RELATIONSHIP OF HYDROMETER READINGS TO THE COMPOSITION AND SOME PHYSICAL PROPERTIES OF PAN CONDENSED ICE CREAM MIXES

Thesis for the Degree of M. S.

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Respectfully submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science.

by

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THESIS

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INTRODUCTION

Commercial ice cream is made largely from dairy products. The fresher and sweeter these products are, the greater is the opportunity of securing a wholesome and readily salable product. Because of this fact the practice of condensing the ice cream mix in the vacuum pan has grown tremendously in the last twenty years.

The sources of concentrated forms of solids-not-fat for an ice cream mix are usually condensed skim milk or condensed whole milk, skim milk powder, or whole milk powder. By using sweetened condensed skim milk or sweetened condensed whole milk, both the solids-not-fat and sugar are furnished almost entirely from one source.

Through the use of the vacuum pan in the ice cream plant it is possible to add the desired ingredients to the pan and condense the entire mix, excepting the flavoring materials. This eliminates the use of any concentrated milk product and makes possible the usage of fresher products.

Because of the increasing use of the pan in condensing the ice cream mix it is of great convenience that there be available a satisfactory method of determining when to strike the batch. The Baume hydrometer, as used in striking batches of other condensed dairy products, is at present the most practical instrument for use in determining the proper time to draw the mix from the pan. Unfortunately there are no data correlating Baume hydrometer readings with corresponding solids content for ice cream mixes.

The use of the vacuum pan in an ice cream plant, especially where the factory is a combination ice cream and market milk plant, makes it possible to take care of surplus milk. There is usually a surplus of dairy

products when the ice cream demand is the heaviest. Condensation of the mix, however, has certain disadvantages such as, lower in price in condensery than in market milk areas, the cost of condensing equipment is high, space required for it in the plant is considerable, and the concentrated or dried milks are very convenient to use. In spite of these disadvantages the practice continues to grow.

Practically all plants condensing mix at the present time have determined the proper hydrometer reading to use by having analyses made of their mix and selecting the particular reading which corresponded to the composition they desired. This trial and error method is not only unscientific but is tiresome and expensive of time and effort. It may often prevent a smaller plant from acceptance of orders of composition different from that regularly made. Many inquiries are sent yearly to college dairy departments, trade magazines, and manufacturers of condensing equipment asking for tables of Baume readings corresponding to definite mix compositions. The answer has necessarily been that such data are not available and that readings must be made until by successive analyses the desired composition is reached. This reading obtained at that point must become the standard reading to be used for future condensation. This overlooks the little understood effects of temperature variations and homogenization, not to mention the disadvantage previously cited. It is believed that lack of knowledge of hydrometer reading relationship to composition has held back the development of this phase of the dairy industry.

REVIEW OF LITERATURE

No extended published data are available in respect to the relationship of hydrometer readings to solids content of ice cream mixes condensed in a vacuum pan. Because the Baume hydrometer is almost universally used in specific gravity determinations of dairy products the history and development of the Baume hydrometer is of interest. This particular type of hydrometer was perfected some time after several other types had come into use.

The hydrometer (1), which is usually a hollow instrument of glass or metal, designed to float upright in a liquid, makes use of the principle of Archimedes that the weight of the volume of liquid displaced by a body is equal to the weight of the body itself. There is evidence (2) that Archimedes (287-212 B.C.) was familiar with the hydrometer. The original hydrometer probably was invented by Hypotia of Alexandria (3), but it appears that it was neglected until it was again popularized by Robert Boyle in 1675. Its first use was for detecting counterfeit coin, especially the guinea and half-guinea.

Clarke later constructed an instrument on the same principle for measuring densities of liquors. This instrument was retained as standard for excise purposes until 1787 when it was displaced by a hydrometer developed by Sikes.

Many modifications of hydrometers have been made, including those of Desaguliers, Deparcieux, Fahrenheit, Nicholson, and many others. Each modification was for the purpose of filling a specific need in such determinations.

The Baume series of hydrometers (4) was constructed by Antoine Baume (1728-1804), a French chemist. Baume in 1752 was professor of chemistry at the Ecole de Pharmacie. He devoted most of his life to commercial and research work in chemistry, but is best known as the inventor of the hydrometer associated with his name. The graduations of his hydrometer were made in the following manner: certain fixed points were first determined upon the stem of the hydrometer. The first of these was determined by immersing the instrument in pure water and marking the stem at the level of the surface. This corresponded to the zero reading of the scale. Fifteen standard solutions of pure common salt were prepared, containing one to fifteen per cent by weight of dry salt. These different readings were then marked on the scale of the hydrometer. A similar hydrometer was developed by Baume for densities less than water, being used at that time mainly for spirits.

All Baume hydrometers must be calibrated for different liquids because of the effect of surface tension on the reading. When the hydrometer is floating in the liquid the surface of the liquid does not remain level to the point of contact with the emergent stem of the hydrometer, but the liquid piles up against the stem. There is a downward pull on the stem of the hydrometer equal to the product of the surface tension of the liquid and the perimeter of the stem. It should be noted that by 1881 Professor Chandler had collected 23 different formulae for standardizing the heavy Baume hydrometer, and 11 formulae for standardizing the light Baume hydrometer. It was suggested by

Professor Chandler that the best way of ending the confusion "which has grown up around the Baume hydrometer is to discontinue its use entirely and to substitute hydrometers indicating densities directly."

The hydrometer plays an important part in the condensery. It fills an important place in determining the specific gravity of the condensed liquid indicating the proper time to strike a batch in the vacuum pan.

Condensing ice cream mix in a vacuum pan dates back about sixteen years. Peterson and Tracy (5) state that the condensation process of preparing an ice cream mix has developed mostly since 1922. Lucas (6) also states that its greatest development has been made since this time.

The apparent advantages of preparing an ice cream mix in a vacuum pan are noteworthy. Liedel (7) states that the advantages are (1) removal of off-flavors because of violent boiling under vacuum, (2) mix is condensed less than ordinary condensed milk which obviates condensed milk flavor, and (3) decreases in cost of processing. He summarizes these advantages by saying, "That a better flavored and cleaner product is produced by this method has been proven in actual practice since it has been found that only two-thirds the amount of flavoring formerly used is now necessary since all the flavoring added acts as a flavor, and not as a neutralizer to counteract off-flavors". Lucas (6) states the advantages are in the use of fresh milk and cream with additional desirable effects on the taste of the mix; use of fresher products; removal of off-flavors; use of surplus milk at a time when the ice cream demand is the heaviest, and a financial saving if a sufficient volume is condensed. Mojonnier and Troy (8) find the apparent advantages

are that the mix can be stored for a considerable time and can be shipped considerable distances. By condensing in excess of desired concentration it saves space and transportation cost. It later can be diluted back with water prior to freezing. Sommer (9) believes that it is more economical to make the mix in the vacuum pan when condensed milk is made in the home plant. In making a comparison between making a mix in a vacuum pan and condensing milk alone he gives the following facts:

Plain Condensed Milk Method	Vacuum Pan Method
1. Preheat milk to be condensed.	1. Preheat milk, sugar, cream, and gelatin.
2. Condense in pan - (3:1).	2. Condense in pan - (1.5:1).
3. Cool plain condensed milk.	3. Homogenize and cool.
4. Test for fat and total solids.	4. Test for fat and total solids.
5. Figure mix and mix ingredients.	5. Standardize, if necessary.
6. Heat to dissolve and pasteurize.	
7. Homogenize and cool.	
8. Test for fat and total solids.	

Sommer (9) states that the vacuum pan method of preparing an ice cream mix saves more than one-half the time and labor required when condensed milk is concentrated alone and the mix made from the concentrated milk.

Mojonnier (10) adds to the advantages of making a mix in a vacuum pan by saying it insures better pasteurization, better flavor, and greater overrun.

The usual method for condensing an ice cream mix is that given

above by Sommer (9). Some procedures vary from this and one variation is that mentioned by Lucas (6). By this method the cream is pasteurized alone. The skim milk is condensed after adding the sugar and gelatin. This mixture is forewarmed to 185° F. and condensed, mixed with the cream, and the whole mix is pasteurized, homogenized, and cooled. It is then standardized if not in desired proportions.

Other variations in processing of a mix are easily possible. Hening (11) states that the characteristics of the mix or the quality of the finished ice cream were little altered by adding gelatin before or after homogenization. He concluded that it was of such slight difference that it was of no commercial importance. He found also that a mix homogenized before condensing contained smaller globule clumps, was easier to whip, and produced an ice cream slightly better in texture and quality than a similar mix homogenized after condensing.

No published work is available on super-heating an ice cream mix just before it is drawn from the vacuum pan. However, in super-heating condensed milk, Tracy (12) found that the viscosity was increased sixty times over unsuperheated. The overrun of the ice cream using the super-heated condensed milk was slightly higher than that not super-heated, and a heavier, smoother bodied ice cream was obtained. However, the use of condensed milk not super-heated gave an ice cream that had a superior flavor.

In forewarming an ice cream mix Martin (13) found that mixes can be heated to 150° F. for three and one-half hours without impairing the whipping qualities of the ice cream. When the holding period is prolonged there is a slight decrease in viscosity and an increase in

protein stability. The above writer states that there will be no trouble encountered from heat-loving bacteria, provided the process is properly carried out. Peterson and Tracy (5) found that forewarming to 160-170° F. resulted in destruction of 99.47-99.98 per cent of the bacteria present before forewarming. After the mix is drawn from the pan little bacterial growth occurs, and this is mainly due to breaking up of the bacteria clusters. Bird, Willingham, and Iverson (14) found that in condensing milk in a vacuum pan the heat treatment of the fat had no apparent effect on off-flavor development. Hening (15) found that the overrun increased and viscosity decreased with increased pasteurization temperatures. The size of the fat globule clusters decreased with increased heating temperature. He found that the body, texture, and flavor were not affected by heating at 165° F. for 30 minutes, but that a cooked flavor resulted when heated to 180° F. for 30 minutes.

As to the question of adding the flavoring material before condensing Brown (16) concluded that heat treatment of 145° F. for 30 minutes showed little or no effect on the change or potency of the flavor. He used all flavors that are commonly used in ice cream.

Dahle, Girard, Connell and Paterson (17) found that mixes concentrated in a vacuum pan to double normal total solids content, with gelatin omitted, could be stored at 0° F. and 40° F. with slight increase in acidity. After six months storage excellent ice cream was made from the mix stored at 0° F., but a slightly tallowy flavor resulted in that stored at 40° F. Storing at room temperature for six months made the ice cream unsalable. They found that lactose crystals appeared in all of the stored samples, but when the mix was processed the crystals

dissolved. The different storage temperatures did not affect the whipping properties of the mix, all freezing normally.

Peterson and Tracy (5) state that a mix made in a vacuum pan may be stored at 32-35° F. for two weeks and remain in very good condition. Tracy (18) found that an ice cream mix concentrated to 70-75 per cent total solids, with no gelatin or vanilla, could be stored in five gallon cans for one month at -10-0° F. and made into good ice cream. When the mix was stored at 40° F. it became very tallowy at the end of three months.

The calculations of an ice cream mix made in a vacuum pan differes slightly from figuring a regular mix. Edel (19) has worked out a chart showing there are three cream values for each per cent of available cream, using with cream either skim milk, three per cent, or four per cent milk. By consulting the chart the amount of sugar and gelatin needed may be determined for that particular mix. This chart is designed for fresh products only, and a mix ranging in weight from 1,000 to 10,000 pounds can be calculated from it.

Other methods that are commonly used for calculating a mix made in the vacuum pan are the serum point method, the normal equation method, and a variation of methods involving the use of the Pearson Square.

The most common way of determining the total solids content of ice cream is by the Mojonnier method. Fisher and Walts (20) have developed a modified test where one gram of mix is added to one cc. of hot redistilled water. This is put on an electric hot plate at 180° C. until slightly brown, and then dried in a water oven until constant

weight is reached. This method was compared with the Mojonnier method and the official method which the authors adapted from the official method for testing total solids of sweetened condensed milk. Both the Mojonnier and modified methods gave average tests higher than the official method, with the modified method giving average results of 0.223 per cent lower than the Mojonnier method. The modified method is simple, economical, and accurate, but requires two to three hours for completion.

In determining the specific gravity of an ice cream mix it is important that the same method be used in heating or cooling the samples. For calculating solids of milk from their specific gravity, Sharp and Hart (21) found there are thirty-six different equations published in the past seventy-five years for calculating the relationship between the specific gravity and solids and fat content of milk. They state, "a large part of this lack of agreement and reproducibility is due to one factor which has never been limited adequately, namely, the lag in the change in the physical state of the fat as the temperature is adjusted to that at which the specific gravity is determined." They found that a sample of milk which has been held cold for some time and then is warmed to 15° C. will have a greater specific gravity than a sample of the same milk which has been held warm and then is cooled to 15° C. They concluded that the variations were due to the fat present, because fat free milk showed no such variations and the variations in whole milk are linearly related to the fat content. Determinations of the specific gravity at 30° C. after previous warming to 45° C. for one-half minute is recommended as a method which will insure that the determinations are made while the fat is in the liquid state.

Doan (22) working with condensed milk determined the specific gravity by making weighings at 60° F., 120° F., 130° F., and 140° F., and made comparisons with water at 60° F. He found there was no uniform increase in specific gravity with a given increase in per cent total solids. He found it possible to calculate the solids content of plain condensed milk fromthe specific gravity to within 0.9 of one per cent.

Masurovsky (23) states that a knowledge of the specific gravity of an ice cream mix helps (1) to estimate the gallonage of the mix; (2) to figure out the overrun during the process of freezing, and (3) serves as a fair index as far as the total solids-not-fat of the mix are concerned.

Lucas, Matsui, and Mook (24) found that for each two per cent increase in sugar content there resulted a 0.2 per cent increase in specific gravity.

Dealing with the surface tension and viscosity of ice cream a great deal of published material is available.

Leighton and Williams (25) differentiate between basic viscosity and apparent viscosity by stating that apparent viscosity is the viscosity of an unagitated ripened mix. Basic viscosity, shown by the same investigators (26), is exhibited when a mix is stirred with enough vigor that the viscosity drops to a certain value beyond which it is not lowered by continuous stirring. They conclude that viscosity bears an inverse linear relationship to temperature. They state also that during the freezing process lowering of the temperature results in a concentration of the milk solids and milk sugar in the liquid phase.

This progressive concentration increases in the liquid phase and increases its viscosity.

Sommer (21) states that a high viscosity of a mix does not always accompany good whipping ability, and good body and good texture in the finished ice cream. He believes it is "merely a phenomenon that frequently accompanies these attributes."

Leighton and Williams (28) found that the viscosity value of an ice cream is not a direct measure of quality but that viscosity is an indication of changes in quality and of the physical action of that factor in ice cream. An investigation by Sherwood and Smallfield (28) showed that viscosity of cream is due to greater grouping together of fat globules during aging with fixation of a part of the free serum. Agitation causes a reduction in viscosity because it reduces the size of the fat globule clumps.

According to Sommer and North (30) the fat globules in milk and cream normally carry a negative charge, and aging or heating to 142° F. decrease the charge; the increase in viscosity of pastuerized cream on aging is due to the decrease in the charge of the fat globules, thus permitting them to cluster together.

Leighton and Williams (28) found that an increase in the fat content of an ice cream mix first increased viscosity and then decreased it to a minimum from 12-18 parts, after which an increase was noted again at 21 parts. There is evidence that with increasing fat content the viscosity of ice cream is first increased through a binding or mass effect of the milk fat. With an increasing quantity of fat the protective effect on the ice crystals or a lubricating action resulted in lower viscosity, simultaneously with better texture. Finally the mass effect

of the large amount of fat became evident and the viscosity increased.

Nelson and Reid (31) found that viscosity increased with increased fat percentage, with greater viscosity increase at the higher fat concentrations.

Martin (32) believes that the viscosity is affected by (1) composition of the mix; (2) pasteurization temperature; (3) homogenization temperature and pressure; (4) length of aging period; (5) temperature of aging; and (6), use of improvers. By causing a change in any of the six factors mentioned the viscosity can be controlled to some extent.

Sommer (27) states that heating an ice cream mix above 145° F. reduces the viscosity accordingly. This was also found to be true as reported by Turnbow and Milner (33), who found that heating the mix to 155° F. for 30 minutes does not injure the flavor but a little longer time is required to regain the viscosity.

Turnbow (34) found that ice cream mixes slowly agitated during pasteurization developed twice as much viscosity during aging as mixes agitated rapidly during pasteurization. Masurovsky (35) states that increased acidity produced a greater viscosity in the mix. However, increased acidity was found to be of little value in ice cream manufacture and it may impart an objectionable flavor, thereby not being recommended.

DePew (36) found that mixes with high viscosity incorporated overrun more slowly and in smaller amount than those with less viscosity. These findings agree with those of Wright (37) who reports that the whipping properties of the mix decreased as the viscosity increased.

Turnbow and Milner (33) determined the viscosity of all ingredients

in an ice cream mix and found thatsugar and fat had little effect on the viscosity. This is in disagreement with Reid and Russell (33) who found that increasing the butterfat increased the viscosity and surface tension of a mix.

Lucas and Roberts (39) through their work found that the viscosity of normal mixes increased about 25 per cent with each increase of 2 per cent in milk solids-not-fat. There was no relation between maximum viscosity and overrun. A 6 per cent solids-not-fat mix had half the viscosity of a 12 per cent solids-not-fat mix. Jensen (40) found no results to indicate viscosity value in whipping ability of mixes and Gould (41) found no correlation between the whipping ability and viscosity and surface tension.

Scott (42) found in his work that viscosity, as a measure of quality in ice cream, is practically worthless. Turnbow (43) states that more stable viscosity can be secured by aging the mix from 33-34° F. than at higher temperatures. Gregory and Manhart (44), in summing up their findings, make a statement that would appear to cover most findings resulting from work done on viscosity. They conclude "that under most conditions viscosity is necessary to obtain maximum overrun, but certain substances when added to the mix may increase the viscosity but decrease the ability of the mix to incorporate air."

Most of the investigators, in working with viscosity, found a varying relationship with surface tension of the icecream mix.

Sommer (27) states that the surface tension of a fresh mix is higher than one standing undisturbed for some time. He believes this to be due to the increase of concentration of dissolved substances in the surface film, or adsorption. Adsorption is caused by forces involved in surface tension and can be calculated on the basis of surface tension.

Turnbow and Raffetto (45) state that the lower the surface tension the faster the mix whips in the freezer, while Dahlberg and Hening (46) report that in a general way decreased surface tension is associated with good whipping qualities. They found that the surface tension decreased as the fat content was increased and this is in agreement with the findings of Gebhardt (47) who reports no correlation between surface tension and whipping quality. Sommer, Coruthers and Gebhardt (48) report no correlation between surface tension and whipping qualities. Reid and Russell (38) conclude that aging and homogenization increase the surface tension and is contrary to the theory that a low surface tension favors whipping ability.

PURPOSE OF THE EXPERIMENT

The purpose of this experiment was to originate a formula by which the hydrometer reading of an ice cream mix could be predicted from its desired composition, to study the relationship between the Baume readings and temperature, with proper corrections, therefor, and to note some of the physical properties of pan condensed ice cream mixes. It was found, however, that to accomplish these objectives much preliminary work, chiefly the accurate determination of density of ice cream ingredients, had to be done.

The method of attack included the following:

1. Preliminary studies using a small improvised vacuum apparatus to secure Baume readings for different composition mixes.
2. Study of the effect of temperature upon changes in Baume readings.
3. Determination of the surface tension and the apparent and basic viscosities of pan condensed mixes.
4. Repeatal of 1, using a commercial size vacuum pan, striking the batch at the proper time as indicated by a Baume hydrometer, and checking all compositions with the Mojonnier tester.
5. The determination of the densities of the ingredients used in the average ice cream mix, and, to perfect, if possible, a system for predicting the Baume hydrometer reading of any mix, using the desired mix composition as basic data.

PROCEDURE

PART I

Condensing in the Small Vacuum Apparatus

Twelve basic mixes were used throughout the experiment. Their calculated compositionsare shown in Table I.

Table I. Compositionsof Basic Mixes Used in Experiment

Mix Number	Fat %	Solids-not-fat %	Sugar %	Gelatin %
1	8	11	14	0.4
2	8	11	15	0.4
3	8	11	16	0.4
4	10	10.5	14	0.4
5	10	10.5	15	0.4
6	10	10.5	16	0.4
7	12	10	14	0.4
8	12	10	15	0.4
9	12	10	16	0.4
10	14	9	14	0.4
11	14	9	15	0.4
12	14	9	16	0.4

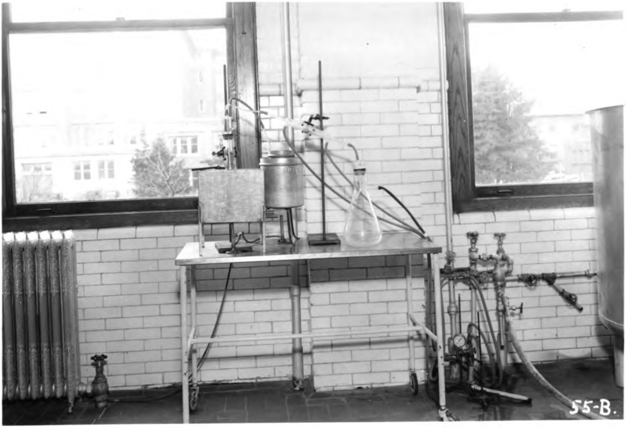
It will be noted that each group of three mixes contains the same percentage fat, solids-not-fat, and gelatin but varies in sugar content. These compositions cover practically all the variations of ice cream mixes made in this country. They do not include gelatin or sugar substitutes or condensed dairy products.

In the first part of the experiment ice cream mixes were condensed in a small laboratory vacuum pan, similar in principle to a commercial condensing outfit. The purpose was to reduce expense during the preliminary work and to apply, if possible, these findings to the operation of thelarger size pan. Five pounds of finished mix of the desired composition was made each time in the laboratory size pan.

The small laboratory vacuum apparatus made use of a small suction pump, connected with a gauge to measure the vacuum in inches of mercury. This pump was connected with a water line to obtain the desired vacuum. A condenser was connected to the vacuum pump by means of hard rubber tubing. The other end of the condenser was connected by similar tubing to a five-liter pump flask containing the mix to to condensed. The mix was forewarmed in a one-gallon ice cream container and drawn into the five-liter flask by means of a partial vacuum in the flask. The rate of inflow was controlled by a stop-cock inserted through the rubber stopper of the flask. An accurate Fahrenheit thermometer was placed through the stopper far enough that the bulb was immersed in the mix during the condensing process.

During the course of the experiment it was found necessary to use some glass connections with the rubber tubing to prevent the vacuum line from collapsing under the reduced pressure. It was possible to secure a vacuum as high as 28 inches when condensing with the small laboratory pan.

Considerable difficulty was experienced in the prevention of water from backing up from the suction pump to the condensing flask. To obviate this difficulty it was found necessary to install a four-liter suction flask between the vacuum "shut off" at the pump and the condenser, and to place a stop-cock on the suction flask. To prevent completely the water from backing through the condenser the suction pump was placed at a lower level than the rest of the equipment and the rubber hose from the water discharge line was removed. A larger pipe used to replace the hose facilitated the handling of the discharge water. These arrangements are shown in the accompanying picture.



Showing the small laboratory vacuum apparatus used in the preliminary experiment. Description of the unit is on previous page.

Mix Preparation and Condensing

It was necessary to remove approximately three pounds of water for each five pounds of finished mix, depending upon the desired composition and the test of the ingredients used. Fresh, pasteurized or raw milk and fresh, sweet pasteurized cream were used as the source of fat and solids-not-fat in the mix. All mixes were calculated using the normal equation method.

The milk and cream were mixed in a one-gallon ice cream container, heated to approximately 95° F. and the sugar and gelatin added. Condensing of the mix in the small laboratory pan required about two hours. If over condensed the mix was brought to five pounds of weight by the addition of water, and restandardized, if necessary, after having been checked for fat and total solids by the Mojonnier method.

Samples were taken for Baume readings, and these readings were made within one hour after condensing. Each batch was immediately cooled to 60° F. and samples taken for viscosity and surface tension determinations.

Surface Tension and Viscosity

The immediately cooled samples taken for surface tension and viscosity determinations were held in a refrigerator at about 40° F. for 22-24 hours, tempered to 68° F., and the observations made.

A du Nouy Direct Reading Tensiometer was used for the surface tension measurements and a MacMichael Viscosimeter and a Mojonnier-Doolittle Viscosimeter for the viscosity determinations. In all cases both the apparent and basic or real viscosities were taken. The apparent viscosity was taken of a sample of the mix that had been held the 22-24 hour period,

tempered to 68° F., and poured into the receptacles of the viscosimeters without any previous agitation. The basic or real viscosity was taken of a sample of mix which had been poured back and forth for ten minutes, a length of time which previously had been found sufficient to break down the structural viscosity of exceedingly heavy mixes.

A standardized No. 30 wire, or a No. 26 wire, in the case of very viscous mixes, was used on the MacMichael Viscosimeter. One hundred ml. samples were used in the determinations. The du Nouy Tensiometer was standardized by the absolute method and the method using boiled, distilled water, a description of both methods being published by the manufacturer of the apparatus.

Baume Readings and Pycnometer Determinations

All Baume readings were taken within one hour after the mixes were condensed and cooled. The technical considerations involved are discussed in detail later. A normal size 5° - 15° Baume hydrometer, with 0.1 degree graduations, was used for all hydrometer readings. The samples were heated to 155° F., with occasional stirring, and held for five minutes to make sure the fat in the mix was in a liquid state. An accurate 0° - 200° F. thermometer was used for the temperature readings. Baume readings from 155° F. to 60° F. were taken at 5° F. intervals.

To determine the accuracy of the Baume hydrometer in converting the reading to density all mixes were checked for density using the pycnometer method. The density determinations by the pycnometer were made at 70° F. The pycnometers were previously calibrated with boiled, distilled water.

Effect of Position of Thermometer on Temperature of Boiling

Several readings were taken to note any difference in temperature of the boiling mix in different parts of the small vacuum pan. Temperature readings were taken below the surface of the boiling mix, about one-half inch above the boiling liquid, and in the vapor near the top of the flask.

The condensing temperature, with the corresponding vacuum readings, were taken on most of the mixes to gain some knowledge as to the correct vacuum when condensing different composition ice cream mixes. Results are shown in Table II.

Effect of Homogenization on Baume Reading

To learn the effect of homogenization on the Baume reading duplicate samples of condensedmix were taken, one of which was homogenized at 2300 pounds pressure. Both the unhomogenized and homogenized samples were held in a refrigerator for one and one-half to two hours, taken out and heated to 155° F., and Baume readings taken from 155° F. to 60° F. Since the results were identical, making allowance for experimental error, the readings were not recorded independently, the figures being a duplication of Tables V and IX.

A number of determinations were run to check the effect of the state of the fat on the Baume reading. Duplicate samples of condensed mix were taken immediately after cooling and placed in a refrigerator at approximately 40° F. for four hours. The samples were taken from the refrigerator, and one group was warmed to 60° F. and Baume readings taken. The corresponding duplicate samples were heated to 155° F., cooled to 60° F.,

and the Baume readings again taken. The results are recorded in Table III.

As an added precaution in obtaining accurate Baume readings, a number of readings were taken to learn the effect, if any, of taking the readings at a low temperature without previous cooling, or taking the readings from a hot mix. Samples were taken from the pan and Baume readings made immediately, while the mix was hot. The duplicate samples were cooled to 60° F. and successive readings for each five degrees at temperatures to 155° F. were taken. From the results obtained there was no indication that the Baume determinations were any different using the two methods. The results are not recorded here because they are a duplication of Table IX.

PART II

Use of Commercial Size Vacuum Pan

Calculation of a 1000-pound finished mix containing 8 per cent fat, 11 per cent solids-not-fat, 14 per cent sugar and 0.4 per cent gelatin.

Standardization By The Normal Equation Method.

Finished Mix = 1000 pounds

1000 x 0.14 = 140 pounds sugar

1000 x 0.004 = 4 pounds gelatin

1000 x 0.08 = 80 pounds fat

1000 x 0.11 = 110 pounds solids-not-fat

Fat Test of Cream = 40.5 per cent Solids-not-fat in cream = 5.2 per cent

" " " Milk = 3.5 " " " " " " milk = 8.5 " "

Let x = pounds milk

Let y = " cream

Solving for pounds cream:

$$\begin{array}{r} 0.035\ x + 0.405\ y = 80 \\ \underline{0.085\ x + 0.052\ y = 110} \\ 0.002975\ x + 0.034425\ y = 6.80 \\ \underline{-0.002975\ x + -0.001820\ y = -3.85} \\ - \qquad 0.032605\ y = 2.95 \\ y = 90.74 \text{ pounds cream} \end{array}$$

Solving for pounds milk:

$$\begin{array}{r} 0.034425\ x + 0.02160\ y = 44.55 \\ \underline{-0.001820\ x + -0.02160\ y = -4.16} \\ 0.032605\ x = \quad - \quad = 40.39 \\ x = 1238 \text{ pounds milk} \end{array}$$

Sugar = 140 pounds

Gelatin = 4 pounds

Cream = 90.74 pounds

Milk = 1238 pounds

1472.74 pounds Basic Mix

472.74 " water to evaporate

1000.00 pounds finished mix

Check on Fat and Solids-not-fat

90.74 x 0.405 = 36.75 pounds fat in cream

1238 x 0.035 = 43.33 pounds fat in milk

80.08 pounds fat in mix

90.74 x 0.052 = 4.72 pounds solids-not-fat in cream

1238 x 0.085 = 105.23 pounds solids-not-fat in milk

109.95 pounds solids-not-fat in mix

Procedure in Condensing Mix in Large Vacuum Pan

The same ingredients as used in the preliminary studies were used in condensing inthe 42-inch vacuum pan. All mixes were calculated using the normal equation method as illustrated on the previous page.

The milk and cream were heated in the hot well to 95° F. The sugar and gelatin were added and the complete mix was preheated to 155° F.-160° F. with live steam. The mixes were condensed at about 140° F.-145° F., never going above the latter temperature. The condensing of a 1000 pound finished mix required approximately one hour. The twelve basic mixes were struck by using as a standard the Baume readings obtained from similar mixes condensed in the small vacuum pan. Either a 1000 pound or a 1235 pound finished mix was made. The mix was standardized with water to desired weight if condensed too far.

Samples for viscosity and surface tension were taken after being homogenized at 2300 pounds pressure and were immediately cooled. They were treated in the same manner as in the preliminary experiment. No attempt was made to follow the history of the mix from the freezer.

Baume Readings and Pycnometer Determinations

All Baume readings were taken within one hour after the mixes were condensed and cooled. This was the exact procedure used in the preliminary experiment. The samples were heated to 155° F. and readings taken at 5° F. intervals to 60° F. Occasional stirring of the mix in the hydrometer cylinder was necessary to prevent oiling off of the mix. The hydrometer was carefully dried with a clean cloth between each reading to prevent any

material from adhering to the stem above the surface of the liquid. The pycnometer density determinations were made at 70° F. The Baume reading at this temperature was converted into density and this value compared to the density obtained from the pycnometer weight. This showed the accuracy of the Baume hydrometer at this particular temperature, when compared to weighed portions of the mix as determined by the pycnometer.

Mojonnier Determinations of Mixes

All condensed mixes, after having been brought to desired weight with water, were checked for fat and total solids by the Mojonnier method. Duplicates were run on all samples, and if necessary, the mixes were restandardized.

PART III

Density Determination of Ice Cream Ingredients

Manufacturers of pan condensed ice cream mix have felt a need for a system of predicting the correct Baume reading for a condensed mix of a particular composition. Such a system would require an accurate knowledge of the density of ingredients making up the mix and these determinations require apparently an approach somewhat at variance with the usual methods of measuring density of solids, which with water forms true or colloidal solutions.

It was thought that the specific gravity of the ingredients could be utilized in this respect according to the following hypothetical mix, calculated on a 100 pound basis. In case more or less than 100 pounds of mix is made the percentage of each ingredient could be substituted for the pounds of each ingredient.

12 pounds butterfat	x	specific gravity	=	fat density factor
10 pounds solids-not-fat	x	" "	=	solids-not-fat density factor
15 pounds sugar	x	" "	=	sugar density factor
0.4 pounds gelatin	x	" "	=	gelatin density factor
62.6 pounds water	x	" "	=	water density factor
100 pounds			=	sum of density factors

If the above reasoning were correct and if the data on specific gravity of the above were applicable to the ingredients in their particular state in the mix, the sum of the density factors divided by the sums of the weights or percentages should give the exact specific gravity of the finished mix. This specific gravity could easily be transformed to the correct Baume reading. In practice it was found that either this reasoning was incorrect or some other factor, such as specific gravity, was misleading. Consequently it became necessary to determine specific gravity of the ingredients and to seek such a factor as would give correct specific gravity when it was multiplied by the sum of the density factors divided by the weight of the mix. Since hydrometers are calibrated for determination of density rather than specific gravity the results are apt to be confusing unless each is defined clearly.

Among the methods used for determination of the density of liquids are the hydrometer and pycnometer methods. Essentially the pycnometer is a specific gravity bottle used to compare the weight of the same volume of water. Physicists generally define specific gravity as being identical with relative density. Density is defined as mass divided by volume. Weight varies with distances above sea level. Mass does not vary. Weight is numerically equal to mass provided it is determined on an equal arm

balance rather than on a spring scale. Since a balance was used in all determinations and since only grams per cubic milliliters were used it is apparent that the specific gravity and density of solids and liquids are synonymous terms. Although the term density is used chiefly in this thesis it is with the understanding that its value is equivalent to specific gravity.

While density value under the above conditions, is the same as specific gravity, it is nevertheless not a direct comparison of the weight of a unit volume with the same volume of water. It is merely the weight of a unit volume divided by the volume. In cases of temperature rise the mass of the unit volume will decrease provided the material expands when heated, and the density value will decrease. If the material does not expand when heated the density value remains the same. Liquid mix expands; so far as could be determined the solid materials of the mix, excepting butterfat, did not expand. This introduces a slight error in the calculations that follow.

The Baume hydrometer is so calibrated as to compensate for expansion at varying temperatures. Inasmuch as coefficients of expansion vary considerably for different liquids the Baume hydrometer cannot be correct for all liquids. It is doubtful if this error is sufficiently great to be of practical importance. Calibration of the hydrometer to care for these temperature effects makes possible the use of the following formula to convert degrees Baume to specific gravity: Specific gravity $= \frac{145}{145 - {}^{\circ}\text{Baume}}$,

or $^{\circ}$ Baume $= 145 - \frac{145}{\text{SPECIFIC GRAVITY}}$. This is the well known Baume conversion formula and may be used for ice cream mix, remembering in this work the terms specific gravity and density are used interchangeably.

Taylor Instrument Companies (51) in their hydrometer brochure make the statement, "intervening ranges covering the interval of 0° to 30° Baume or sometime corresponding density values expressed in Specific Gravity are used in the process of manufacture." In the above the authors refer to the manufacture of sweetened condensed milk, but their statement is equally applicable to condensed ice cream mix since it comes within the same Baume range.

Baume readings were made of all mixes whether condensed in the laboratory or commercial size vacuum pan. These readings were converted into density values by means of the above formula. Thus a Baume reading of 12.0 at 120° F. will be equivalent to a density value of 1.0902.

As previously mentioned, these Baume readings after being converted to density values were checked against pycnometer determinations of density. These latter were calculated from the formula:

$$\text{Density of mix} = \frac{\text{Weight in gms. in pycnometer}}{\text{Volume in ml. in pycnometer.}}$$

Determinations for each calculation were made with weight and volume measured at the same temperature. Volume was determined by using water at the same temperature.

Density Evaluation of Solid Constituents of Ice Cream Mix

On the supposition that the data available on density of the ice cream ingredients, milk solids-not-fat, sugar, and gelatin might be incorrect, and therefore responsible for the lack of workability of the formula for predicting Baume readings given at the beginning of Part III,it was necessary to consider making certain of the proper values.

Among the methods for ascertaining density of solids the two most commonly used is the capsule method in which the powdered solid is tightly packed and measured for volume and weight. It is logical that in this method there is considerable air space measured as volume, thereby giving an incorrect value. Elimination of this air space would be similar to efforts to eliminate the air space in a capsule of shot. For this reason the method was discarded.

The second method recognized by physicists is the calculation of density by dividing the weight by the volume, the latter being calculated by measuring the displacement, as well as the weight of the displaced liquid, the liquid being a material in which the solid is insoluble. This method could be used for a powder such as skim milk powder. Secondly this method was used probably to secure the values which were utilized in the preliminary work on this thesis and which proved unsatisfactory. In the third place the solid ingredients inthe ice cream mix are in true solution or colloidal solution or suspension. If present in suspension only this method would probably have been satisfactory.

The method finally adopted is not mentioned in text books on physics either favorably or unfavorably. The results, however, seem to justify the reasoning behind its choice. The solid materials of the mix are not altogether insoluble in the water of the mix. Neither do the pores of the water hold all the soluble ingredients, for even with sucrose, its addition to water increases the volume of the mixture. Consequently the density of each ingredient was determined by using a 100 ml. volumetric flask, the neck of which was graduated by 0.1 ml. from 100 to 110 milliliters. This could be read as accurately as a burette.

Density of Milk Solids-not-Fat

The density of solids-not-fat in milk was obtained by using skim milk powder as a source of solids-not-fat. The moisture and fat content of the skim milk powder were determined by A.O.A.C. methods and corrections made for these when calculating the density of the solids-not-fat.

The density of milk solids-not-fat was obtained by weighing in an analytical balance ten grams of skim milk powder directly into the 100 ml. volumetric flask just described. From a carefully standardized burette 100 ml. of boiled, distilled water were measured into the flask at its calibrated temperature of 68° F. This mixture was shaken thoroughly. It was then allowed to stand a sufficient time to allow all foam to be eliminated. Volume determinations of this mixture were read at 5° F. intervals from 60° F. to 155° F. The volume of the flask was determined with boiled, distilled water at the temperatures used so that no correction for glass expansion had to be taken into consideration when calculating the density of the mixture. Several duplicate determinations were carried out in this manner. The same procedure was followed using 12 grams and 14 grams of skim milk powder to 100 ml. boiled, distilled water. However, 10 grams of powder with 100 ml. water seemed to be the most satisfactory mixture. The volume increase caused by the addition of the skim milk powder was read on the graduated portion of the flask neck and was taken as the volume of the 10 grams of powder.

To check the accuracy of the volume reading at the different temperatures, the density of the mixture was also determined using a 25 ml. pycnometer. All the pycnometer weighings were made at room temperature. The pycnometer was filled with the skim milk powder-water mixture and heated

to the desired temperature in a hot water bath. The bath was accurately controlled by means of a steam coil in the bottom of the tank. When the desired temperature was attained the pycnometers were taken out of the bath, carefully dried, cooled, to room temperature, and weighed. By this method the proper volume for a given temperature was obtained and still the weighings could be made at room temperature. A control pycnometer was used to get the correct temperature for the volume readings.

The density of the mixture by the pycnometer determination was calculated by calibrating the volume at different temperatures and weighing the volume of mix the pycnometer held at the corresponding temperatures.

The following formula gave the density of the mixture:

$$\text{Density of Mixture} = \frac{\text{Pycnometer weight of mixture}}{\text{Pycnometer vol. of mixture.}}$$

All determinations in one calculation were made at the same temperature.

No correction had to be made for glass expansion as the volume of both the water and the mixture were calibrated at all the temperatures used.

The following formulae were used to calculate the density of the mixture and the density of the solids-not-fat from the volume readings:

$$\text{Density of Mixture} = \frac{\text{Weight of all water present + weight of dry powder}}{\text{Volume of all water present + volume of dry powder.}}$$

$$\text{Density of solids-not-fat} = \frac{\text{Weight of dry powder}}{\text{Volume of dry powder.}}$$

As with density of mixture, each determination was made from weight and volume findings at the same temperature.

The density of the solids-not-fat as taken, may be affected by hydration and cannot be taken as absolute density. However, for simplicity in this work it will be referred to as the density of solids-not-fat

because it is in combination similar to that in which it exists in an ice cream mix.

By knowing the density of the mixture determined with the pycnometer an accurate check can be made on the volume readingsof the mixture. This directly influences the results of calculating the density of the solids-not-fat. If the volume readings of the mixture are correct, and knowing the volume of the water present in the mixture, the difference represents the volume due to the presence of the powder. As the weight of the powder is always constant there will be a change in the density of the solids-not-fat if the volume changes at a different temperature. The amount of fat in the skim milk powder was so small (0.1 per cent) that it was calculated as water. This made a difference of less than 0.0001 in the density of solids-not-fat.

Density of Sucrose and Gelatin

The same procedure was used as above in determining the density of sucrose and gelatin, varying the amount of each used.

Several determinations were run on sucrose, using 10 grams and 12 grams to 100 ml. water. As sugar was readily soluble in water its density in solution was not as difficult to determine as the density of milk solids-not-fat.

The density of a good grade of ice cream gelatin was determined by using one gram and two grams of gelatin to 100 ml. water and noting the volume change due to the presence of the gelatin.

The densities of milk solids-not-fat, sugar, and gelatin will be referred to as their normal densities. But it should be noted that the determinations were made in a water mixture or solution, and strictly speaking, the values given are their densities only in the percentage of water used in this experiment. Different concentrations of water within the range used did not change these values. The method used was believed most desirable because it gives the densities of the three ingredients as they would most likely appear in an ice cream mix.

Density of Water and Butterfat

The density of water at different temperatures was taken from Lange's, "Handbookof Chemistry" (49). Densities of butterfat at different temperatures was taken from the work of Bailey (50).

PART IV

Predicted Density Determinations

Calculation of Predicted Density of Mix From Density of Mix Ingredients

With the densities of all ingredients of the ice cream mix available the correct Baume reading for any composition mix was sought from the conversion of the density to Baume degrees. The method which it was believed would be satisfactory is given on page 27. The sum of the densities of each ingredient is referred to here as the additive density.

To test the practicability of this method the predicted densities of the mix at a given temperature were compared with the densities of the mixes at the same temperature as taken at the pan. These densities were obtained by converting the Baume readings to densities. If it is true that some factor, multiplied by the additive density of the mix, will give

a value significantly close to the measured density as converted from the Baume reading, then there must be a straight line relationship between the additive density of a mix and its measured density at different temperatures. Additive densities, therefore, should be calculated to the fourth decimal place. Conversely, equal care must be taken in reading the Baume hydrometer for its smallest graduation is 0.1°, and since the reading should be made at the surface of the liquid rather than at the top of the meniscus, the reading at the best is approximate. Add to this the known inaccuracy of many Baume hydrometers, the need for care becomes increasingly obvious.

RESULTS OF EXPERIMENT

PARTS I AND II

The question is often raised as to the proper position of the thermometer in the vacuum pan, i.e. whether it should be placed in the liquid being condensed, in the vapor immediately above the liquid, or in the top of the pan. While it may appear that this factor had no bearing on the problem under consideration, the observations were necessary in order to duplicate in the commercial size pan the conditions under which condensations were made in the small pan. The results are given in Table II.

Table II. Effect of Position of Thermometer on Temperature Reading.

	Position of Thermometer		
Vacuum	Immersed in Liquid	1/2 inch above Liquid	In Vapor
	Temperature	Temperature	Temperature
22.75	152° F.	151° F.	151° F.
23.00	149	148	148
23.50	146	145	145
21.50	156	155	155
22.00	153	153	153
23.50	147	146	146
24.00	141	140	140

From the results shown above the position of the thermometer in the laboratory vacuum pan had a slight effect on the temperature reading of the boiling liquid under reduced pressure. Of the readings taken, in one instance only, was the temperature of the boiling liquid the same as that immediately above the liquid, or that of the vapor from the boiling liquid. In all other readings the temperature of the liquid was one degree higher than that of the vapor. The reason for the boiling liquid showing a slightly higher temperature is probably that it became slightly super-

heated by continued boiling under reduced pressure. Assuming that the behavior of the liquid under similar conditions in a large vacuum pan showed the same results the position of the thermometer in the large vacuum pan would be of no special importance as far as the accuracy of the reading was concerned. The small laboratory apparatus was so similar in principle and construction to the largepan that results secured from it were apparently identical to those secured with the larger pan.

State of Fat Effect on Baume Reading

When mixes stand, especially at moderately low temperature, viscosity continues to develop, and if densities were determined by hydrometer readings at different intervals, they would be found to vary. This variation in readings, it is reasonable to suppose, is due in part also to the mechanical obstruction offered by the partially solidified and crystallized butterfat. Samples of the mixes were cooled to 60° F., stored for four hours at 40° F., heated to 60° F., and hydrometer readings made. Duplicate samples were handled in exactly the same manner except that after four hours in the refrigerator they were heated to 155° F. to thoroughly liquify the fat, and cooled to 60° F. and a Baume determination made. Results were as follows:

Table III. Average effect of State of Fat on Baume Reading of Ice Cream Mixes.

Composition of Mix	Baume Reading with Fat in Liquid State	Baume Reading with Fat in Solid State
8 : 11 : 14 : 0.4	13.10	13.25
8 : 11 : 15 : 0.4	13.35	13.50
8 : 11 : 16 : 0.4	13.75	13.90
10 :10.5: 14 : 0.4	12.30	12.50
10 :10.5: 14 : 0.4	12.80	12.95
10 :10.5: 14 : 0.4	13.30	13.45
12 : 10 : 14 : 0.4	11.80	12.00
14 : 9 : 14 : 0.4	11.20	11.40

In all cases the ice cream mixes that were not heated above 60° F. after being held in the refrigerator for 4 hours, showed higher Baume readings. The mixes that had been heated to 155° F. and cooled to 60° F. before the Baume readings were taken showed lower readings because the fat was in a liquid state. This may become an important source of error in the commercial plant or laboratory unless previous checks have been made on the proper Baume reading for that temperature. By heating the ice cream mix sample above the melting point of fat and cooling down to the proper temperature the correct Baume reading may be secured.

Relation of Vacuum to Boiling Point

In order to condense mixes of different composition at comparatively low temperatures, the inches of vacuum required in the small pan was recorded in each case so that they could be duplicated when the large pan was used. The readings follow:

Table IV. Relation of Temperature of Boiling to Composition of Mix and Inches of Vacuum

Composition of Mix				Temperature of	Vacuum in
Fat	SNF	Sugar	Gelatin	Boiling Liquid	Inches HG
8	11	14	0.4	159	20.75
				154	22.00
				150	23.00
8	11	15	0.4	160	20.50
				154	22.00
				137	27.00
8	11	16	0.4	145	23.25
10	10.5	14	0.4	156	21.25
				153	22.00
				147	23.50
				141	24.00
10	10.5	15	0.4	146	23.75
10	10.5	16	0.4	154	22.00
				146	23.50
12	10	14	0.4	148	22.50
				146	23.00
12	10	15	0.4	150	22.50
				154	22.00
12	10	16	0.4	150	22.50
				148	23.00
14	9	14	0.4	144	23.50
				142	23.75
14	9	15	0.4	148	23.00
14	9	16	0.4	151	22.25
				150	22.50

For each 1° F. change in temperature there is a change of 0.25 inch in vacuum at most changes of temperature. However, there are irregularities in the observations, especially in the higher total solids mixes. This may be due to experimental error.

Baume Readings on Mixes of Varying Composition at Different Temperatures

The following represent the average Baume readings of mixes from both the small and large pans. The averages are segregated according to composition, the latter being given at the bottom of each table. Each

sample taken was read from 155° F., by 5° F. gradations to 60° F., in order that the correct reading might be made available at varying temperatures for commercial use. In no case does an average value represent less than two readings; in most cases it represents three.

Tables V to IX show there is a change of 0.2° Baume for each 5° F. change within the temperature range of 110° F. to 155° F. This is true for all mixes except one, in which there was a change of 0.15° Baume from 115° F. to 110° F. All mixes showed a 0.15° Baume change for each 5° F. within the range of 110° F. to 70° F., excepting one mix. In most cases the 5° F. change from 60° F. to 65° F. caused 0.1° Baume change.

Because 110° F. is approaching the change of fat from a liquid to a solid state, reading from higher temperatures, the apparent change in the state of the fat may cause a smaller variation in Baume reading for a specified change in temperature. This may explain why there is a greater Baume change above 110° F. than there is below this temperature. However, the readings were taken within a short period so that the fat may not have had sufficient time to change from the liquid to the solid state.

The plotting of the Baume readings against temperature, as given in Charts I to IV, shows the direct influence of temperature on the degree of change of the Baume reading. The composition of the mix did not affect this relationship to any extent.

Table V. Averages of Baume Readings For Different Composition Ice Cream Mixes.

Mix No. 1		Mix No. 2		Mix No. 3	
Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.
9.8	155	10.1	155	10.6	155
10.0	150	10.3	150	10.8	150
10.2	145	10.5	145	11.0	145
10.4	140	10.7	140	11.2	140
10.6	135	10.9	135	11.4	135
10.8	130	11.1	130	11.6	130
11.0	125	11.3	125	11.8	125
11.2	120	11.5	120	12.0	120
11.4	115	11.7	115	12.2	115
11.6	110	11.9	110	12.4	110
11.8	105	12.05	105	12.55	105
11.95	100	12.20	100	12.70	100
12.10	95	12.35	95	12.85	95
12.25	90	12.50	90	13.00	90
12.40	85	12.65	85	13.15	85
12.55	80	12.80	80	13.30	80
12.70	75	12.95	75	13.45	75
12.85	70	13.10	70	13.55	70
13.00	65	13.20	65	13.65	65
13.10	60	13.30	60	13.75	60

Mix Number	Percentage Composition			
	Fat	SNF	Sugar	Gelatin
1	8	11	14	0.4
2	8	11	15	0.4
3	8	11	16	0.4

Table VI. Averages of Baume Readings For Different Composition Ice Cream Mixes

Mix No. 1		Mix No. 2		Mix No. 3	
Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.
9.1	155	9.7	155	10.0	155
9.3	150	9.9	150	10.2	150
9.5	145	10.1	145	10.4	145
9.7	140	10.3	140	10.6	140
9.9	135	10.5	135	10.8	135
10.1	130	10.7	130	11.0	130
10.3	125	10.9	125	11.2	125
10.5	120	11.1	120	11.4	120
10.7	115	11.3	115	11.6	115
10.9	110	11.45	110	11.8	110
11.10	105	11.60	105	11.95	105
11.25	100	11.75	100	12.10	100
11.40	95	11.90	95	12.25	95
11.55	90	12.05	90	12.40	90
11.70	85	12.20	85	12.55	85
11.85	80	12.35	80	12.70	80
12.00	75	12.50	75	12.85	75
12.10	70	12.65	70	13.00	70
12.20	65	12.80	65	13.15	65
12.30	60	12.90	60	13.30	60

Mix Number	Percentage Composition			
	Fat	SNF	Sugar	Gelatin
1	10	10.5	14	0.4
2	10	10.5	15	0.4
3	10	10.5	16	0.4

Table VII. Averages of Baume Readings For Different Composition Ice Cream Mixes

Mix No. 1		Mix No. 2		Mix No. 3	
Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.
8.5	155	9.3	155	10.0	155
8.7	150	9.5	150	10.2	150
8.9	145	9.7	145	10.4	145
9.1	140	9.9	140	10.6	140
9.3	135	10.1	135	10.80	135
9.5	130	10.3	130	11.00	130
9.7	125	10.5	125	11.20	125
9.9	120	10.7	120	11.40	120
10.1	115	10.9	115	11.60	115
10.3	110	11.1	110	11.80	110
10.45	105	11.25	105	11.95	105
10.60	100	11.40	100	12.10	100
10.75	95	11.55	95	12.25	95
10.90	90	11.70	90	12.40	90
11.05	85	11.85	85	12.55	85
11.20	80	12.00	80	12.70	80
11.35	75	12.15	75	12.85	75
11.50	70	12.30	70	13.00	70
11.65	65	12.45	65	13.15	65
11.80	60	12.60	60	13.30	60

	Percentage Composition			
Mix Number	Fat	SNF	Sugar	Gelatin
1	12	10	14	0.4
2	12	10	15	0.4
3	12	10	16	0.4

Table VIII. Averages of Baume Readings For Different Composition Ice Cream Mixes

Mix No. 1		Mix No. 2		Mix No. 3	
Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.
7.9	155	8.5	155	9.3	155
8.1	150	8.7	150	9.5	150
8.3	145	8.9	145	9.7	145
8.5	140	9.1	140	9.9	140
8.7	135	9.3	135	10.1	135
8.9	130	9.5	130	10.3	130
9.1	125	9.7	125	10.5	125
9.3	120	9.9	120	10.7	120
9.5	115	10.1	115	10.9	115
9.7	110	10.3	110	11.1	110
9.85	105	10.45	105	11.25	105
10.00	100	10.60	100	11.40	100
10.15	95	10.75	95	11.55	95
10.30	90	10.90	90	11.70	90
10.45	85	11.05	85	11.85	85
10.60	80	11.20	80	12.00	80
10.75	75	11.35	75	12.15	75
10.90	70	11.50	70	12.30	70
11.05	65	11.60	65	12.45	65
11.20	60	11.70	60	12.60	60

	Percentage Composition			
Mix Number	Fat	SNF	Sugar	Gelatin
1	14	9	14	0.4
2	14	9	15	0.4
3	14	9	16	0.4

Table IX. Averages of Baume Readings of Miscellaneous Mixes of Different Compositions

Mix No. 1		Mix No. 2		Mix No. 3	
Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.	Degrees Baume	Degrees Fahr.
8.7	155	8.8	155	8.8	155
8.9	150	9.0	150	9.0	150
9.1	145	9.2	145	9.2	145
9.3	140	9.4	140	9.4	140
9.5	135	9.6	135	9.6	135
9.7	130	9.8	130	9.8	130
9.9	125	10.0	125	10.0	125
10.1	120	10.2	120	10.2	120
10.3	115	10.4	115	10.4	115
10.5	110	10.6	110	10.6	110
10.65	105	10.75	105	10.75	105
10.80	100	10.90	100	10.90	100
10.95	95	11.05	95	11.05	95
11.10	90	11.20	90	11.20	90
11.25	85	11.35	85	11.35	85
11.40	80	11.50	80	11.50	80
11.55	75	11.65	75	11.60	75
11.70	70	11.80	70	11.70	70
11.80	65	11.90	65	11.80	65
11.90	60	12.00	60	11.90	60

Percentage Composition

Mix Number	Fat	SNF	Sugar	Gelatin
1	13.90	9.45	15	0.4
2	13.85	9.55	15	0.4
3	14.50	11.00	14	0.4

Baume vs Pycnometer Determinations of Density

In the following Table X the mixes are grouped according to their composition. The average density of each group is given as calculated from the average Baume readings made for the mixes of that composition. Using the temperature corrections given in Tables V to IX for Baume at 70°, column five of Table X gives the Baume converted to density. In column six is given the average density as determined by pycnometer. The latter was calibrated for use at 68° F. This is the reason that 70° F. was chosen as the temperature from which the Baume should be converted. This table is intended for no other use than as a check on the accuracy of the Baume determinations.

Table X. Average Densities at 70° F. of Ice Cream Mixes Calculated by Baume and Pycnometer Methods

Mix Composition Percentage				Density		Difference
Fat	Solids-not-fat	Sugar	Gelatin	Baume	Pycnometer	
8	11	14	0.4	1.0972	1.0980	0.0008
8	11	15	0.4	1.1009	1.1015	0.0006
8	11	16	0.4	1.1032	1.1150	0.0018
10	10.5	14	0.4	1.0841	1.0848	0.0007
10	10.5	15	0.4	1.0939	1.0934	0.0005
10	10.5	16	0.4	1.0985	1.1003	0.0018
12	10	14	0.4	1.0865	1.0890	0.0005
12	10	15	0.4	1.0927	1.0935	0.0008
12	10	16	0.4	1.0985	1.1004	0.0019
14	9	14	0.4	1.0813	1.0825	0.0012
14	9	15	0.4	1.0861	1.0864	0.0003
14	9	16	0.4	1.0927	1.0923	0.0004
13.90	9.45	15	0.4	1.0856	1.0878	0.0022
13.85	9.55	15	0.4	1.0886	1.0892	0.0006
14.50	11.0	14	0.4	1.0877	1.0863	0.0014
9.9	10.2	14	0.4	1.0841	1.0862	0.0021

Chart I. Relation Between Temperature and Baume Readings of Different Composition Ice Cream Mixes

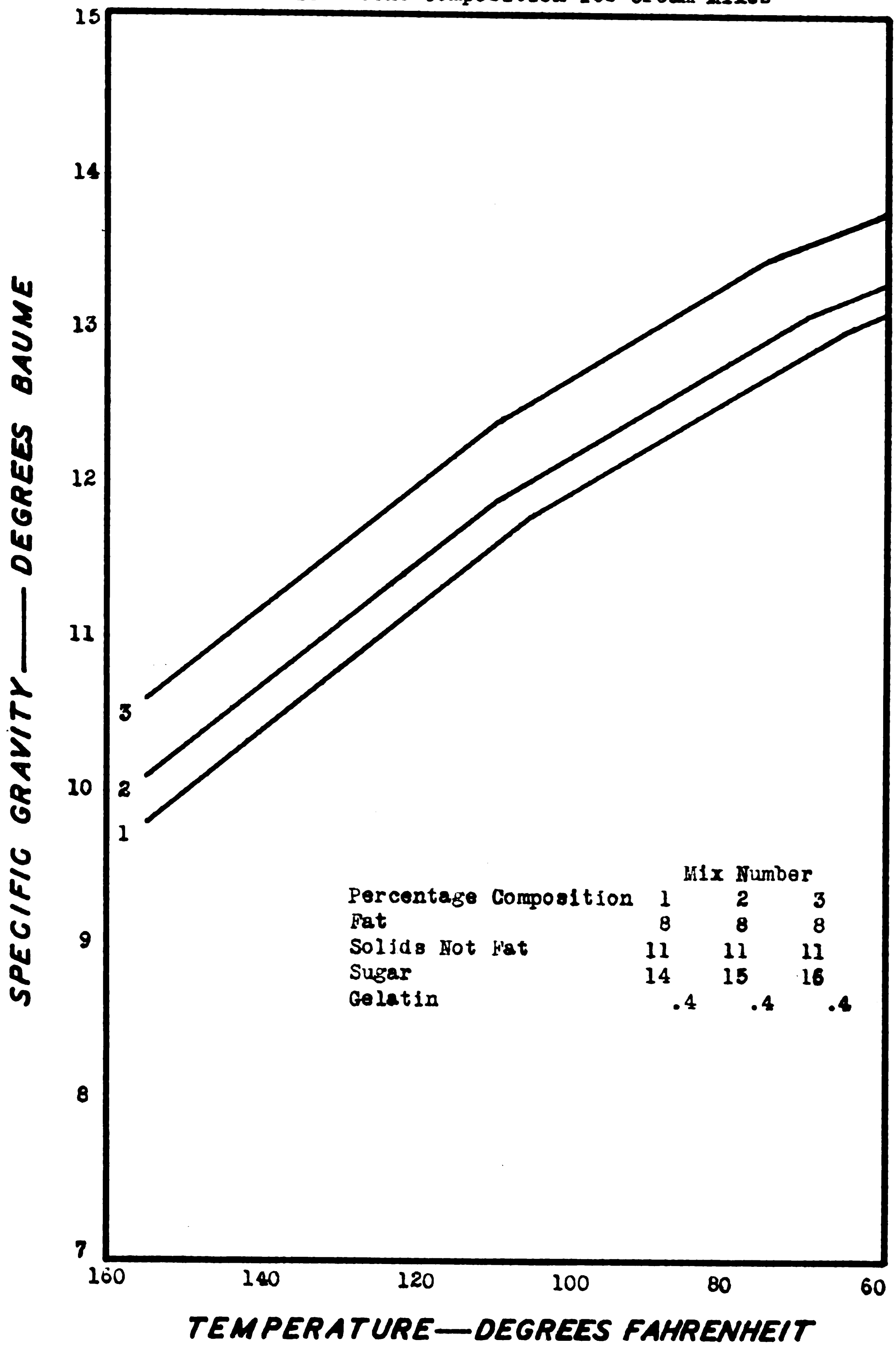


Chart II. Relation Between Temperature and Baume Readings of Different Composition Ice Cream Mixes

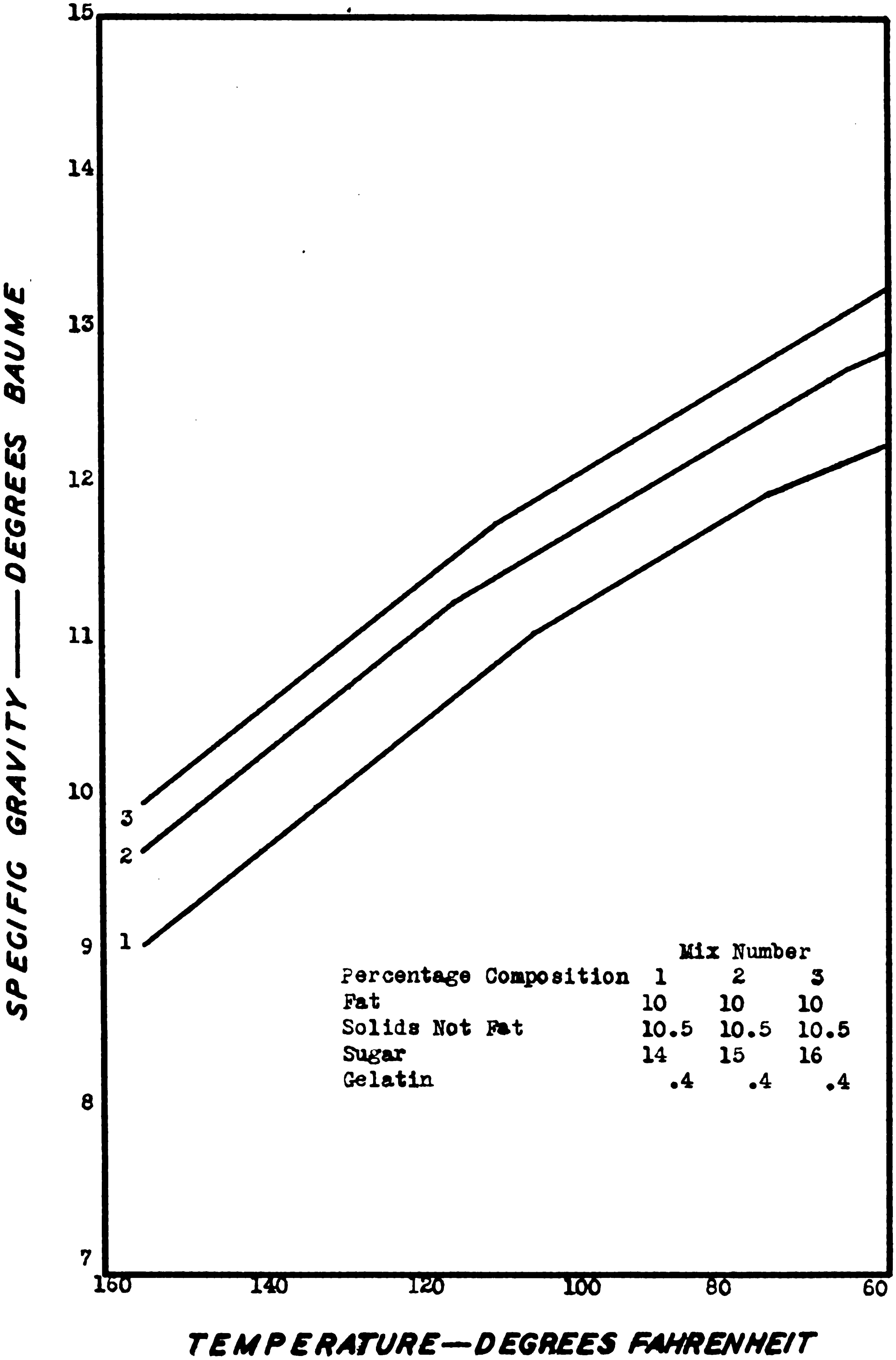


Chart III. Relation Between Temperature and Baume Readings of Different Composition Ice Cream Mixes

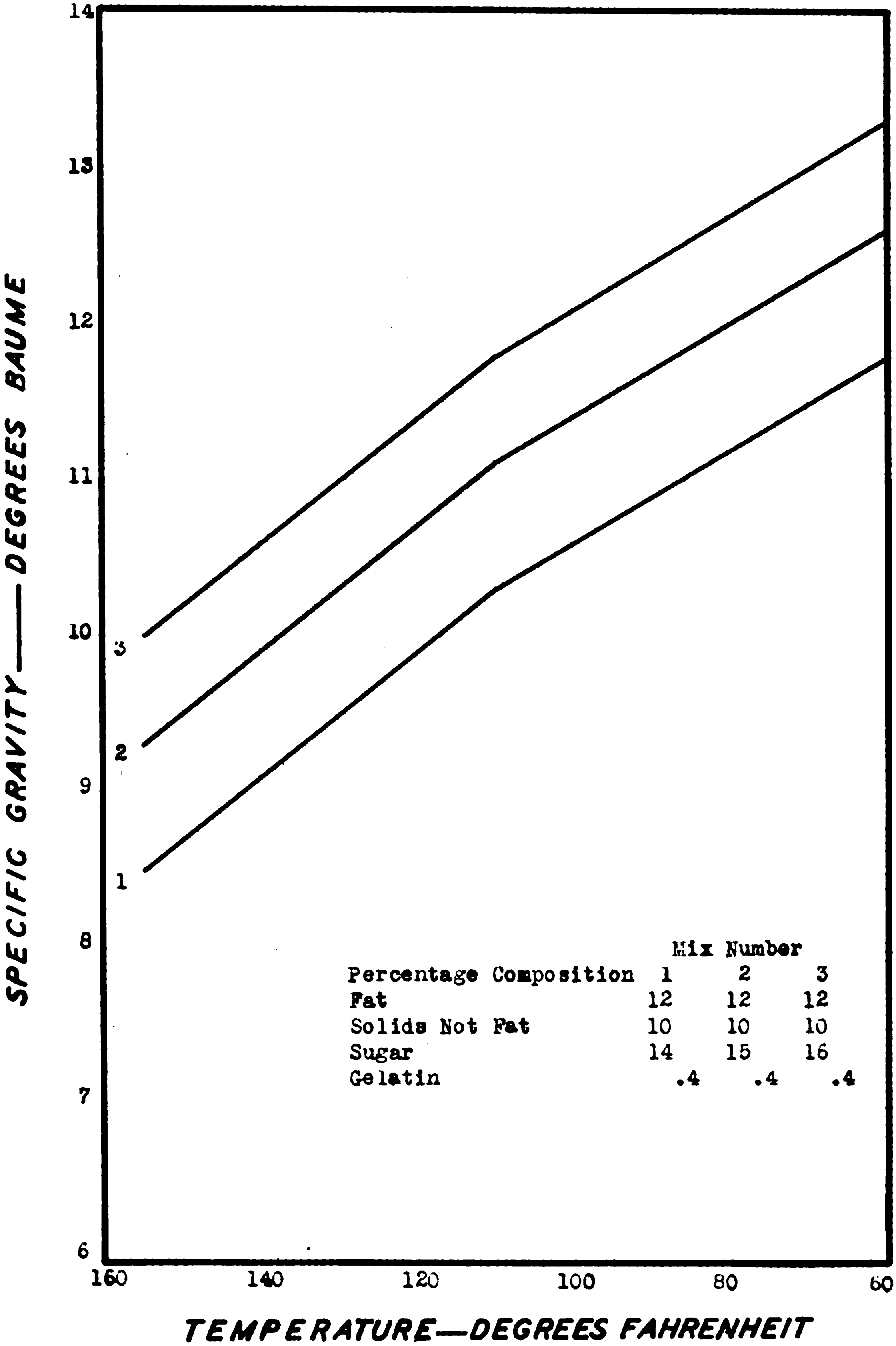
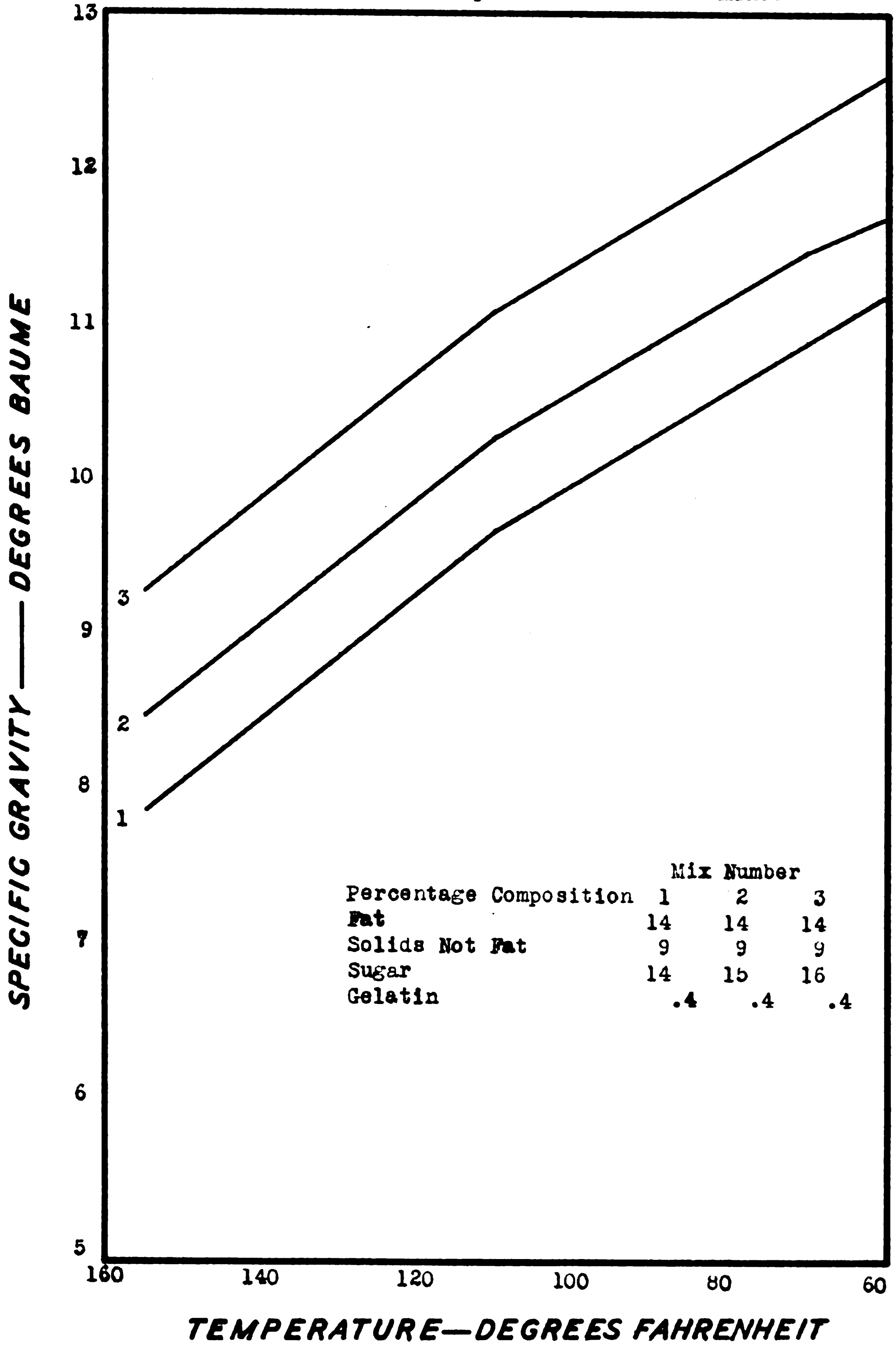


Chart IV. Relation Between Temperature and Baume Readings of Different Composition Ice Cream Mixes



Checking against each other the density, as converted from the observed Baume reading and as secured by pycnometer determination not only established the accuracy or inaccuracy of the Baume hydrometer, but also indicated how accurately the hydrometer could be read. Results show that the average of the Baume converted readings varied 0.0011 from the pycnometer density values, or slightly more than 0.1° Baume. Nearly one-half of the readings were more than 0.1° Baume greater or less than the density as determined by the pycnometer. The source of error, therefore, seems to be with the hydrometer itself and with the operator. The temperature must be checked carefully as this is the greatest source of mechanical error. Since 0.1° variation Baume means a difference of 0.0008 in density, and since the hydrometer can be read no more closely than 0.1°, it is advisable that only the best grade of rechecked hydrometers with easily read graduations be used.

The Mojonnier determinations for fat and total solids in all ice cream mixes studied are recorded in Table X.

Homogenization Effect on Viscosity and Surface Tension

Viscosity and surface tension undoubtedly affect density determinations made with a hydrometer. Unfortunately no mixes in this study were made from butter as a source of fat. The following table must be interpreted as applying to mixes only, carrying fat as it normally occurs in milk. Butter mixes would probably show much less viscosity, due to the dispersion of fat.

Table XI. Viscosity and Surface Tension of Unhomogenized and Homogenized Pan Condensed Ice Cream Mixes

Treatment	Calculated Mix Composition	Basic Viscosity		Surface Tension	Apparent Viscosity		Surface Tension
		Degrees Retardation	Centipoises		Degrees Retardation	Centipoises	
Unhomog.	8:11 :14:0.4	10	30.52	47.5	15	52.36	47.0
Homog.	8:11 :14:0.4	14	39.24	46.0	32	117.73	46.0
Unhomog.	8:11 :15:0.4						
Homog.	8:11 :15:0.4	15	39.24	45.5	30	95.93	45.5
Unhomog.	8:11 :16:0.4	10	30.52	45.5	15	52.36	45.5
Homog.	8:11 :16:0.4	13	34.88	45.0	25	78.49	46.0
Unhomog.	10:10.5:14:0.4	10	26.13	48.0	20	43.60	47.0
Homog.	10:10.5:14:0.4	18	47.96	46.0	28	87.21	45.5
Unhomog.	10:10.5:15:0.4	16	43.60	46.0	25	74.13	45.0
Homog.	10:10.5:15:0.4	18	52.32	47.5	45	148.26	48.0
Unhomog.	10:10.5:16:0.4	18	52.32	47.5	52	161.33	47.0
Homog.	10:10.5:16:0.4	17	53.32	45.5	50	196.22	45.0
Unhomog.	12:10 :14:0.4	31	78.48	46.0	65	135.53	45.0
Homog.	12:10 :14:0.4	30	74.13	49.0	70	279.07	48.0
Unhomog.	12:10 :15:0.4	10	26.16	46.5	37	91.56	45.5
Homog.	12:10 :15:0.4	30	87.21	45.5	68	252.90	45.5
Unhomog.	12:10 :16:0.4	28	60.04	50.0	35	91.56	46.5
Homog.	12:10 :16:0.4	40	130.15	46.0	125	470.80	46.5
Unhomog.	14: 9 :14:0.4	25	69.77	46.5	62	226.70	45.5
Homog.	14: 9 :14:0.4	40	113.37	47.0	160	396.51	46.5
Unhomog.	14: 9 :15:0.4	37	82.85	49.0	90	327.03	47.5
Homog.	14: 9 :15:0.4	38	100.30	47.0	97	344.48	46.5
Unhomog.	14: 9 :16:0.4	35	95.93	45.5	70	279.07	47.0
Homog.	14: 9 :16:0.4	40	95.93	45.5	88	375.00	46.0

The unhomogenized mix made in the small laboratory pan developed a great deal of viscosity. The viscosity varied from one-half as much to almost as much viscosity as the homogenized mix with a similar composition.

There was no sharp change in surface tension for a great increase in viscosity, but, as a general rule, an increase in viscosity resulted in a slight lowering of the surface tension.

The surface tension and viscosity of a pan condensed, homogenized mix was normal compared to a vat processed mix of a similar composition.

The MacMichael viscosity values measured in centipoises, were on the average approximately three times as great as the value in degrees retardation secured by the Mojonnier-Doolittle Viscosimeter.

The apparent viscosity of the homogenized mixes varied from less than twice to more than three and one-half times the basic viscosity. Stated differently the pan condensed homogenized mix more than tripled its viscosity during a 24-hour period. This occurred particularly with the high fat and high total solids content mixes.

PART III

Density Determinations of the Solid Ingredients of the Ice Cream Mixes

The method of making these determinations has been described rather fully. Rather than use questioned data on coefficients of expansion of water, the 110 ml. flasks used were calibrated for several temperatures. The flasks held 100 ml. at 68^{o} F. When heated throughout to 120^{o} F. the water had risen in the graduated neck to 101.05 ml. (Table XII). Remaining calibrations were determined similarly.

Table XII. Volume Readings Secured in Calibration at Varying Temperatures of 110 ml. Graduated Volumetric Flasks Using Boiled, Distilled Water.

Temperature Degrees Fahr.	Volume in Ml. Flask 1	Volume in Ml. Flask 2
155	102.05	102.05
150	101.90	101.90
145	101.70	101.70
140	101.60	101.60
135	101.40	101.40
130	101.30	101.30
125	101.20	101.20
120	101.05	101.05
68	100.00	100.00
60	99.90	99.90

There was no straight line relationship between an increase in temperature and an increase in volume of the water. However, the average increase in volume was about 0.15 ml. per 5° F. change in temperature.

The above values were used in determining the volume of skim milk powder (milk solids-not-fat), gelatin, and sugar. Thus if ten grams of skim milk powder were added to flask number one containing water at 68° F., and heated to 130° F. the volume of the water was taken as 101.3 ml. and this subtracted from the reading of the mixture on the flask's graduated neck. The difference between the two readings was the volume of water displaced by the ten grams of skim milk powder. This value or volume divided by the weight of the powder gave the density of solids-not-fat or powder. Corrections were made for moisture and fat content of the powder. Densities of gelatin and sucrose were similarly determined.

Table XIII. Volume Readings of Skim Milk Powder at Various Temperatures.

Temperature Degrees Fahr.	Volume 100 ml. Water	Volume 100 ml. water 10 grams powder	Volume 100 ml. water 12 gms. powder	Volume Due to 10 gms. powder	Volume Due to 12 gms. powder
60	99.00	106.20 ml.	107.46 ml.	6.30 ml.	7.56 ml.
68	100.00	106.30	107.56	6.30	7.56
120	101.05	107.35	108.61	6.30	7.56
125	101.20	107.50	108.76	6.30	7.56
130	101.30	107.60	108.86	6.30	7.56
135	101.40	107.70	108.96	6.30	7.56
140	101.60	107.90	109.16	6.30	7.56
145	101.70	108.00	109.26	6.30	7.56
150	101.90	108.20	109.46	6.30	7.56
155	102.05	108.35	109.61	6.30	7.56

From Table XIII it may be noted that an increase in temperature did not cause a change of volume of the skim milk powder, either using 10 grams or 12 grams in 100 ml. water. This verified preliminary data when 10, 12, and 14 grams of skim milk powder were used. Therefore, the volume increase must be entirely due to the water.

Table XIV. Density of Solids-not-fat From Volume Readings.

Temperature	Density of Suspension (10 gms. powder + 100 ml. water) By Pycnometer	Density of Suspension (10 gms. powder + 100 ml. water) By Volume	Density of S N F
60	1.0351	1.0353	1.6185
68	1.0351	1.0350	1.6185
120	1.0375	1.0355	1.6185
125	1.0372	1.0355	1.6185
130	1.0364	1.0356	1.6185
135	1.0378	1.0358	1.6185
140	1.0380	1.0358	1.6185
145	1.0367	1.0358	1.6185
150	1.0360	1.0359	1.6185
155	1.0354	1.0360	1.6185

Density of SNF at any temperature $= \frac{\text{Wt. SNF}}{\text{Vol. SNF}}$ at any temperature

Table XV. Density of Solids-not-fat From Volume Readings

Temperature Degrees Fahr.	Density of Suspension (12 gms. powder + 100 ml. water) By Pycnometer	By Volume	Density of Solids-not-fat
60	1.0413	1.0420	1.6185
68	1.0410	1.0421	1.6185
120	1.0424	1.0422	1.6185
125	1.0434	1.0421	1.6185
130	1.0424	1.0423	1.6185
135	1.0438	1.0441	1.6185
140	1.0447	1.0431	1.6185
145	1.0427	1.0431	1.6185
150	1.0420	1.0438	1.6185
155	1.0404	1.0434	1.6185

The density of the solids-not-fat (column four) was the same at all temperatures within the 60° F. to 155° F. range. This was as would be expected; there was no change in volume of mixture due to the solids-not-fat (columns four and five Table XIII) with change in temperature, weight was constant, therefore the density remained constant at varying temperatures.

Table XV gives similar results obtained where 12 instead of ten grams skim milk powder was used.

The above calculations are from the suspension and solution of the skim milk powder in the water and the density is really the density due to the solids-not-fat in suspension in the water.

The density of the suspension, as determined by the pycnometer weighings, may be used to check the accuracy of the volume reading by comparing columns two and three of Tables XIV and XV.

Table XVI. Volume Readings of Sugar Solution at Various Temperatures

Temperature Degrees Fahr.	Volume 100 ml. Water	Volume Readings ml. Sample 1	Volume Readings ml. Sample 2	Volume due to Sugar
60	99.90	107.35	107.35	6.45
68	100.00	107.45	107.45	6.45
120	101.05	108.50	108.50	6.45
125	101.20	108.65	108.65	6.45
130	101.30	108.75	108.75	6.45
135	101.40	108.85	109.05	6.45
140	101.60	109.05	109.05	6.45
145	101.70	109.15	109.15	6.45
150	101.90	109.35	109.35	6.45
155	102.05	109.50	109.50	6.45

Table XVI gives as a final result the volume due to the presence of 12 grams sugar in 100 ml. boiled, distilled water. Other work, results of which are not recorded here, using 10 and 14 grams sugar in 100 ml. water, was carried on and was verified by the work above.

Table XVII. Density of Sugar From Volume Readings

Temperature Degrees Fahr.	Density of Solution (12 gms sugar 100 ml. water) By Pycnometer	By Volume	Density of Sugar
60	1.0435	1.0425	1.6107
68	1.0431	1.0425	1.6107
120	1.0424	1.0432	1.6107
125	1.0423	1.0432	1.6107
130	1.0422	1.0434	1.6107
135	1.0433	1.0434	1.6107
140	1.0434	1.0436	1.6107
145	1.0428	1.0436	1.6107
150	1.0414	1.0438	1.6107
155	1.0436	1.0439	1.6107

The density of the sugar was calculated from its known weight in the solution. As the volume was not changed by a change in temperature the density remained the same throughout the temperature range used. Although

there may be a slight change in volume, with change of temperature, it was not visible in the determinations made in this experiment.

Table XVIII. Volume Readings of Gelatin at Various Temperatures.

Temperature Degrees Fahr.	Volume 100 ml. Water	Volume 1 gm. Gelatin 100 ml. Water	Readings ml. 2 gms Gelatin 100 ml. Water	Volume Due to 1 gm. Gelatin	2 gm. Gelatin
60	99.90	100.55	101.20	0.65	1.30
68	100.00	100.65	101.35	0.65	1.30
120	101.05	101.70	102.35	0.65	1.30
125	101.20	101.85	102.50	0.65	1.30
130	101.30	101.95	102.60	0.65	1.30
135	101.40	102.05	102.70	0.65	1.30
140	101.60	102.25	102.90	0.65	1.30
145	101.70	102.35	103.00	0.65	1.30
150	101.90	102.55	103.20	0.65	1.30
155	102.05	102.65	103.35	0.65	1.30

In Table XVIII the results show that as the weight of the gelatin was doubled the volume of water displaced doubled. As the amounts used are greater than the amounts used in an ice cream mix the values can be safely used in the density determination.

Table XIX. Density of Gelatin From Volume Readings

Temperature Degrees Fahr.	Density of Suspension (1 gm. Gelatin + 100 ml. Water) By Pyncometer	By Volume	Density of Gelatin
60	1.0027	1.0034	1.5384
68	1.0030	1.0034	1.5384
120	1.0035	1.0035	1.5384
125	1.0032	1.0035	1.5384
130	1.0030	1.0035	1.5384
135	1.0040	1.0035	1.5384
140	1.0039	1.0036	1.5384
145	1.0026	1.0035	1.5384
150	1.0025	1.0036	1.5384
155	1.0041	1.0041	1.5384
Same determinations using 2 grams gelatin to 100 ml. water			
60	1.0056	1.0069	1.5384
68	1.0056	1.0064	1.5384
120	1.0062	1.0070	1.5384
125	1.0056	1.0069	1.5384
130	1.0059	1.0070	1.5384
135	1.0068	1.0071	1.5384
140	1.0071	1.0071	1.5384
145	1.0064	1.0071	1.5384
150	1.0058	1.0071	1.5384
155	1.0078	1.0072	1.5384

Table XX. Density of Butterfat and Water at Various Temperatures

Temperature Degrees Fahr.	Density of Butterfat	Density of Water
60	0.92014	0.99905
68	0.9016	0.99823
120	0.8974	0.98856
125	0.8955	0.98729
130	0.8936	0.98597
135	0.8917	0.98507
140	0.8898	0.98324
145	0.8879	0.98262
150	0.8860	0.98032
155	0.8841	0.97881

The above densities of butterfat were calculated from the work done by Bailey (50). According to Bailey the density of butterfat changes 0.00038 per degree Fahrenheit change. The density of butterfat at 113° F. is 0.9000.

The above values for density of water were taken from the Handbook of Chemistry (49).

In Table XXI the values in the first two columns were taken from the Handbook of Chemistry (49) and the last column was calculated from these values.

Table XXI. Relation Between Density and Baume Scale For Densities Above Unity

Density	Baume°	Density to Make 1° Baume
1.05	6.91	0.00752
1.06	8.21	0.00763
1.07	9.49	0.00781
1.08	10.78	0.00775
1.09	11.97	0.00840
1.10	13.18	0.00826
1.11	14.37	0.00840
1.12	15.54	0.00854
1.13	16.68	0.00877
1.14	17.81	0.00885

Part IV

Prediction of Baume Reading According to Mix Composition

Because most of the density readings of the mixes made in this study, which cover the normal range of commercial mixes, come within the range of 1.06 - 1.11, the above table is particularly ap licable. It

shows that within this range, a change of 0.0008 in density will make 0.1° Baume change. If it is possible, therefore, to predict the density of the mix within 0.0008 on the Baume hydrometer scale in terms of specific gravity it is possible to predict the correct Baume reading within 0.1°, which under practical conditions, is as accurately as a Baume hydrometer can be read.

In preparing the data given in the following tables these density values were used:

1. Density of fat @ 113° F. = 0.9000
2. " " SNF = 1.618
3. " " sugar = 1.61
4. " " gelatin = 1.54
5. " " water @ 60° F. = 0.99823.

The density of solids-not-fat, sugar, and gelatin were calculated as being constant through the 60-155° F. temperature range. The densities of the butterfat and water were taken as given in Table XX, for changes in temperature.

Table XXII. Baume and Predicted Density Relationship of Different Composition Ice Cream Mixes

Percentage Composition of Mix	Temperature Degrees Fahr.	Baume Reading	Density from Baume Readings	Additive Density of Mix Ingredients	Factor times Additive Density	Factored Density	Difference *
8 : 11 : 14 : 0.4	60	13.10	1.0993	1.1478	0.955	1.0961	0.0032
	120	11.20	1.0837	1.1397	0.949	1.0816	0.0021
	125	11.00	1.0821	1.1387	0.949	1.0806	0.0015
	130	10.80	1.0805	1.1377	0.949	1.0797	0.0008
	135	10.60	1.0789	1.1369	0.949	1.0789	0.0000
8 : 11 : 15 : 0.4	60	13.35	1.1014	1.1549	0.955	1.1029	0.0015
	120	11.50	1.0861	1.1463	0.949	1.0878	0.0017
	125	11.30	1.0845	1.1453	0.949	1.0869	0.0024
	130	11.10	1.0829	1.1443	0.949	1.0859	0.0030
	135	10.90	1.0813	1.1435	0.949	1.0852	0.0039
8 : 11 : 16 : 0.4	60	13.75	1.1048	1.1600	0.955	1.1078	0.0030
	120	12.00	1.0902	1.1514	0.949	1.0926	0.0024
	125	11.80	1.0886	1.1505	0.949	1.0917	0.0031
	130	11.60	1.0869	1.1495	0.949	1.0907	0.0038
	135	11.40	1.0853	1.1487	0.949	1.0901	0.0048
9.9 : 10.2 : 14 : 0.4	60	12.00	1.0902	1.1411	0.955	1.0898	0.0004
	120	10.10	1.0749	1.1328	0.949	1.0750	0.0001
	125	9.90	1.0733	1.1319	0.949	1.0741	0.0008
	130	9.70	1.0717	1.1309	0.949	1.0732	0.0015
	135	9.50	1.0701	1.1301	0.949	1.0724	0.0023

* Represents difference between predicted density and density actually measured by Baume reading.

Table XXIII. Baume and Predicted Density Relationship of Different Composition Ice Cream Mixes

Percentage Composition of Mix	Temperature Degrees Fahr.	Baume Reading	Density from Baume Reading	Added Density of Mix Ingredients	Factor times Additive Density	Factored Density	Difference *
10 : 10.5 : 14 :0.4	60	12.30	1.0927	1.1445	0.955	1.0929	0.0002
	120	10.50	1.0781	1.1355	0.949	1.0776	0.0005
	125	10.30	1.0764	1.1345	0.949	1.0765	0.0001
	130	10.10	1.0749	1.1334	0.949	1.0799	0.0006
	135	9.90	1.0733	1.1326	0.949	1.0748	0.0015
10 : 10.5 : 15 :0.4	60	12.80	1.0985	1.1493	0.955	1.0976	0.0009
	120	10.90	1.0813	1.1403	0.949	1.0821	0.0008
	125	10.70	1.0796	1.1393	0.949	1.0811	0.0015
	130	10.50	1.0780	1.1383	0.949	1.0802	0.0022
	135	10.30	1.0765	1.1377	0.949	1.0795	0.0030
10 : 10.5 : 16 :0.4	60	13.30	1.1010	1.1561	0.955	1.1040	0.0030
	120	11.40	1.0853	1.1472	0.949	1.0886	0.0033
	125	11.20	1.0837	1.1463	0.949	1.0877	0.0040
	130	11.00	1.0821	1.1453	0.949	1.0867	0.0046
	135	10.80	1.0805	1.1445	0.949	1.0861	0.0056
12 : 10 : 14 :0.4	60	11.80	1.0886	1.1431	0.955	1.0916	0.0019
	120	9.90	1.0733	1.1301	0.949	1.0725	0.0008
	125	9.70	1.0719	1.1291	0.949	1.0715	0.0002
	130	9.50	1.0701	1.1280	0.949	1.0701	0.0000
	135	9.30	1.0687	1.1272	0.949	1.0690	0.0003

* Represents difference between predicted density and density actually measured by Baume reading.

Table XXIV. Baume and Predicted Density Relationship of Different Composition Ice Cream Mixes

Percentage Composition of Mix	Temperature Degrees Fahr.	Baume Reading	Density from Baume reading	Added Density of Mix Ingredients	Factor times Additive Density	Factored Density	Difference *
12 : 10 : 15 : 0.4	60	12.60	1.0910	1.1456	0.955	1.0916	0.0006
	120	10.70	1.0797	1.1364	0.949	1.0784	0.0013
	125	10.50	1.0780	1.1353	0.949	1.0774	0.0006
	130	10.30	1.0765	1.1343	0.949	1.0765	0.0000
	135	10.10	1.0749	1.1335	0.949	1.0756	0.0007
12 : 10 : 16 : 0.4	60	13.30	1.1009	1.1511	0.955	1.0993	0.0016
	120	11.40	1.0853	1.1420	0.949	1.0837	0.0016
	125	11.20	1.0837	1.1411	0.949	1.0820	0.0008
	130	11.00	1.0821	1.1399	0.949	1.0818	0.0003
	135	10.80	1.0805	1.1391	0.949	1.0810	0.0005
14 : 9 : 14 : 0.4	60	11.20	1.0837	1.1317	0.955	1.0808	0.0029
	120	9.30	1.0685	1.1220	0.949	1.0648	0.0027
	125	9.10	1.0670	1.1209	0.949	1.0637	0.0033
	130	8.90	1.0654	1.1198	0.949	1.0627	0.0027
	135	8.70	1.0638	1.1190	0.949	1.0619	0.0019
14 : 9 : 15 : 0.4	60	11.70	1.0878	1.1379	0.955	1.0866	0.0012
	120	9.90	1.0733	1.1283	0.949	1.0708	0.0025
	125	9.70	1.0716	1.1272	0.949	1.0697	0.0019
	130	9.50	1.0701	1.1261	0.949	1.0687	0.0014
	135	9.30	1.0677	1.1253	0.949	1.0679	0.0002

* Represents difference between predicted density and density actually measured by Baume reading.

Table XXV. Baume and Predicted Density Relationship of Different Composition Ice Cream Mixes

Percentage Composition of Mix	Temperature Degrees Fahr.	Baume Reading	Density From Baume Reading	Added Density of Mix Ingredients	Factor times Additive Density	Factored Density	Difference *
14 : 9 :14:0.4	60	12.30	1.0927	1.1439	0.955	1.0924	0.0003
	120	10.70	1.0797	1.1344	0.949	1.0765	0.0032
	125	10.50	1.0780	1.1333	0.949	1.0755	0.0025
	130	10.30	1.0765	1.1323	0.949	1.0745	0.0020
	135	10.10	1.0749	1.1315	0.949	1.0738	0.0011
8.55:12.6: 14:0.4	60	13.70	1.1043	1.1564	0.955	1.0924	0.0019
	120	12.20	1.0919	1.1493	0.949	1.0907	0.0012
	125	12.00	1.0902	1.1483	0.949	1.0897	0.0005
	130	11.80	1.0886	1.1473	0.949	1.0888	0.0002
	135	11.60	1.0870	1.1466	0.949	1.0880	0.0010
7.4 :10.4: 16:0.4	60	13.70	1.1043	1.1575	0.955	1.1053	0.0010
	120	12.20	1.0919	1.1489	0.949	1.0903	0.0016
	125	12.00	1.0902	1.1479	0.949	1.0894	0.0008
	130	11.80	1.0886	1.1469	0.949	1.0885	0.0001
	135	11.60	1.0870	1.1461	0.949	1.0876	0.0006
10.5:12.85:14:0.4	60	14.00	1.1069	1.1580	0.955	1.1059	0.0010
	120	12.10	1.0910	1.1491	0.949	1.0905	0.0005
	125	11.90	1.0894	1.1481	0.949	1.0895	0.0001
	130	11.70	1.0878	1.1471	0.949	1.0885	0.0007
	135	11.50	1.0861	1.1460	0.949	1.0874	0.0013

* Represents difference between predicted density and density actually measured by Baume reading.

Table XXVI. Baume and Predicted Density of Different Composition Ice Cream Mixes

Percentage Composition of Mix	Temperature Degrees Fahr.	Baume Reading	Density From Baume Reading	Added Density of Mix Ingredients	Factor times Additive Density	Factored Density	Difference*
9.3: 12.00:14:0.4	60	13.60	1.1035	1.1537	0.955	1.1018	0.0017
	120	11.70	1.0878	1.1449	0.949	1.0865	0.0013
	125	11.50	1.0861	1.1439	0.949	1.0856	0.0005
	130	11.30	1.0845	1.1429	0.949	1.0846	0.0001
	135	11.10	1.0829	1.1421	0.949	1.0838	0.0009
11.8:11.45: 14 :0.4	60	12.80	1.0968	1.1453	0.955	1.0938	0.0030
	120	10.90	1.0813	1.1381	0.949	1.0801	0.0012
	125	10.70	1.0797	1.1373	0.949	1.0793	0.0004
	130	10.50	1.0781	1.1363	0.949	1.0783	0.0002
	135	10.30	1.0765	1.1355	0.949	1.0775	0.0010

* Represents difference between predicted density and density actually measured by Baume reading.

By choosing the factor, 0.949, and multiplying this factor by the additive density of any normal composition ice cream mix, in the temperature range of 120-135° F., it was found that of the 72 actual readings taken the average variation from the density as calculated from the Baume reading was 0.0015. As it takes 0.0008 density to effect a change of 0.1° Baume it may be seen that the accuracy of the above readings, on the average, was within 0.2° Baume in this temperature range. All mixes condensed in a vacuum pan would be normally read in this temperature range at 125° F. The density variation was less than 0.2° Baume.

Using the factor of 0.955 at 60° F., when the mix would be more viscous and the fat would be in a solid state, it was found that of the 18 readings observed an average accuracy of 0.2° Baume could be obtained.

Variations were from an extreme of 0.6° Baume to a perfect reading as calculated from the additive density of the mix. Of the 18 readings taken at 60° F., the predicted density was within 0.1° Baume of observed readings in 27 per cent of the readings, while all of the readings were within 0.4° Baume. Because of the small number of readings taken using this factor the results cannot be considered conclusive.

When using the factor of 0.949 to predict the density of a mix in the temperature range of 120-135° F. it was found that 41.67 per cent of the readings came within 0.1° of the observed Baume reading.

Of the 90 readings taken 40 per cent were within 0.1° Baume of the observed readings. There were 25 readings higher than the 0.0008 density allowance for 0.1° Baume and 29 readings below this value.

It is difficult to accurately predict the correct Baume reading

for a mix becuase of the many sources of error. A density variation of 0.0008 makes a 0.1° Baume change. A slight change in the Mojonnier determination of the fat or solids-not-fat would easily make a 0.1° Baume reading change. Because of this the Mojonnier tests may be as important sources of error as an error in the Baume reading itself or one in predicting density. This is true especially at the higher temperatures when there is a marked difference in the density of water and butterfat from that of sugar, solids-not-fat, and gelatin. A small loss of mix during condensing changes its composition, especially as regards actual amounts of fat, solids-not-fat, sugar, and gelatin present. When the product is standardized back by weight these are not compensated for. The actual composition, therefore, is not exactly as calculated, and predicted densities from composition are not strictly correct. A mistake in the Mojonnier test of 0.1 per cent solids-not-fat means the per cent water present is increased or decreased by 0.1 per cent. This will cause a change of 0.0008 in density of 0.1° Baume reading. This applies when the calculation is made at 125° F., the temperature at which the mix would usually be read for the Baume determination. The above variation applies to a 8:11:14:0.4 composition mix. Slight changes in the sugar and gelatin content,or any solids used with a density much greater than water, would cause a corresponding change in the Baume reading.

The additive densities may not hold perfectly in a straight line when determined at different temperatures by more sensitive means than used by the author. However, if any change took place it was so small that the volume change was not noticeable when they were in suspension and solution with water.

It is believed that with many more determinations of ice cream mixes and with extreme accuracy when reading the Beume hydrometer the density or Beume reading could be predicted even more accuratly than the results of this experiment show.

SUMMARY

1. A correct Baume reading for any normal mix condensed in the pan is an accurate indicator of when to strike the batch.

2. By using data obtained in the first part of the experiment it was found possible, when condensing in the large vacuum pan, to strike the ice cream mixes by the Baume hydrometer within 10 pounds of the desired weight on a 1235-pound finished mix.

3. Homogenization of the ice cream mix caused no change in the Baume reading.

4. For greatest accuracy all Baume readings should be taken when the fat is in the same state, solid or liquid. It is desirable that Baume readings be made at a uniform temperature from day to day.

5. In condensing a mix, a change of 1° F. caused a change of approximately 0.25 inches in vacuum.

6. A normal mix, at a 24 inch vacuum, boiled at approximately 140° F. This boiling point varied slightly with variations in the composition of the mix.

7. For all mixes studied within the range of 115-155° F., a 5° F. change in temperature caused a 0.2° Baume change, or a change of 0.0016 density.

8. Tables were constructed for 12 basic mixes showing the proper time for striking the batch using the Baume hydrometer as the indicator. Results secured from trials in a commercial vacuum pan proved these to be very satisfactory.

9. Pan condensed ice cream mix is normal in viscosity and surface tension. There is a tendency for development of high viscosity,

especially when the mix has a high total solids content.

10. As a general rule, a great increase in viscosity resulted in a slight decrease in surface tension.

11. The volume of milk solids-not-fat, sugar, and gelatin, in suspension or solution, showed no increase in volume as the temperature was raised from 60° F. to 155° F.

12. By calculating the additive density of a mix as shown previously, dividing it by 100, and multiplying the result by factor 0.949, it was found that the average accuracy obtained in the experiment was within 0.2° Baume. This is true for a temperature range of 120° F.- 135° F.

13. The density of milk solids-not-fat, in a suspension with water, was found to be 1.6184; of sucrose in solution 1.6107; and of gelatin, in suspension, 1.5384. These values are to be used when predicting a correct Baume reading of any composition mix. They hold constant for the condensing temperature range of a mix. Values for water and butterfat are given in Table XX. These values used must be taken as those at the temperature at which the Baume readings will be made, probably 125° F. in most cases.

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