characteristics. Since the quality of the finished product showed such slight variation, it was concluded that the pasteurization temperatures used in this study were not important in determining the quality of the resulting ice cream.

An increase in the homogenization pressure on a single-stage valve resulted in an increase in the fat globule clumping, viscosity, surface tension, body and texture score, and rate and smoothness of melt down. However, a decrease in the fat globule size and protein stability were obtained by an increase in the pressure of homogenization. Other factors that were not affected were the acidity, pH, and ice crystal size. Thus, homogenization pressure is important in determining the quality of the ice cream; however, present mix composition, stabilizers, whipping aids, homogenization efficiency, and freezers have reduced the importance of the pressure that is used, providing fat globule size has been reduced sufficiently.

The viscosity, fat globule clumping, and rate and capacity of whipping were increased by a decrease in homogenization temperature, while the rate of melt down was noted to be decreased slightly. However, the temperature of homogenization had no noticeable effect on the acidity, pH, protein stability, surface tension, body and texture score, and ice crystal size. Since the temperature of homogenization will be governed largely by the equipment available, the viscosity of the resulting mix will be the limiting factor in determining the lowest temperature at which the mix can be homogenized under commercial conditions.

An increase in the length of the aging period of the mix resulted in an increase in the viscosity and rate and capacity of whipping with slight increases being noted in the rate and smoothness of melt down and body and texture score. However, the length of the aging period had no significant effect on the acidity, pH, surface tension, protein stability, fat globule size and clumping, and ice crystal size. In this problem, the benefits due to aging were not great; therefore, it was concluded that aging of the mix, unless it is conducive to plant efficiency, is of little commercial value.

Freezing the mix reduced the viscosity, surface tension, and fat globule clumping, increased the size of the fat globules, but had no apparent effect on the acidity, pH, or protein stability. Continuously frozen ice cream compared with batch frozen ice cream, handled in the same manner except for freezing, had a smoother texture, smaller ice crystal size, and slower rate of melt down. Consequently, other factors being constant, continuously frozen ice cream was found to be superior to the batch frozen product.

Reducing the temperature of hardening resulted in an increase in the rate of hardening and a decrease in the rate of melt down and ice crystal size. The rate of temperature decline was dependent on the hardening temperature and was not significantly affected by the type of freezer used. The improvement in quality brought about by the increased rate of hardening led to the conclusion that a decrease in the hardening temperature resulted in an increase in the quality of the resultant ice cream.

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