May, 1939 Research Bulletin 255

The Physical and Chemical Characteristics of Lards and Other Fats in Relation to Their Culinary Value

II. USE IN PLAIN CAKE

By Belle Lowe and P. Mabel Nelson

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

FOODS AND NUTRITION SUBSECTION
HOME ECONOMICS SECTION
CHEMISTRY SECTION

AMES, IOWA

CONTENTS

SUMMARY

The results herein reported on the use of lard and other fats in plain cake are for a cake (a layer or loaf type) containing about 40 parts of fat per 100 parts of flour.

THE CREAMED MIXTURES

1. The temperature rise in the ingredients, from the creaming of the fat and sugar, varied from 1° to 7°C. This rise in temperature of the creamed mix was greater with the longer creaming periods. It is partly due to friction, but the production of positive heat because of adsorption of the fat by the sugar is probably the greatest factor in causing the temperature rise. Butter proved an exception to the behavior of the other fats, in that the temperature of the creamed mix first falls, probably due to negative heat of solution of the sugar in the water of the butter, and later rises.

2. The time required to reach the maximum volume during the creaming process of a plastic fat and sugar depends on the speed of agitation, the quantity of material used, the proportion of fat to sugar, the kind of fat and the temperature of the ingredients. After maintaining the maximum volume for a varying period, the volume gradually decreases.

The time to reach this maximum volume varied from 8 to 210 minutes for the 42 lards used in the 260-minute creaming periods. In general, the softer lards attained this volume more rapidly.

3. For each fat there is, in general, an optimum temperature at which it creams best, this temperature being lower for softer fats of higher iodine number and higher for firmer fats.

4. Smooth lard creamed to a larger volume than grainy lard at both 25° and 30°C. when both textures of lard were obtained from the same original lard.

5. In all instances the larger proportion of fat to sugar (1: 1.3) gave greater creamed volumes than the smaller proportion of fat to sugar (1: 2.6) at both 25° and 30°C.

6. With 1 part of fat to 2.6 parts of sugar and creaming for 30 minutes at slow speed of KitchenAid (ingredients and room temperature 24° to 25°C.) the order for decreasing creamed volume was as follows: hydrogenated lard, hydrogenated cottonseed oil, open-kettle rendered lard, A. H. Composite lards, A. H. Individual lards, butter and prime-steam rendered lard.

7. Five minutes creaming by hand gave volumes comparable to those obtained on the KitchenAid (slow speed) in 30 minutes.

THE CAKE BATTER

The method of combining the ingredients affected the viscosity of the batter, some methods giving a more viscous batter than others. The stiffer, more viscous batters produced higher scoring cakes.

THE CAKE

1. There was a tendency for the cake volumes to become smaller with larger creamed volumes.

2. The effect of temperature of the ingredients when combined was variable. Buel found a highly significant correlation between temperature of the creamed mix and cake batter, and the cake volume, the volume decreasing with increased temperature. (The range of the temperatures was from 23° to 33°C.). Myers found no significant differences in cake volume when the ingredients were combined at 25° and 30°C. Higher scoring cakes were obtained when the ingredients were combined at 25°C. than at 30°C.

3. Both the kind of fat used and the method of combining the ingredients affected the cake volume and the cake score. A particular fat produced better cake volume and better scores by some methods than by others. In general, the methods whereby the egg was added late in the combining process gave best results. The increase in cake volume by these methods was particularly noticeable for the lards and oil.

4. The palatability of the cakes was affected by the method and by the temperature of combining the ingredients as well as by the kind of fat and the texture of the lard.

5. In most instances, higher scores accompanied larger creamed volumes.

6. Smooth lard, when soft and plastic and not waxy, yielded higher scoring cakes than grainy lard.

7. Fat distribution was affected as follows: As the temperature of the ingredients at time of mixing was elevated the proportion of fat distributed within the crumb, i.e., as an oil-in-water emulsion and as pools, increased, but the quality of the cake as shown by scores decreased.

The Physical and Chemical Characteristics of Lards and Other Fats in Relation to Their Culinary Value

II. Use in Plain Cake[1]

BY BELLE LOWE AND P. MABEL NELSON [2]

These studies on the use of lards in plain cake were initiated in the fall of 1932 and completed during the summer of 1936. The major results of these investigations with cake have been included in a series of four theses by Martin (11), Buel (2), Minard (13) and Myers (15).

Cakes containing fat may be divided into two types:

1. The pound cake, named from the proportions formerly used by our great-grandmothers, consists of a pound each of fat, sugar, flour and eggs, with no baking powder or soda. The volume of the cake depends upon the expansion of moisture from the eggs and from the air incorporated in the creamed mixture and in the beaten eggs. Although the old pound cake recipe is generally modified for modern formulas, it is essentially a type carrying a high percentage of fat, and the texture is rather close, fine, even and compact.

2. Far more commonly used at present by homemakers is a loaf, cup or layer cake, the volume of which depends upon air incorporated in beaten eggs, a leavening agent such as baking powder or soda, the expansion of the moisture into steam and, to a much lesser extent, upon the air incorporated in creaming. An analysis of recipes commonly used for this type of cake shows that they may be very lean, containing as little as 18 parts of fat per 100 parts of flour. A frequently used yet a fairly rich recipe may carry from 40 to 50 parts of fat, and a very rich one may carry 60 to 70 or occasionally 75 parts of fat per 100 parts of flour.

REVIEW OF LITERATURE

Berrigan (1), using the procedure and formula developed by the American Association of Cereal Chemists[3] for the testing of cake flour, worked to attain a product made from lard that

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[1] Project 325 of the Iowa Agricultural Experiment Station. This project was cooperative between the Foods and Nutrition Subsection of the Home Economics Section and the Chemistry Section. The Animal Husbandry Section rendered and furnished the individual hog and composite lards used in the culinary tests.

[2] Prepared with the assistance of Elizabeth L. Martin, Eva I. Buel, Lois C. Minard and Elizabeth Myers of the Foods and Nutrition Subsection and of W. Bosch, B. Demoratsky, E. W. Eickelberg and D. Starr of the Chemistry Section.

[3] Cereal Chem. **10**: 627, 1933; **12**: 294, 295 and 300. 1935.

would be comparable to a product obtained from a hydrogenated fat. Dried milk and dried egg albumen were used in this A.A.C.C. formula so that results could be readily replicated. Tests indicated that the viscosity of the cake batter was related to the volume and quality of the cakes. Cake batters having high initial viscosity produced cakes of good volume and crumb texture, whereas those having low viscosity produced cakes of small volume and poor texture.

Cakes comparable to those obtained with hydrogenated fats were obtained with lard by varying the original formula as follows: Increasing the amount of fat, decreasing the liquid, reducing the sugar and changing the procedure for mixing. With hydrogenated fats in the original formula, good results were obtained by mixing all of the ingredients simultaneously. Berrigan suggested that lard and egg albumen have an antagonistic reaction in the batter, the effect of which results in poor cake volume and quality if they are mixed simultaneously with the other ingredients. But when the egg albumen and part of the sugar were reserved, whipped into a meringue and this meringue added after the other ingredients were combined, a batter of high viscosity and cakes of increased volume and quality were obtained.

Swartz (21) worked out a suitable formula and method for mixing lard cakes on the bakery scale. A practical retail baker was engaged to make cakes from lard and at the same time to make cakes from a special shortening made from hydrogenated vegetable oil. For cakes of the latter type, the formula recommended by the shortening manufacturers was used. Samples of these lard and hydrogenated vegetable oil cakes were compared by many persons and their preferences recorded. These results (table 1) indicate that lard can be used under bakery conditions for making cakes that are as acceptable and satisfactory to the consuming public as the cakes from the hydrogenated shortenings. In fact, for the devil's food 3 out of 4 persons preferred the cake made with lard to that made with hydrogenated vegetable oil. (It should be remembered that these choices were between the same kind of cakes made from lard and hydrogenated shortening, not among yellow, white and devil's food cakes.)

TABLE 1. NUMBER OF PERSONS EXPRESSING PREFERENCE FOR EACH KIND OF CAKE (SWARTZ).

Kind of cake	Number preferring cake from lard	Number preferring cake from hydrogenated fat	Number having no preference	Total
Yellow	470	440	116	1026
White	248	198	67	513
Devil's food	354	109	44	507

It was found that smaller quantities of lard could be used in the yellow cake formula than of hydrogenated shortening, and a more tender and elastic cake was obtained than with the hydrogenated fat. Yet the amount of hydrogenated shortening used was that suggested by the manufacturer of the hydrogenated product.

Grewe (8) studied creamed mixtures microscopically. The temperature of the ingredients was 22.5°C. when put in the mixer bowl and the room temperature was maintained at 22.5°C. The sugar and butter (ratio 2.2 to 1) were creamed together to a definite specific gravity or for a definite time before the egg was added. If the egg was added gradually over a period of 2.75 minutes to the creamed sugar and fat, then agitated for 11.25 minutes (Hobart mixer, flat beater, medium speed), the water-in-oil emulsion formed was much more stable than if all the egg was added at once and the mixture agitated for 15 minutes. She suggests that better cake quality is obtained from the more stable emulsion.

When the temperature of the fat was varied at the time it went into the mixing bowl, the creamed volume became progressively greater or the specific gravity less, as the temperature was increased from 19° through 21° and 23° to 25°C. The temperature at which the most stable emulsion was obtained with butter was at 22°C.

There was a greater difference in the specific gravity of the creamed butter mixture as the temperature was varied than there was for butter oil or hydrogenated fat.

Dunn and White (4) found that the "creaming, dough, and loaf volumes of pound cake were very poor with very coarse sugars and that they become better and better as the granulation becomes finer. This fruit-powdered granulated sugar gives the highest values."

They also found that the conditioning of the shortening prior to use affected the creaming, dough and loaf volumes. They used two hydrogenated fats and one "soft compound" in each set. One set was conditioned at 50°F. for 100 hours and then held at 70°F. for 100 hours. A second set was held at 70°F. for 200 hours prior to use, whereas a third set was conditioned at 90°F. for 100 hours and subsequently stored at 70°F. for 100 hours. The fats stored at 70°F. for 200 hours prior to use yielded cakes of the greatest volume. These workers also found that they obtained smaller cake volumes at 65 than at 25 percent relative humidity.

Davies (3) has reported that if the proportion of sugar, fat, liquid or baking powder in a cake formula was varied, the cake quality was affected. With each of these ingredients there was an optimum amount that produced the best textured cakes. In addition, if the formula and other conditions were kept standardized, variation in mixing time, the quantity of batter baked in a particular pan and the baking temperature all affected the cake quality.

THE INVESTIGATIONS

METHOD AND PROCEDURE

Recipe. The same plain cake recipe was used throughout the entire series of studies. This recipe is one commonly used by homemakers. It carries about 40 parts of fat per 100 parts of flour. It had been used in a series of other investigations in the department, hence its use was continued in the lard series, for in this way additional data for comparison were obtained.

Fat	112 grams	(½ cup)
Sugar, extra fine	300 grams	(1½ cups)
Salt	6 grams	
Eggs	96 grams	(2)
Milk, whole	244 grams	(1 cup)
Flour, cake	284 grams	(2⅞ cups)
Baking powder, tartrate [4]	8.4 grams	(about 3 teaspoons)

Part of recipe used. In practically all the tests, one-fourth the recipe (the same amount of batter, 240 grams, was used throughout the entire series) was baked in a small loaf cake. For some tests by Martin one-half the recipe was mixed at one time, but the batter was divided into two cakes. At the close of a series of tests, the full recipe was made in order to determine whether the results obtained with one-fourth the recipe applied to the full recipe. These tests with the larger quantity are not included in the results.

STEPS AND PROCEDURES COMMON THROUGHOUT THE SERIES

Certain steps and procedures have been common throughout all the series of tests. Other procedures have varied with the investigator and her particular problem.

Pans. Loaf cake pans were used throughout. The pans, about 2¾ inches deep, 3x5¼ inches at the bottom and 3½x5⅝ inches at the top, were lined with wax paper cut to fit the bottom. This paper was greased on the side next to the batter. The sides of the pans were left ungreased.

Temperatures recorded. The incubator temperature, the initial temperature of the fat when taken from the incubator, the room temperature, the temperature of the creamed mixture and of the cake batter were recorded.

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[4] Martin and Buel used 8.4 grams, but Minard and Myers, after the completion of McLean's (12) work, used 9 grams of baking powder.

Baking. The baking throughout the entire series was done in the same oven, a Clark-Jewel. The oven was equipped with a glass door and a Lorain heat control, used to regulate the gas flow to keep the oven at the desired temperature. The oven thermometer was an especially constructed one, calibrated in 2° intervals. It could be read accurately to 1°.

Martin: .... All cakes baked at 175°C. for 40 minutes.
Buel: .... All cakes baked at 176°C. for 40 minutes.
Minard: .... All cakes baked at 176°C. for 40 minutes.
Myers: .... All cakes baked at 176°C. for 45 minutes.

Cooling the cake. All cakes were cooled in the pan, the pan being placed on a wire cake rack, right side up. This procedure has been followed in this laboratory for all investigations on plain cake. Since this series of studies was initiated Glabau (7) has reported that cakes containing fat should not be removed from the pan nor handled before the interior temperature of the cakes is lowered to 140°F. The cake structure when first removed from the oven is fragile, but upon cooling it becomes more rigid and better withstands the shock of handling.

INGREDIENTS OTHER THAN FAT

Sugar. Only extra-fine granulated sugar was used during the 4 years. The sugar for 1 year's tests was taken from the same lot, but each year's supply was from a different source.

Flour. A cake flour[5] was purchased in large quantities. When more than 100 pounds was to be used throughout a year, the flour from all sacks was blended, then stored in large, tight galvanized containers in the laboratory. The same brand was always used, but that for each year's tests was from a different source.

Baking powder. A tartrate[6] baking powder was used throughout the entire series. The brand chosen had been used in previous studies with the same plain cake recipe, and for that reason its use was continued.

Salt. All the salt for any one year was taken from the same source. A fine table salt was used.

Flavoring. No flavoring was used so as not to detract from the taste and odor of the other ingredients.

Milk. Milk was obtained fresh daily from the Dairy Industry Department of the Iowa State College. Any one day's supply was from the same lot. The use of dried milk would probably have made for greater uniformity, but would have also been less like the procedure followed by the housewife.

Eggs. The eggs, usually from the Poutry Husbandry Department of the Iowa State College, were obtained daily through the

[5] Swansdown.
[6] Royal.

Foods and Nutrition storeroom. The eggs for a day's tests were beaten together, then divided to make the day's series uniform.

THE FATS USED

During 1932-33 lards and other fats from commercial sources were used, as well as lards from individual and groups of animals, of known history, fed specific rations.

FATS USED BY MARTIN

In all Martin used 44 different lards ranging in texture at 24.5°C. (76.1°F.) from firm to very soft and oily, and in iodine number from 58.6 to 83.4.

Animal Husbandry Individual lards. The Animal Husbandry Section cooperated by furnishing 33 lards obtained from individual hogs. These lards are hereafter designated as A. H. Individual lards. The hogs from which these lards were obtained were fed similar feeds, all conditions being as nearly standard as possible. Three hogs from each lot were slaughtered at the 225-pound weight. The fat rendered into lard from each carcass consisted of equal parts of leaf and back fat; thus, the weight of the leaf fat determined the weight of the back fat used and, to a certain extent, the amount of lard obtained from each hog. After grinding, the fat was rendered by the open-kettle method (steam jacketed) in the Animal Husbandry Laboratory.

Most of these A. H. Individual lards were somewhat grainy in texture, but the degree of graininess varied. The fat after being rendered was run into pails and cooled at room temperature without stirring. Because both the quantity of lard and the room temperature during cooling varied, the lards solidifying most rapidly would tend to be less grainy in texture. The iodine number of these lards varied from 58.6 to 68.7.

Animal Husbandry Composite lards. Nine composite lards from groups of five pigs each were furnished from a project designed to study the influence of feed, especially soybeans and soybean products, upon the character and quality of fat and lard from swine. Nine lots of 10 pigs each were fed varying rations. The lots were fed until the pigs in each group averaged 225 pounds in weight. The five pigs nearest the 225-pound weight were slaughtered from each lot and the carcasses studied. Equal parts of leaf and back fat were again used for the composite lards, the same amount being taken from each pig in the group. The lard was rendered by the Animal Husbandry Section in the same manner as lard from individual hogs. These lards are hereafter designated as A. H. Composite lards.

The lards from this group also varied in texture, some, because of the varying unsaturated fatty acid content and the rate of cooling, being more grainy than others. The iodine number varied from 63.6 to 83.4.

Commercial lards. Two commercial lards were furnished for this project through the courtesy of the Institute of American Meat Packers and Wilson and Company of Chicago. One of these, a representative lard of its type, was a smooth, bleached, prime-steam lard[7], prepared from miscellaneous cutting and killing fats and rendered under 40 pounds of steam pressure for about 10 hours. This rendered lard was bleached with fuller's earth at a temperature of 165°F. and run over a cooling roll.

The other lard[8], also representative of its type, was a grainy, open-kettle rendered lard and was prepared from back fat and leaf fat only. The rendering temperature was increased to a final point of 240°F. and held at this temperature for about an hour. It was then strained through cloths without bleaching.

Hydrogenated fats. Two hydrogenated fats were used, the first, an animal fat (hydrogenated lard[9]), was furnished through the courtesy of the Cudahy Packing Company, and the second, a hydrogenated vegetable oil[10], was purchased at a retail market.

Butter. Butter obtained from the Dairy Industry Department of the Iowa State College was used throughout. The entire supply used in the cake experiments and the sample sent to the Chemistry Section for analysis were taken from the same churning. Part of the butter used for the creaming experiments came from a different churning made at about the same time. There was no apparent difference in the two samples.

Corn oil. One sample of corn oil[11] was used, which was furnished through the courtesy of the Corn Products Refining Company.

FATS USED BY BUEL

Buel compared a smooth prime-steam rendered lard, a grainy open-kettle rendered lard, a hydrogenated lard and butter. The brands were the same as those used by Martin, and they were furnished through the same channels.

A tub of each fat (except butter) was obtained during the fall and stored in the Animal Husbandry cooler during the fall and winter. Lard was removed from these tubs as needed for other experiments. Just before Buel's tests were started the remaining lard was placed in a refrigerator and taken from this source as needed. The butter was from one churning and was stored in a refrigerator until it was weighed and put in the incubator.

[7] Laurel-leaf lard.

[8] Certified lard.

[9] Clix.

[10] Crisco.

[11] Mazola.

FATS USED BY MINARD

Minard used two prime-steam rendered lards[12], No. 1 and No. 2; one open-kettle rendered lard[13], two drip rendered lards[14] (lot 3 and lot 4); and butter. A sufficient amount of each lard (except drip-rendered lard, lot 4) for 90 cakes was slowly and carefully melted over hot water. Half of this lard was then put in a container and set immediately in the incubator (25°C.) and left overnight in order to produce grainy lard. The next morning the containers were put in a room which was cooler than the incubator to allow the lards to finish solidifying. In the meantime, the other portion of the melted lard was poured into a tin pail which was set in a pan of chipped ice and water and stirred until it became smooth and solidified. This required less than 30 minutes. This procedure gave a firm, smooth, waxy lard. The drip-rendered lard, lot 4, was used in its original smooth condition as obtained from the packing company. The butter (from the Dairy Industry Department, Iowa State College) was all from the same churning. All the fats were stored in the refrigerator until weighed and placed in the incubator for the next day's baking tests.

These samples of fat, 28 grams as used for one-fourth the cake recipe, after being in the incubator (25°C.) overnight, are described as follows:

1. Butter—soft, smooth, usually one or two drops of oil had separated in the container.
2. Open-kettle rendered lard:
   Grainy — the granular part soft but not runny; usually one-fifth to one-tenth of the fat had separated as oil.
   Smooth — smooth, firm, no oil, waxy.
3. Drip-rendered lard, lot 3:
   Grainy—very soft, granular part runny and thin; about one-half of the lard had separated as oil.
   Smooth—soft or very soft, no oil separated.
4. Drip-rendered lard, lot 4 (original sample) — quite firm, smooth and no oil separated.
5. Prime-steam rendered lard, No. 1:
   Grainy — soft, granular part not runny; usually one-fifth to one-half the sample had separated as oil.
   Smooth — smooth, firm, no oil, waxy.
6. Prime-steam rendered lard, No. 2:
   Grainy — granular part soft, but not runny, usually one-

[12] No. 1. Laurel-leaf lard, through courtesy of the American Institute of Meat Packers and Wilson and Company; No. 2. through the courtesy of Swift and Company.

[13] Certified lard, through the same source as Laurel-leaf.

[14] Lot 3, through courtesy of the French Oil Mill Machinery Co., Piqua, Ohio, and lot 4 through courtesy of Morrell and Company.

tenth to one-fifth of sample had separated as oil.

Smooth — smooth, quite firm, no oil separated.

Since Minard used two textures, grainy and smooth from four of the lards, this was equivalent to using 10 different fats in her series of cakes. In general, the grainy lards prepared in the laboratory were softer and had larger granules than commercial grainy lards. The smooth lards were firmer and far less plastic than the usual commercial smooth lards except in the case of the smooth portion of drip-rendered lard, lot 3, which was soft and plastic after incubation.

FATS USED BY MYERS

Myers used one open-kettle rendered lard and butter, the lard being used in two textures, grainy and smooth. Myers followed Minard's technic to produce the grainy lard, but the smooth lard prepared and used by Minard had been cooled too rapidly, hence it was very firm and waxy and not typical of the commercial smooth lards. For a smooth lard, Myers followed a technic suggested by a patent granted to the Procter and Gamble Company (18). The melted portion of lard was cooled in a pail, the pail being surrounded by running tap water at 10°-15°C. More than 1 hour of constant stirring was required before the lard solidified. The product was then transferred to a container which was set in the incubator (25°C.) for 12 hours. The resulting smooth lard had a very desirable consistency, neither too soft nor too hard, and was very plastic.

The butter used was from the Dairy Industry Department, Iowa State College, and again enough was obtained from one churning for all the cakes baked in this series.

INCUBATION OF INGREDIENTS

The fat, sugar, flour, baking powder, salt and eggs in the shell were placed in a constant-temperature incubator, usually overnight, but at least 6 hours before they were to be used. The incubator temperature for the greater portion of the time was 24.5° to 25°C., with a range from 23.5° to 25.5°C. for all tests except those by Buel and those by Myers. Myers used 30°C. Buel used 20°C. because her tests were conducted in very warm weather.

Just before starting to mix the cake ingredients, the quart bottle of milk was placed in a pitcher surrounded by warm water and stirred with a thermometer until the desired temperature was reached. It was then weighed in small containers for the day's tests, covered and placed in the incubator until used. If it had been placed in the incubator overnight, a period of 12 to 20 hours would have elapsed before it was used, and during this long period it might have soured.

COMBINING THE INGREDIENTS

Martin used lard in plain cake in a preliminary study during the spring of 1932. It soon became apparent that lard often imparted an unsatisfactory texture and flavor if the conventional method of combining the ingredients was used. Part of Martin's problem was to find satisfactory ways of combining ingredients when lard was used as the fat in plain cake. This unit of the investigations was continued by Buel.

In her preliminary work Buel (2) tried 35 methods for combining ingredients. Of these, six were selected for use in her study.

STEPS COMMON FOR ALL METHODS

The flour and baking powder were sifted together three times.

The initial temperature of the room, incubator, fat and sugar were recorded as the materials were taken from the incubator.

Martin recorded the temperature of the creamed mixture and its volume at various intervals as designated. All others determined these data at the end of the creaming period.

The temperature of the creamed batter was recorded. After baking and cooling the volume of the cake was determined.

STANDARD METHOD

(Used by Martin)

1. The fat, sugar and salt were creamed for 30 minutes with a flat beater on the first speed of the KitchenAid. The creaming volume, room temperature and creamed mixture temperature were recorded at 5, 10, 20 and 30 minutes.
2. The beaten egg was combined with the milk.
3. One-third of the milk and egg mixture and one-third of the flour and baking powder were added to the creamed mixture and beaten 75 strokes with a wooden spoon. An over and under motion was used in lifting the batter each time. The beating was quite gentle, yet thorough and fairly rapid. The sides of the KitchenAid mixing bowl and the spoon were scraped before adding more flour and milk. This was repeated until all the flour and milk were added.

FLOUR-BATTER METHOD

(Used by Martin)

1. The fat, one-half the sugar, and the salt were creamed 20 minutes at first speed on the KitchenAid. The creamed volume and temperature were recorded at 5, 10 and 20 minutes. One-half the flour was added to the creamed mixture and the creaming continued an additional 10 minutes. Creamed volume and room and creamed mix-

ture temperature were again recorded.

2. One-half of the milk was then added to the creamed mixture and stirred 50 strokes with a wooden spoon.
3. One-half of the remaining flour was added to the mixture with 35 strokes.
4. The remaining milk was added with 35 strokes, the rest of the flour with 50 strokes.
5. The egg, previously slightly beaten for weighing, was then beaten with the remaining sugar in a deep cylindrical jar, 200 whirls of the rotary egg-beater being used. The mixture was very thick, light and creamy. This was added to the batter and folded in gently but quickly and thoroughly with 50 strokes.

CONVENTIONAL-SPONGE METHOD

(Used by Martin, Buel, Minard and Myers)

1. Martin creamed the fat, one-half the sugar, and the salt on first speed of KitchenAid for 30 minutes. Buel creamed the same proportions for 5 minutes by hand, using a wooden spoon. Minard and Myers creamed the same proportions with a flat beater on the KitchenAid at second speed for 3 minutes. The sides of the bowl were scraped down and creaming continued an additional 4 minutes. After again scraping down the sides of the bowl, creaming was continued for a total of 15 minutes.
2. Martin added the flour and milk to the creamed mixture in the KitchenAid bowl. Minard and Myers transferred the creamed mixture to a crockery bowl before continuing the mixing.
3. One tablespoon of flour was added to the creamed mixture and folded in gently with 15 strokes with a wooden spoon. A second tablespoon of flour was added in the same manner.
4. One tablespoon of milk was added with 15 strokes. Martin added 1 more tablespoon of flour with 15 strokes, but Minard and Myers omitted this step.
5. Martin added one-half the remaining milk and flour with 70 strokes. This was repeated. Myers used 80 strokes for the first portion of flour and milk and 85 for the second.
6. The egg and remaining sugar were beaten together as in the Flour-Batter method and added with 55 strokes. Minard and Myers beat the egg and sugar with the whip on third (high) speed on the KitchenAid for 3 minutes. This light sponge was then added to the batter with 35 strokes.

CONVENTIONAL METHOD
(Used by Buel, Minard and Myers)

1. Buel creamed the fat, sugar and salt for 5 minutes with a wooden spoon. Minard and Myers followed the same procedure for creaming as for the Conventional-Sponge method except that all the sugar was used. Buel added the flour and milk in the same bowl in which the creaming was done. Minard and Myers carefully transferred all the creamed mixture to a crockery bowl.
2. Buel added the beaten egg to the creamed mixture with 55 strokes. Minard and Myers used 70 strokes.
3. Buel added one-half of the milk and one-half of the flour with 55 strokes. The rest of the flour and milk was added with 85 strokes. Minard added each portion of the milk and flour with 100 strokes. Myers added the first with 110, the second with 115 strokes.

MODIFIED CONVENTIONAL METHOD
(Used by Buel and Minard)

1. The fat, salt and sugar were creamed with a wooden spoon in a crockery bowl for 5 minutes by Buel. Minard followed the same procedure as for the Conventional method.
2. All of the milk and all of the flour were added with 150 strokes.
3. The egg, without additional beating after weighing, was added with 55 strokes.

FLOUR-BATTER METHOD
(Used by Buel)

1. All of the sugar was added to the milk.
2. The fat, two-thirds of the flour, and the salt were creamed 5 minutes with a wooden spoon.
3. All of the milk-sugar mixtures and the remaining flour were added with 150 strokes. It was important that this part of the procedure be done very rapidly if the most viscous batter were to be obtained.
4. The whole eggs were beaten until very light and frothy with 200 whirls of the rotary beater and gently but quickly folded into the batter with 55 strokes.

NUMBER 26
(Used by Buel)

1. One-half of the sugar was added to the milk.
2. The fat, one-half the sugar, and the salt were creamed 5 minutes with a wooden spoon.
3. All of the milk-sugar mixture and the flour were added to the creamed mixture with 150 strokes.
4. The eggs were beaten until light and frothy and folded in with 55 strokes.

NUMBER 31
(Used by Buel)

1. The fat, three-fourths of the sugar, the salt and 1 tablespoon of milk were creamed 5 minutes with a wooden spoon.
2. One-half the remaining milk and one-half of the flour were added with 85 strokes. This was repeated for the remaining portions.
3. The eggs and the remaining one-fourth of the sugar were beaten until very light, 20 whirls of the rotary beater, and gently folded into the batter with 55 strokes.

OBJECTIVE AND SUBJECTIVE TESTS

CREAMED VOLUME

The volume of the creamed mixture was determined by alcohol displacement. For this purpose 25 grams of the creamed mixture were weighed on a piece of wax paper 2½ x 4 inches and immersed in 95 percent alcohol in a conical, graduated cylinder. The increase in depth of the alcohol gave the volume of the creamed mixture in cubic centimeters. The wax papers were kept standard in size throughout all the series of tests and their volume disregarded. The creamed mixture was returned and included with the rest of the creamed mixture for further creaming tests or for mixing with cakes, the alcohol clinging to the surface soon evaporating.

CAKE VOLUME

The volumes of all cakes after they had cooled were determined by seed (rape) displacement.

SCORES

Subjective tests were necessary to judge the eating quality of the cakes. Five judges scored the cakes in all instances, with the exception of those made by Minard, when six judges were used. The score card is given in table F, in the appendix. For Martin's and Buell's cakes the four qualities scored and their brief definition were as follows: 1. Crumb, 30 points; cell walls thin and fine, cells rather small in size, not too large, not too compact, the crumb springy and elastic; 2. tenderness, 20 points; not tough or gummy; 3. velvetiness, 20 points; crumb smooth, soft and like velvet to the tactile sense (finger or palate); 4. eating quality, 30 points; includes aroma, flavor, velvetiness and all the qualities that make a cake agreeable or disagreeable for eating. The total or final score is the sum of all four of these qualities. For the series baked by Minard and Myers tenderness was omitted from the score card, the crumb and velvetiness each being weighted 30 points and eating quality 40 points.

BREAKING ANGLE

This test was developed in an attempt to find an objective test for tenderness. It was used only in Myer's study. An instru-

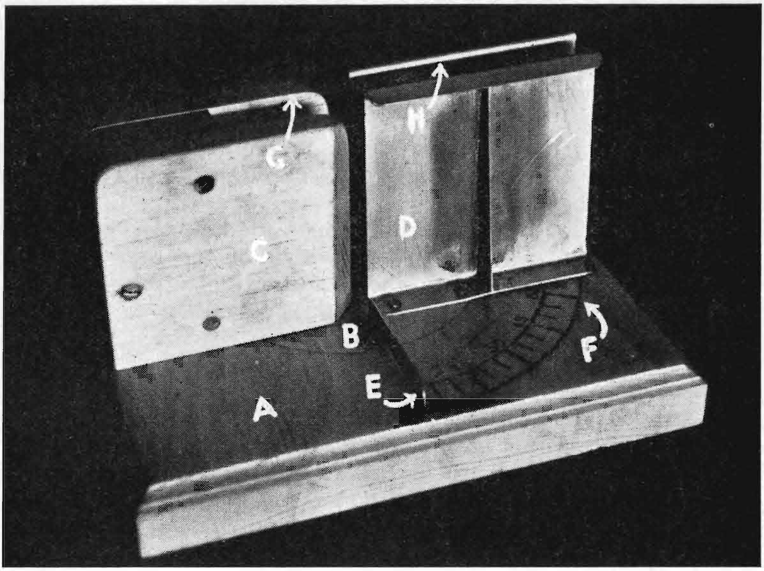

Fig. 1. Breaking angle apparatus.

ment to measure the angle to which the slice of cake could be bent before breaking was developed by O. F. Larsen of the College Instrument Shop. A slice of cake 1/2 inch thick was cut by means of a miter box and then cut with a cookie cutter to a definite size, 1½ to 2½ inches.

The apparatus used to measure the angle of breakage (fig. 1) consisted of a 6-inch square board base (a) with a 3-inch circular piece (b) set in the center of the base so that it could revolve freely on its axis. The frame or holder, in which the slice of cake was inserted, was in two portions, a stationary half (c) which allowed the circular piece beneath it to revolve and a movable part (d) attached to the circular piece. A pointer (e) was attached to the movable part. These holders were placed so that when in a straight line or at an angle of 180° the edge of the cake farthest from the operator was directly over the axis and the pointer was at 0°.

When the movable holder (d) was pushed away from the operator to break the slice of cake, the pointer registered on the scale (f) the number of degrees required for breaking the slice. The observations were recorded as 0° to 90°.

Two samples from each cake were tested on the day after they were baked, and the two figures were averaged. Great care was necessary in cutting the slice of cake in the miter box to get the slices of uniform thickness. A very slight difference in the pressure used to hold the cake or knife definitely varied the thickness of the slice, and this affected the breaking angle. A definite technic also had to be developed in turning the movable holder slowly and steadily and in recognizing the end point at which the sample would be considered "broken." A later model of this apparatus is placed on a metal base, and the movable holder is operated with a motor.

TEXTURE INDEX

This test[15] was used only in Myer's study. Two pieces of cake of the same thickness as those used for the breaking angle test were cut with a circular cutter $1\frac{1}{2}$ inches in diameter. The surfaces facing each other were used, and the results averaged. A piece of cake was weighed, and approximately 1 teaspoonful of fine sand, which just went through a 40-mesh sieve, was dropped on it. This piece was then revolved twice on the surface of an inclined board set at a 45° angle, so that the excess sand would run off. The piece was then weighed a second time. The difference between this and the original weight represented the total amount of sand which remained in the cells of the cake. After this the piece of cake was inverted and shaken 3 or 4 times so that the excess sand would fall out and then weighed again. The difference between this third weight and the original weight represented the sand which was retained on the walls of the cells.

There were, therefore, three possible figures that could be used for the texture index as follows:

1. The weight of sand retained on the slice of cake after revolving at a 45° angle.
2. The weight of sand remaining in the cake after inverting the piece and shaking.
3. The difference between these two figures which represents the weight of sand held loosely in the cells of the cake, without regard for that attached to the cell walls. In duplicate samples, however, less variation was found when this third figure was used, so that this was the figure used to represent the texture index in Myer's study.

In actual practice it would be unnecessary, in using this third figure, to weigh the cake samples in the first place, as only the difference between the second and third weights is used.

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[15]This procedure was suggested to the director of these studies by Miss VeNona Swartz of the Institute of American Meat Packers. By its use it was hoped that a positive index of texture might be obtained, the results of which could be analyzed statistically.

HISTOLOGICAL SECTIONS AND MICROSCOPICAL STUDY OF FAT DISTRIBUTION

The principal problem in developing a method for microscopical examination of fat distribution in the baked cake was to find a stain that would act without wetting the cake crumb. Subsequent treatment also had to be non-softening. Osmic acid fumes, which both stain and fix the fat, appeared to be the most desirable.

The director of these studies had previously found with the aid and direction of Miss Margaret Sloss that paraffined sections of cake could be sliced on a microtome and that fat, stained with Scarlet R or Sudan III before incorporation in the cake batter, tended to lose this stain to the paraffin when the cake was subsequently immersed in paraffin, but if the fat was stained with osmic acid solution the stain was permanent. An osmic acid solution, however, altered the texture of the cake crumb, and no further attempts to perfect this method were made at that time.

The technic for examination of cake microscopically was developed by Minard under the guidance of Dr. E. R. Becker, professor of protozoology at Iowa State College. The time indicated after each step is approximate, but results indicate that a longer period for clearing and infiltration is not desirable. The method for preparing the sections follows:

1. Small pieces of cake about 1 x 1 x ½ centimeters were placed around and near the center of a flat china or glass surface, the number of the cake being marked on the china surface with a glass pencil. The diameter of the glass should not be large, about 6 inches.

2. About 1½ cc. of a 5 percent fresh aqueous solution of osmic acid were placed in a small glass receptacle in the center of the china surface by means of a calibrated medicine dropper or pipette. The whole was covered by a small glass jar or bell jar about 6 inches in diameter and as low as possible in height, the edge being well sealed with desiccator grease. It is important to have the staining carried on in a sealed container to prevent the escape of fumes, and the smaller the glass bell jar the greater the concentration of fumes coming in contact with the cake.

3. The sealed container was set aside in a dark place for 4 or more hours or until the cake was well blackened.

4. The pieces of cake were then transferred to a dessicator overnight. (For some post-tests, Myers omitted this step, and the results were satisfactory.)

5. The cake was cleared in thin cedar oil for 2 hours or until clear, after which the excess oil was allowed to drain off for a few seconds.

6. The cake was then infiltrated in two paraffin baths, each infiltration taking about 3 hours. The formula for the paraffin mixture follows:

Paraffin	425 grams
Stearin	50 grams
Beeswax	25 grams

The apparatus used to keep the paraffin in a liquid state consisted of a galvanized cylinder about 8 inches in diameter and about 8 inches high, with a small door on one side. At the top a cone-shaped metal piece held a 60 watt bulb. The height of the light was adjustable so that it could be kept just close enough to the paraffin mixture to keep it melted. If available, an incubator is preferable to the apparatus described.

7. The cake was then imbedded in fresh paraffin mixture and hardened in ice water.

8. The blocks of paraffin were trimmed down and mounted on the carrying disc of the microtome. They were sectioned by using a safety razor blade in a special holder. Minard cut most of her sections 20 microns thick, some 15, whereas Myers used sections 20 microns thick. It has been found that in photographing the sections, if greater than 150 magnifications are desired, it is preferable to cut the sections 10 microns thick, if this is possible without crumbling.

9. The ribbons were mounted on slides with water, no fixative being used on the slides.

10. After the slides had dried at least 12 hours they were immersed in xylene to dissolve the paraffin. Cover glasses, mounted in thin balsam, were placed over the sections. The slides were then set in an oven at 50°C. or left in the room for the balsam to dry. They were then ready for observation.

CREAMING QUALITIES AND VOLUMES OF LARDS AND OTHER FATS

For years it has been assumed that the creaming of fat and sugar is an important part of the cake-making process. In order to obtain a palatable, satisfactory texture, they must cream to a foam, a mass that is light, fluffy, spongy and plastic so that it blends well with the flour and liquid. Bakers have not considered lard satisfactory to use in cake, partly because it does not cream to a good volume and partly due to its flavor.

Little has been published concerning the creaming quality of different fats for the type of cake formula used in the studies herein reported. It is a striking fact that creaming for pound cake is almost the sole criterion for judging the creaming quality of a shortening by commercial bakers and bakery engineers, although this type of cake is now rarely made by the home-maker. It is almost as out of date as the salt-rising bread of our grandmothers. It has been replaced by a cup, layer or loaf cake. It is the creaming quality of fats in their relation to cake quality in the latter types, cakes containing about 40 parts of fat per 100 parts of flour, that is herein reported.

INVESTIGATIONS OF CREAMING

The Procter and Gamble Company (17) have reported the following concerning factors affecting the creamed volumes of fats and sugar. These results were obtained with a hydrogenated shortening, with the proportion by weight of 1 part of fat to 2 parts of sugar for pound cakes. At low temperatures, 45° to 50°F., the creamed volume was low. With an increase of temperature, both the creamed volume and cake (pound) volume increased until at approximately 75°F. a maximum volume was obtained for the creamed mixture and the cake. When the temperature of the creamed mixture exceeded 80°F. the volume of both the creamed mixture and the cake decreased. Th Procter and Gamble Company states that the best proportion is 1 part of fat to 2 parts of sugar. Larger or smaller proportions of sugar do not produce as desirable a creamed volume. They also state that extra-fine granulated sugar, known as berry sugar, gives greater creamed volume than coarser granules or than powdered sugar and that butter does not have the consistency to stand creaming to the best advantage and is very susceptible to temperature change.

The Procter and Gamble Company also states that the speed of the mixing machine plays an important part in controlling cake quality. At optimum temperature conditions (70° to 75°F.), it does not make much difference whether a low or medium speed is used. At higher than optimum temperatures they suggest that the low speed is preferable. Because of greater friction medium speed tends to increase the temperature of the creamed mixture faster than slow speed. They suggest that the creamed mixture should fill the bowl to about one-fourth capacity. When a bowl is too full the beater cannot whip so much air into the mix and if too small a quantity of material is used a good creamed volume is not obtained. After a certain time interval (25 minutes with the hydrogenated fat they used) the maximum amount of air is incorporated, and further creaming is waste motion. In fact, with some fats the volume will decrease.

Minton (14), keeping all other conditions as nearly uniform as possible, also found that the finer the sugar granulation the better the creamed volume, provided the granulation was a natural one obtained in the refinery. He suggests that the natural shape crystals, which are somewhat hexagonal with sharp angular edges, by tumbling in the mix aid in incorporating air, whereas the powdered sugars, because the particles are more or less rounded, are less efficient. Minton also found that lard did not cream as well as a hydrogenated fat.

Farnham (5) with the same formula used in the cake investigations with lard (112 grams or ½ cup of fat to 300 grams or 1½ cups of sugar, 1 : 2.6 parts by weight) found that creamed volumes varied with the mixing machine used and the speed of the machine. At low speed the time to reach maximum volume was 27 minutes for both mixers and at medium speed 24 minutes, both mixers again requiring the same time. The maximum volume on low speed was greater for both mixers than that obtained at medium speed. At high speed the maximum volume was less than that obtained at medium speed. Farnham also found that the final creamed volume of a hydrogenated fat not only increased with increases of temperature up to 80°F. but also reached maximum volume more rapidly. With her tests the maximum volume of butter was reached at 77°F.

Dunn and White (4) have reported that creaming, dough and cake volumes were poor with coarse granulated sugars and that they became better as the granulation became finer, until the best volume was obtained with fruit-fine powdered sugar. This sugar was the smallest used with a crystalline structure. As the crystalline structure was ruptured by grinding, i.e., standard powdered and confectioners' powdered, which are of smaller size than the fruit-fine granulated sugars, the cake volumes again decreased.

These investigators also have reported that the ''conditioning'' or storage of the fat prior to use affects the creamed, the dough and the cake volumes. Two ''all hydrogenated'' shortenings and one soft compound were stored under the following conditions prior to use: 1. For 100 hours at 50°F. and then for 100 hours at 70°F. before use; 2. for 200 hours at 70°F.; and 3. for 100 hours at 90°F. and then for 100 hours at 70°F. The volumes of the cakes were greatest from the fats stored at 70°F. for 200 hours prior to use. Storage for 100 hours at 50°F. and then for 100 hours at 70°F. gave the next largest volumes. Dunn and White concluded that warm storage conditions exert a deleterious effect on soft-bodied fats and that some ''all hydrogenated'' shortenings are more affected by temperatures as high as 90°F. than others.

AMOUNT, PROPORTIONS AND PROCEDURE FOR CREAMING TESTS

The most extensive creaming tests in these investigations were those of Martin. She used 44 lards, 2 hydrogenated fats and butter. The tests were in two series. In the long-time series, creaming was continued for 260 minutes, the stop watch being stopped whenever the mixer was stopped. The 260-minute creamed mixtures were not used in cake. In the short series, the creaming process was arbitrarily stopped at the end of 30 minutes and the creamed mixture used in cake.

AMOUNT

For the 260-minute series, Martin used the fat, salt and sugar for the full recipe (112 grams, ½ cup of fat; 6 grams salt; and 300 grams, 1½ cups sugar). For the 30-minute series half the quantity for the full recipe was used. Buel, Minard and Myers used only one-fourth the quantity given in the recipe for their creaming tests, and all creamed mixtures were used in cakes.

FATS USED

Martin used the 33 A. H. Individual lards and 9 A. H. Composite lards in the 260-minute tests. She used two commercial lards, two hydrogenated fats and butter in a 60-minute series and all of these in a 30-minute series. The fats used for creaming by the other investigators have been listed previously.

PROPORTIONS FOR CREAMING

The proportion of fat to sugar used in the 260-minute series by Martin was always 1 part of fat to 2.6 parts of sugar by weight. For the shorter creaming periods, the proportions used depended on the method of mixing employed. For the Standard method used by Martin, the Conventional and Modified-Conventional used by Buel and Minard, and the Conventional method used by Myers, the ratio of fat to sugar was 1 : 2.6. For all other methods used, 1 part of fat to 1.3 parts of sugar by weight was used for creaming. When the smaller proportion of sugar was used in creaming the remainder of the sugar was added to the mix with the milk or with the egg as a sponge or meringue.

PROCEDURE

Martin used the KitchenAid with the flat beater and a 3-quart bowl for all creaming tests. All creaming was done at first (slow) speed. Preliminary experiments with creaming lard indicated that for the 260-minute series, greater speed tended to beat the air out of the mixture after a certain point, causing the volume to decrease earlier and more rapidly than if the slower speed were used. The creamed mixture seemed to reach maximum volume as soon at slow speed as at high and to hold this volume longer, though not enough preliminary work was done to determine this fact conclusively. Farnham's work has since practically substantiated this observation. The fact that lard did not appear to hold its maximum creaming volume over as long a period as some of the hydrogenated fats, made the speed selected for creaming important.

For the 260-minute period, Martin determined the creaming volume at intervals as follows: Up to 20 minutes, every 2 minutes; 20 minutes to 80 minutes, every 5 minutes; 80 minutes to 260 minutes, every 10 minutes. The temperatures of the room and creamed mixture were recorded every 5 minutes throughout the experiment. Any particular weather conditions or characteristics of the creamed batter were noted throughout the process. For the 30-minute series, Martin determined the volume at 5, 10, 20 and 30 minutes. All other investigators determined the creamed volume at the end of the creaming period just before the flour and liquid were added.

Minard creamed the fat, salt and part or all of the sugar (depending on the method used for combining the cake) for one-fourth the recipe at second or medium speed on the KitchenAid for 3 minutes. The bowl was then scraped and the mixture creamed 4 minutes; the bowl was scraped down the second time and the mixture creamed 8 more minutes. The fat and sugar with the small proportions used tended to pack on the beater and bowl during the creaming process, but when scraped off as indicated they remained in the bottom of the bowl for the latter half of the period and creamed very uniformly.

Myers followed Minard's procedure for creaming.

Although most of the creaming was done on the KitchenAid, Buel used hand creaming. Her procedure was as follows: Creaming of materials for one-fourth the recipe was done with a wooden spoon for 5 minutes. A stirring motion was used at the average rate of about 120 stirs per minute. As the creamed mixture worked up on the sides of the bowl it was scraped down. The fat which usually worked up on the spoon at the beginning of the process was scraped off with a spatula.

The materials were taken from the incubator for creaming. At this time the temperatures of the room, incubator, fat and sugar were recorded. Physical characteristics of the fat, i.e., degree of softness, separated oil, if any, were noted and a record made.

TEMPERATURE RISE OF THE CREAMED MIXTURE

During the creaming process the temperature of the creamed mixture gradually rises, even when the room temperature remains constant throughout the creaming period and the initial temperature of the fat and sugar is the same as that of the room. For the results given in table 2, the room temperature was kept constant between 24° and 25°C., most of the time at 24.5°C. Under these conditions, the effect of the room temperature would be to cool the creamed mixture as its temperature rises and to keep it at the initial temperature.

TABLE 2. TEMPERATURE RISE OF CREAMED MIXTURE DURING THE CREAMING PROCESS. INITIAL TEMPERATURE OF INGREDIENTS AND ROOM TEMPERATURE THROUGHOUT, 24°—25°C. (MARTIN)

Fat	No. of tests with each fat	Length of creaming period, min.	Temperature rise of creamed mixture	
			Range °C.	Average °C.
9 Composite A. H. lards	2	260	3 — 7	4.8
9 Composite A. H. lards	2	30	1 — 3	2.2
1 Hydrogenated lard	10	30	1 — 3.5	2.5
1 Hydrogenated vegetable oil	11	30	2.5 — 4	3.5
1 corn oil	12	30	0.5 — 3.5	1.5
1 butter	10	30	−0.5 — 1.5	0.6

As shown by data in table 2, the temperature rise is greater for the longer creaming period. Butter behaves differently from the other fats. The temperature of the creamed mixture drops from the initial temperature and after a time rises again. The temperature for three tests was still lower than that of the initial temperature of the butter or of the room at the end of the 30-minute creaming period. This is probably because of the sugar going into solution in water of the butter, with negative heat of solution.

CAUSE OF TEMPERATURE RISE

The temperature rise of the creamed mixtures probably is due chiefly to two factors, friction and heat of adsorption. The friction is produced by the beater piling through and forcing the granular mass against the bowl. More heat is produced by friction at high speeds than at slow ones. Fat is adsorbed by the sugar crystals. In general, adsorption is characterized by the production of positive heat, and in many cases the amount of heat liberated is great. As a general rule, the greater the affinity between the adsorbent and the substance being adsorbed, the greater the amount of heat liberated.

Another cause for the temperature rise was the heat produced by the motor of the KitchenAid. This was of course greater toward the end of a 260-minute period as the motor became warmer or after several 30-minute tests had been run on the same day.

ROOM TEMPERATURE AND TEMPERATURE RISE OF CREAMED MIXTURE

Room temperature is, of course, an important factor affecting the temperature of the creamed mixture. This probably is best shown by Buel's tests. When the room temperature varied from 24° to 35.5°C., the temperature of the creamed mixture varied from 23.5° to 33°C., although the initial temperature of the ingredients was 20°C., and the creaming period lasted only 5 minutes. Martin concluded that the temperature of the creamed mixture was the most important factor in obtaining maximum creaming volume with any designated fat and that other temperature conditions are important only as they affect the temperature of the mix.

CREAMED VOLUMES AND SOME FACTORS AFFECTING CREAMED VOLUME

MAXIMUM VOLUME

During the creaming process, the volume of the creamed mixture gradually increases, reaches a maximum and after maintaining this maximum for a varying period, gradually decreases. In some instances, due to the temperature or physical characteristics of the individual fat, the creaming process started rather slowly, and the creamed mass remained crumbly and granular for some time. In such cases, the increase in volume usually started after a rise in temperature softened the fat. This and other data indicate that the room temperature and mix temperature affect the time for a particular fat to reach maximum volume. Except for Martin's 260-minute tests, no effort was made to obtain maximum creamed volume in this series of studies. For the majority of tests, creaming was stopped at the end of a definite period, and the creamed mass was combined in cake.

260-MINUTE CREAMING PERIODS (MARTIN)

Creamed volumes were determined from 25-gram samples. All the A. H. Individual and Composite lards creamed for 260 minutes reached a maximum volume. The range for the A. H. Individual lards was from 29 to 34 cc., with an average of 32.2 cc., whereas the volume of the A. H. Composite lards varied from 31 to 35 cc. and averaged 32.6 cc. The percentage (table 4) does not adequately express the gain in volume for the softer Com-

TABLE 3. SOME MINIMUM AND MAXIMUM TEMPERATURES, TIME TO AND MAINTENANCE OF MAXIMUM VOLUME AND CREAMED VOLUME OBTAINED WITH LARDS (MARTIN).

Variation	For 260-minute creaming period	
	A. H. Individual lards	A. H. Composite lards
Initial room temperature	18° — 26°	24° — 25°
Room temperature during creaming process	18° — 27°	24° — 25°
Room temperature at maximum creamed volume	22° — 26°	24° — 25°
Initial temperatures of the lard	24.5° — 26°	24° — 25.5°
Temperature of creamed mixtures	22° — 32°	24° — 31.5°
Temperature of creamed mixture at maximum volume	24.5° — 29.5°	24.5° — 29.5°
Time to reach maximum volume	25 — 140 min.	8 — 210 min.
Maintenance of maximum volumes	5 — 85 min.	5 — 150 min.
Average maximum volume of 25 grams of the mix	32.2 cc.	32.6 cc.
	For 30-minute creaming period	
Average maximum volume	30.1 cc.	30.3 cc.

TABLE 4. CREAMING DATA FOR DUPLICATE SAMPLES OF A. H. COMPOSITE LARDS.

Total creaming time 260 minutes (KitchenAid at low speed); full amount of recipe used; proportion of fat to sugar by weight, 1 : 2.6; initial temperature of ingredients 24.5°C. ± 0.5°; room temperature throughout creaming, 24.0° to 25°C. (except C2). Grouped according to increasing iodine number (Martin).

Lard	Temperature of creamed mixture		Volume				Time maximum volume maintained	Iodine number (Wijs)
	Highest reached (° C.)	At maximum volume (° C.)	Time to reach maximum volume (min.)	Of 25 gms. of creamed mix: At end of 2 min. (cc.)	Maximum (cc.)	Percent of maximum volume as air	(min.)	
F	30.0	28.0	50	22	33	33.3	10	63.6
	28.5	27.0	70	22	32	31.2	15	
D	29.5	26.0	40	22	32	31.2	35	67.5
	28.5	27.5	60	22	34	35.2	10	
E	29.5	29.5	120	22	35	37.1	40	68.5
	28.5	28.5	210	22	34	35.2	10	
A	29.5	26.5	45	22	32	31.2	10	70.6
	29.0	28.5	90	22	34	35.2	10	
B	29.5	28.5	110	22	34	35.2	20	70.6
	29.5	28.5	130	24	34	29.4	20	
C	29.5	25.0	30	23	31	29.0	150	75.4
	*27.5	27.5	110	25	33	24.2	20	
I	29.0	25.5	25	25	33	24.2	55	76.8
	29.5	27.0	45	26	34	23.5	10	
G	31.5	26.5	20	24	33	27.2	5	81.5
	30.5	25.5	35	25	33	24.2	5	
H	28.5	24.5	12	25	33	24.2	22	83.4
	30.0	24.5	8	26	33	21.2	32	

*Very cold day. North wind. Room temperature 23.5° to 24°C. for most of time but dropped to 23°C. at various intervals.

posite lards, (lards G, H, and I) because considerable air had been incorporated during the first 2 minutes of creaming, and the figures are based on the volume at the end of this 2-minute interval.

30-MINUTE PERIODS (MARTIN)

The maximum creamed volume for the A. H. Individual lards varied from 26 to 33 cc., averaging 30.1 cc. The volume for the A. H. Composite lards varied from 26 to 33 cc., averaging 30.3 cc. The volume for the 30-minute series was less than that for the same lards in the 260-minute series. The consistency of these lards varied from firm to very soft, the iodine number, from 58.6 to 83.4. (table A in appendix and table 4).

In table 5 are given the minimum, maximum and average creamed volumes of the commercial lards and fats and of the A. H. Individual and Composite lards used by Martin in the 30-minute series. The prime-steam rendered lard had the least and the hydrogenated lard, the largest average creamed volume.

BUEL'S RESULTS, HAND CREAMING

Buel found that the creamed volumes of four fats (prime-steam and open-kettle rendered lards, hydrogenated lard and butter) varied from 24 to 35 cc. (Table 9.) This was for a

5-minute hand creaming period and includes the volumes for all methods of combining ingredients. Although the range of volume of the creamed mixture was 11 cc., the volumes for a specific fat by any particular method were very uniform. The volumes were smaller for the methods whereby all the sugar was creamed with the fat.

MINARD'S RESULTS

Minard found (for butter and five lards, four of which were used in both the smooth and grainy textures) that the creamed volume varied from 22 to 40 cc., averaging 28.5 cc. Minard, like Buel, used methods by which all or half of the sugar was creamed with the fat and obtained larger volumes with the smaller proportion of sugar. She found that though the total range in creamed volume was quite great, the range for an individual fat by a given method was small. There was but one instance in the 450 cakes of a creaming volume of 40 cc. and but one of 22 cc. However, there were numerous cases of creaming volumes of 35 cc. and 23 cc.

MYERS' RESULTS

The average creamed volumes for the butter and smooth and grainy lards are given in table 6.

TIME OF CREAMING

The time required to reach maximum creamed volume for the 33 A. H. Individual lards used by Martin ranged from 25 to 140 minutes, 26 of the experiments falling between 30 and 55 minutes, one at 100, one at 120 and one at 140 minutes. For the 260-minute experiments, table 4, with the A. H. Composite lards, from 8 to 210 minutes were required to reach maximum volume. In other words, under certain standardized conditions of temperature and speed, a definite time is required for a given fat to reach maximum volume.

The ranges for temperature, time and the average maximum creamed volumes for the A. H. lards are given in table 3.

TABLE 5. VOLUME (CC.) OF 25 GRAMS OF CREAMED MIXTURE AT THE END OF 30 MINUTES FOR THE FATS USED BY MARTIN.

Kind of fat	Minimum	Maximum	Average
Prime-steam rendered lard	26	30	27.7
Butter	28	29	28.3
A. H. Individual lards (33)	26	33	30.1
A. H. Composite lards (9)	26	33	30.3
Open-kettle rendered lard	28	35	30.7
Hydrogenated vegetable oil	30	34	31.4
Hydrogenated lard	33	36	34.3

TEMPERATURE

Martin concluded that for each fat there was an optimum temperature at which it creamed best and produced the best results in plain cake. An optimum of 24° to 25°C. was suggested for the lards studied, although the tests were not extensive enough to be conclusive. A slightly higher temperature was indicated for some of the firmer lards. A lower temperature for some of the softer ones might have been used to better advantage. For the hydrogenated fats and the winter butter used in her tests, a higher temperature than 25°C. was indicated as optimum.

Buel found highly significant correlations, table 10, among the temperatures of the room, creamed mixture and cake batter. As one temperature goes up the others tend to follow it.

Myers creamed butter and a smooth and grainy form of the same lard at 25° and 30°C. The butter gave a larger creamed volume at the lower temperature (table 6) with the smaller proportion of sugar (Conventional-Sponge method), but with the larger proportion of sugar (Conventional method) the volumes were the same at 25° and 30°C.

Myers found that both the smooth and grainy lards gave larger volumes at the higher temperature (table 6) than at the lower temperature. But the cakes were superior at the lower temperature, which confirms Martin's conclusion that creamed volume is not the sole criterion of creaming quality. What Martin calls creaming quality, that is, the ability to cream to a light, fluffy, spongy texture, such that a good distribution of the creamed mass throughout the flour and milk is obtained, is more important than creamed volume. Probably a temperature between 25° and 30°C. for the lards used by Myers would have produced better cakes.

TABLE 6. AVERAGE VOLUMES* OF THE CREAMED MIXTURE AND OF THE CAKE.

	Conventional—Sponge method		Conventional method	
	Combined at 25°C. (cc.)	Combined at 30°C. (cc.)	Combined at 25°C. (cc.)	Combined at 30°C. (cc.)
Creaming volume				
Butter	34.4	32.6	23.8	23.8
Smooth lard	34.0	36.8	26.9	28.5
Grainy lard	30.0	31.0	23.9	26.5
Cake volume				
Butter	508.6	501.2	501.0	479.4
Smooth lard	485.6	485.2	477.8	483.4
Grainy lard	482.0	479.8	481.2	478.4

*For creaming volume, 25 grams of the creamed mixture were used. Materials for one-fourth the recipe were creamed 15 minutes on the KitchenAid. Room and ingredients temperature the same and constant in each series, each figure the average of 25 tests. (Myers.)

TABLE 7. ANALYSIS OF VARIANCE OF MYER'S DATA (300 TESTS).

Source of variation	Degrees of freedom	Mean square		
		Creamed volume	Cake volume	Total cake scores
Between means of temperature	1	84.3**	290	3,154**
Between means of methods	1	4,263.9**	1,222**	14,818**
Between means of fats	2	379.0**	13,676**	3,842**
Interactions:				
Temperature-method	1	10.1	140	425**
Temperature-fat	2	70.1**	468*	251**
Method-fat	2	119.1**	175	790**
Temperature-method-fat	2	18.3**	66	149**
Error	288	3.2	151	36

* Significant
** Highly significant

The analysis of variance for creamed volumes, table 7, shows that the variations due to temperature of combining ingredients, method of combining and kind of fat used are all highly significant. The "error" figure, 3.2, is very small, which indicates comparatively little variation within each of the twelve groups. For example, grainy lard combined by the Conventional method at 25°C. always creamed to approximately the same volume.

The greatest variation in creamed volume was due to the method used, and the effect of temperature of combining was least. (Table 6.)

TEXTURE OF FAT

Martin states, that of observed characteristics, the texture of the lard is important. Texture is largely due to the method of rendering and cooling of the lard (which for the A. H. lard was not controlled) rather than to its composition. Best creamed results were obtained from lards that were medium firm, rather granular in appearance and having little liquid fat at 24.5°C. Lards No. 3, 17, 18, 45, 67, and 92 were typical lards of such texture. (Table A, appendix.) The waxy or oily lards did not stand up well under the creaming process and did not give a fluffy, light creamed mixture. The oily lards usually showed a more definite separation of oil at incubator temperature than did the others. This is characteristic of grainy lards, lards that have cooled slowly without stirring at temperatures not far below the melting point.

Minard found that in general grainy lards creamed better than the smooth forms of the same lards. But the smooth lards she used were very firm and waxy and not typical of commercial smooth lards. After creaming 15 minutes they were rather solid and often crumbly. Because they did not cream up fluffy, they did not spread through the cake batter so well. If the smooth lards she used had been softer, her results probably would have been different.

Myers used a grainy and a smooth form of the same lard. The smooth form was soft and desirable with no oil separating out at the temperatures used. The smooth form gave considerably larger creamed volumes than the grainy form (table 6) for both the Conventional-Sponge and the Conventional methods (i.e., for both 1.3 and 2.6 parts of sugar to each part of fat). Since these two lards were from the same original lard, and were identical in every respect, except for texture, and since the conditions and the temperatures were constant, it seems evident that grainy lard is deficient in creaming quality. And as will be shown later, good creaming quality seems to be necessary for the best textured cakes.

KIND OF FAT

Under the conditions of Martin's study, and regardless of whether 1.3 or 2.6 parts of sugar were used for 1 part of fat, the creamed volume of hydrogenated lard was greatest; hydrogenated cottonseed oil was second; the open-kettle rendered commercial lard was third (this order was reversed with butter for the Flour-Batter method); butter, fourth; and, prime-steam commercial rendered lard, fifth.

PHYSICAL AND CHEMICAL CHARACTERISTICS

The iodine numbers for the fats used by Martin are given in the appendix, tables A to E. An arrangement of data for the A. H. Individual lards as shown in table B, appendix, according to temperature of the creamed mixture shows no definite relationship between iodine numbers or the other chemical and physical constants, and creaming volumes. When grouped according to firmness of carcass (table C, appendix) or firmness of lards (data not given) there is a slight tendency for the softer lards from softer carcasses and with higher iodine numbers to yield the greatest creaming volume. However, this tendency may be due to the temperature used for creaming rather than any definite relationships, for similar arrangements for the A. H. Composite lards (table 4) show no such tendency.

The iodine numbers of the A. H. Composite lards (table 4) varied from 63.6 to 83.4. Table 4 and additional data not shown indicate as much or even more variation between duplicate samples of the same lard than among different lards. From this it appears that the creamed volume is not affected by the iodine number or the degree of unsaturation, except as this indirectly affects the plasticity of the lards at a definite temperature.

An outstanding tendency is for the softer, more unsaturated lards to cream to maximum volume more rapidly. (Note the volumes at end of 2 minutes (lards C, I, G and H, table 4.) There is also a tendency for the softer lards to reach maximum creamed volume at a lower temperature than the firmer lards. The degree of unsaturation, as shown by the iodine number, affects the rapidity of creaming. The room temperature and initial temperature of the ingredients in this study were from 24° to 25°.

PROPORTION OF FAT TO SUGAR

The Procter and Gamble Company (17) state that 1 part of a hydrogenated vegetable oil to 2 parts of sugar by weight gives the best creamed volume and that 24°C. is the optimum temperature at which to cream these proportions.

It seems possible that with different proportions of fat and sugar, the optimum temperature may be higher for larger proportions of sugar. In this study, a higher temperature than 24°C. was indicated as optimum when 1 part of hydrogenated vegetable oil was used with 2.6 parts of sugar.

TABLE 8. MEANS FOR CREAMED VOLUME, CAKE VOLUME AND SCORES FOR CAKES MADE BY MARTIN.

Fat	No. cakes	Volume 25 gms. of creamed mix: End of 20 min. (cc.)	End of 30 min. (cc.)	Cake volume (cc.)	Score: Crumb	Tenderness	Velvetiness	Eating quality	Total
Standard method									
Corn oil	12	......	......	486	12.0	10.9	8.4	10.7	42.0
Prime-steam, commercial lard I	12	......	27.8	516	25.0	17.9	17.0	23.6	83.5
Butter	10	......	28.3	529	26.4	18.0	18.0	28.5	90.9
A. H. Individual lards	33	......	30.1	513	26.3	17.9	17.4	25.2	86.8
A. H. Composite lards	18	......	30.3	514	25.8	17.9	17.2	25.3	86.2
Open-kettle, commercial lard II	19	......	30.7	523	26.3	18.3	17.7	25.1	87.4
Hydrogenated oil	11	......	31.4	528	27.4	18.5	17.9	26.1	89.9
Hydrogenated lard	10	......	34.3	530	27.5	18.6	18.1	26.9	91.1
Flour-Batter method									
Corn oil	3	......	......	570	23.5	16.7	16.1	21.9	78.2
Prime-steam lard	2	28.0	23.0	548	27.9	19.6	19.2	28.6	95.3
Butter	2	33.0	23.5	538	26.2	17.1	17.9	27.3	89.0
Open-kettle lard	2	33.5	23.0	559	27.6	18.7	18.5	26.5	91.3
Hydrogenated oil	2	35.5	23.5	553	28.9	18.5	18.9	27.8	94.1
Hydrogenated lard	2	44.0	25.0	539	25.5	17.9	18.1	26.4	87.8
Conventional-Sponge method									
Corn oil	1	......	......	605	26.6	19.0	17.0	25.4	89.2
Prime-steam lard	1	......	30.0	535	28.0	19.2	19.0	28.0	94.2
Butter	1	......	36.0	545	28.4	19.2	18.8	27.4	93.8
Open-kettle lard	2	......	32.0	553	28.1	19.6	19.0	27.8	94.5
Hydrogenated oil	1	......	40.0	530	27.2	19.0	18.8	27.6	92.6
Hydrogenated lard	2	......	46.5	545	28.9	19.4	19.8	28.9	96.5

All the investigators working with cake in this series of the study obtained larger creamed volumes when the smaller proportion of sugar was used. (Tables 6 and 7.) Buel also found it was easier to cream the smaller proportion of sugar (1 part of fat to 1.3 parts of sugar) than when the whole quantity was used (1 part of fat to 2.6 of sugar) when creaming was done by hand.

ADDING FLOUR TO THE CREAMED MIXTURE

When Martin used 1 part of fat to 1.3 parts of sugar and creamed for 20 minutes, a larger volume was obtained than when the larger proportion of sugar was used. (Table 8.) But when one-half the flour was added and the mixture creamed 10 additional minutes, a large portion of the air was lost. (Note volumes by Flour-Batter method at the end of 30 minutes, table 8.) The volume of 25 grams of the hydrogenated lard mixture was 44 cc. at the end of 20 minutes and only 25 cc. after the flour had been added.

HAND VS. MACHINE CREAMING

Minard in a short preliminary study compared:

A. Machine creaming
   1. First or low speed for 30 minutes on the KitchenAid.
   2. Second or medium speed for 15 minutes on the KitchenAid.

B. Hand creaming for 5 minutes.

The temperature of all the ingredients was 25°C. Though there were some cakes made by each of the three methods used in the main problem, most were made by the Conventional method. Several smooth and grainy lards were used. The cake volumes and the cake scores showed that hand creaming was superior to machine creaming for the times and speed used. The apparent reason for the superior cakes made by creaming the fat by hand was that for the small quantity used (fat and sugar for one-fourth the recipe) the mixture creamed better than with the mechanical mixer.

RELATION OF CREAMED VOLUME TO CAKE VOLUME

Martin found that the simple correlations between creaming volume and cake volume (Standard method, table 8) were all non-significant. The fact that four out of five were negative indicated a tendency to smaller cake volume resulting from greater creamed volumes. (The correlation for prime-steam lard was positive and corn oil does not cream.) Buel also obtained a small, negative, non-significant correlation between creamed volume and cake volume, but Minard's correlation, though negative and small, was highly significant. This factor was not analyzed for Myer's data. Because of the large number of cakes made, the large number of fats used and the number of methods used in these studies, it appears that a negative correlation between creamed volume and cake volume would be the general response of this particular cake formula. Martin suggests that for each fat there is a point short of maximum creamed volume at which the creaming process should be stopped in order to produce a cake of maximum volume. These results also suggest that creamed volume in relation to cake volume in this type of cake has been over-emphasized, that results obtained with pound cakes do not hold for this type of cake formula in which about 40 parts of fat to 100 parts of flour are used and that the volume of the creamed mixture is not so important as other factors. A study of the data given in table 8 emphasizes this conclusion. The creamed volumes by the Flour-Batter method are all very low, yet cake volumes all show an increase over those obtained by the Standard method. The results with the corn oil, which does not cream, for cakes made by Flour-Batter and Conventional-Sponge methods are very suggestive and particularly when considered in connection with the cake scores.

From her observations, Martin thought that the creaming *qualities*, the way the fat mixes with the sugar to give a product that combines well with the liquid and flour, were as important for cake volume and quality as creamed volume. It is, of course, possible that creamed volume is more closely related to cake volume with some fats than with others. Butter is a good example of a fat that rather consistently throughout this series gave poor creamed volume, yet under the conditions of these experiments, the cake volume was usually about as great as that from the hydrogenated fats.

A comparison of Myer's order of cake volume with the order or rank of creaming volumes is very interesting, (table 6) since almost complete lack of agreement is found. In all instances, the smooth lards gave the best creaming volumes, whereas all groups of butter cakes had the best cake volumes.

RELATION OF CREAMED VOLUME TO CAKE SCORES

Although the volume of the creamed mix does not determine the cake volume with the type of formula used in these studies, it is important in relation to cake scores.

Martin found that the simple correlations between the volume of the creamed mix and the cake scores indicate a tendency for higher scores for higher creamed volumes. From this it seems that the same conditions which produce the largest creaming volumes likewise produce high scoring cakes or that the amount of air incorporated in creaming affects the blending of cake ingredients and hence the cake scores. There was a noticeable exception in the case of hydrogenated lard in Martin's study. Hydrogenated lard gave the best creamed volume of any of the fats, but in instances where creamed volume was highest, the cakes were less desirable. McLean (12) has shown that too much leavening in the form of baking powder in a cake very decidedly lessens the palatability of the cake. It is possible that too much air in combination with a standard amount of baking powder would cause too great an expansion in the oven and thus affect the cake texture.

Both Buel and Minard obtained a highly significant correlation between the volume of the creamed mix and the total cake score, those with greater creamed volumes giving higher scores. These correlations indicate that a good cake can be expected when the fat creams to a good volume. This is reasonable, for a fat must be plastic to cream, and a plastic creamed mixture would spread easily and uniformly through the cake batter, just as soft butter spreads more readily on a piece of bread than hard butter. This even distribution of the creamed mix insures a more velvety textured cake.

RELATION OF HUMIDITY TO CAKE SCORES

Buel observed that the quality of cakes made on very humid or very hot days declined, but no humidity observations were made.

Minard used a Mason hygrodeik to determine the relative humidity of the room during the time the ingredients were being combined, these determinations being recorded once during the morning and once during the afternoon. Frequently there was no difference in the humidity; sometimes there was either a drop or a rise of a few points, though occasionally there was considerable difference if the window was open during rainy weather. During the spring of 1934 the weather was extremely warm during the period March 1 to July 4, the rainfall being about 0.18 inches during this period. Following July 4, there was about a week of wet weather. It was during this week that Buel noted the effect of hot, sultry weather on cake quality. During the spring of 1935 when baking for Minard's study was completed, the weather was generally cool and damp. Of the 45 days when cakes were baked, 30 of them were cloudy all or part of the time. There was rain during part of 12 days. Only 12 days were recorded as being clear or mostly clear. The lowest relative humidity was 48 percent for just one-half day.

Upon examination of the data it was not easy to relate humidity to cake score. Since the humidity was not controlled during the mixing process, there was no uniformity of the number of cakes, methods or fats under any of the percentages of humidity. Because the methods affected the score so decidedly, straight averages were out of the question. An attempt was made to average the cake scores of a particular method and all fats and to put these points in a sort of scatter diagram. Such a diagram gives at best only a rough idea of a tendency. The cakes made by the Conventional method were quite scattered, with a slight tendency for higher total score to accompany higher relative humidity. With the Modified-Conventional method there was a more pronounced tendency for higher total score to accompany higher relative humidity. On the other hand, the tendency in the cakes made by the Conventional-Sponge method was for the score to go down with increase in humidity. This was accented by three cakes with relatively high scores in the humidity range between 52 and 62 percent. In an effort to throw more light on the relationship, scores from cakes made by a single fat by a given method were plotted. Again, evidence of high correlation was lacking. Usually there was on these diagrams but a single observation for each point and these points were so erratic in placings that drawing of conclusions would be impossible.

Though there was a possibility of finding some effect of humidity on total score through an analysis of covariance, this analysis was not undertaken because there were cakes made by all methods and from all fats under most of the humidities recorded; all of the differences shown by analysis of variance of scores between fats and method were highly significant; there was no possibility of these differences being rendered non-significant by taking into account the humidity; at best, statistically controlling the humidity would only accent already highly significant differences between fats and methods. For these reasons further statistical study of the effect of humidity on the quality of the cake was abandoned.

THE EFFECT OF VISCOSITY OF THE BATTER ON CAKE TEXTURE AND SCORES

Although the viscosity of the cake batter was not determined with a viscosimeter in any units of this study, observations indicate that the viscosity of the batter is closely related to cake quality.

Berrigan (1) reported that by adding the egg white and part of the sugar as a meringue at the last of the mixing process, a batter of high viscosity as determined by a MacMichael viscosimeter was obtained, as well as cakes of increased volume and quality.

Martin states: "It is interesting to note that the thickness of the cake batter as observed throughout this investigation seems to correlate very closely with cake quality, the thicker batters producing the best cakes."

Buel states that the most outstanding fact observed during the preliminary study, in which 35 methods for combining ingredients were tested, was that non-viscous cake batters produced a cake of inferior qualities. If the ingredients were put together in such a manner that the final cake batter was thick or viscous enough to stand up in waves or creases when poured into the baking pan, a good cake could be expected. In all these cakes, the same amount of flour and other ingredients were used, and the stiffness or thinness of the batter depended on the technique of mixing. Another factor that might have affected the viscosity was the temperature of the batter, but in the preliminary investigations of Buel's study this was fairly well controlled. The batters varied from one so viscous that it was necessary to push the batter with a spatula so that it would be distributed in the corners of the baking pan, to a batter so thin that it greatly resembled a liquid when being poured into the baking pan. In appearance, the first batter was lighter in color, had a duller gloss and presented a broken surface due to the uniform distribution throughout of very tiny curds. In contrast, the second batter was oily, shiny, smooth and a darker yellow in color.

All efforts to use melted fat seemed to result in a batter with the undesirable characteristics. But Buel adds that she was not convinced that there are not methods by which good cakes can be obtained from melted fats.

THE METHOD OF COMBINING INGREDIENTS

The method of combining ingredients, even at the initiation of this study, appeared to be a very important factor in obtaining good textured cakes. In testing some recipes for a popular bulletin on lard (16), a spice cake recipe was tried which contained no egg. The texture was velvety. In connection with results obtained with oil in experimental cookery classes, this suggested that with oils and very soft or partially melted fats, the egg tended to disperse the oil or soft fat as an oil-in-water emulsion, with attendant poorly textured and unpalatable cakes. Hence, it was decided to try adding the egg to the cake batter late in the process of combining the ingredients instead of adding it to the creamed mixture and creaming further, as is the procedure followed most commonly in making cake.

THE METHODS OF MARTIN

STANDARD

Of the different methods tried in the preliminary work, Martin obtained greater volume and much improved cake texture by adding the egg to the milk but otherwise combining the ingredients as for the Conventional method. These cakes were so superior to those made with lard by the Conventional method that this method was used as the Standard method in Martin's tests. The average cake scores for the different fats by the Standard method (table 8) indicate that fairly good cakes were obtained with all fats except oil.

THE FLOUR-BATTER METHOD

Part of the aim of Martin's study was to find ways of combining cake ingredients that would give more desirable cakes, particularly when lard was the fat used. The total scores (table 8) for the Flour-Batter method, when one-half of the flour was added to the creamed mix and creamed an additional 10 minutes (which caused loss of creamed volume), indicate striking improvement in the quality of the cakes for all fats except hydrogenated lard.

The decided increase in the score for the oil and prime-steam lard is rather startling. The lower scores for the hydrogenated lard cakes than for those of the Standard method suggest that the Flour-Batter method is not so desirable with a fat as firm as the hydrogenated lard but favors the fats of soft or medium texture.

The average volumes of the cakes made by the Flour-Batter method were increased over the volumes for the Standard method. This was particularly noticeable for cakes made with oil. (Table 8.) The next greatest gain in volume was with the prime-steam and open-kettle rendered commercial lards. The gain in volume for the hydrogenated vegetable oil cakes was almost as great as for the lards. The cakes made with butter and hydrogenated lard had the least increase in volume by the change from the Standard to the Flour-Batter method.

CONVENTIONAL-SPONGE METHOD

The scores for cakes made by the Conventional-Sponge method are all higher than for those made by the Standard method (table 8), with the exception of cakes made with prime-steam lard and hydrogenated vegetable oil, but the relative order for each fat is about the same as in the Standard method. The volumes of all cakes made by the Conventional-Sponge method were larger than those made by the Standard method. There was little difference in volume for the cakes made with most of the fats by the two methods except for the cake made with oil. In fact, the cakes made of prime-steam lard, open-kettle rendered lard and hydrogenated vegetable oil were slightly smaller by the Conventional-Sponge than by the Flour-Batter method. The increase in volume for the cake made with oil (table 8) is again noticeable.

The number of cakes baked by Martin for some methods were too few to draw definite conclusions, but her results did suggest that the next logical step in this investigation was to try out various ways of combining cake ingredients. Buel carried out this unit of the study.

THE METHODS USED BY BUEL

From the group of 35 methods of combining ingredients in the preliminary work, Buel selected 5 which seemed to give good results. In addition, the Conventional method was used for comparison. A total of 360 cakes was made, 15 from each fat by each of the six methods.

To overcome any peculiarity in technique which might be due to the time of day and to any psychological effect which a definite order might have on the judges, the order in which the cakes from the various groups were baked during the study was constantly changed. In this manner the time for baking the cakes of each group of 15 was well distributed throughout the baking periods. On some days only one fat was used with the six methods of mixing, on other days two fats were used in cakes mixed according to the six methods and on still other days one method of mixing was used with four different fats. In this manner duplications of fat and method, duplication of fat only and duplications of method only were introduced into the daily series.

STATISTICAL ANALYSIS OF BUEL'S RESULTS

The means for Buel's study, with the highest and lowest values, the standard deviations and ranges are given in table 9, but no separation of means to method or kind of fat used is indicated in these data.

The simple correlations between the various items for the 360 cakes and the relative weight of velvetiness and eating quality in determining the final score are given in table 10.

There are highly significant correlations (table 10) among the temperatures of the room, creamed mixture and cake batter. As one temperature goes up, the others tend to follow it rather closely. The correlation between velvetiness scores and the creamed-mixture temperature and between velvetiness scores and the cake-batter temperature are non-significant. In contrast the

TABLE 9. THE MEANS, LOWEST AND HIGHEST VALUES, THEIR RANGE AND STANDARD DEVIATIONS AS OBTAINED FROM DATA ON 360 CAKES (BUEL).

Variable	Key to variable	Mean	Highest and lowest values	Range	Standard deviation
Room temperature	X	29.71°	24.0°-35.5°	11.5	2.34
Temperature creamed mixture	A	28.17°	23.5°-33.0°	10.5	1.39
Cake batter temperature	B	25.75°	23.0°-29.5°	6.5	1.29
Creamed volume	C	27.86	24.0 -35.0	11.0	1.06
Cake volume	D	471.36	438.0 -518.0	80.0	15.14
Velvetiness	E	16.21	11.0 -19.0	8.0	1.60
Eating quality	F	24.34	16.0 -29.0	13.0	1.69
Final score	G	84.12	60.0 -94.0	34.0	3.79

TABLE 10. THE SIMPLE CORRELATIONS AND THE BETAS WHICH SHOW THE RELATIVE EFFECT OF THE VELVETINESS AND EATING QUALITY ON THE FINAL SCORE.

	Temperature		Volume		Scores			Betas	
	Creamed mixture A	Cake batter B	Creamed mixture C	Cake D	Velvetiness E	Eating quality F	Final G	β GE	β GF
Room temp.	.80**	.84**	.09	-.21**	-.12*	-.07	-.07	....	....
A	......	.80**	.17**	-.25**	-.06	.00	-.01	......	....
B	......	......	.05	-.24**	.00	-.03	.02	....	......
C	....	......	......	-.08	.02	.15*	.15**	....	....
D	....	......	......	......	.02	-.02	.13*	......	....
E	......	......	......	....	......	.45**	.68**	.50	.....
F	....	....	......	......	....	....	.70**	......	.46

* Significant
** Highly significant

correlation between room temperature and velvetiness scores is a significant negative correlation, probably because of a greater range in room temperature than in the creamed mixture and cake batter. This negative correlation indicates that velvetiness of the cake decreases with a rise in room temperature, which was noticeable in the experiment, since cakes made on very warm days were poorer in quality than those made on cooler days.

TEMPERATURE AND CAKE VOLUME

The highly significant negative correlations among the room, creamed mixture and cake batter temperatures and cake volume indicate that as the temperature rises the volume of the cake decreases.

SCORES

The highly significant correlations existing among the scores on velvetiness, eating quality and final scores verify the supposition that the three scores are greatly dependent upon each other for their values. The velvetiness and eating quality are about equal in the weight which they have on the final score, which is shown by the two betas, table 10.

EFFECT OF METHOD AND FAT

The variation in the cakes due to the four kinds of fats and the six methods of mixing used was analyzed by analysis of

TABLE 11. TEST OF SIGNIFICANCE OF DIFFERENCES BETWEEN ADJUSTED FINAL SCORES FOR SIX METHODS AND FOUR FATS. FINAL SCORES ADJUSTED TO SAME AVERAGE BATTER TEMPERATURE (BUEL).

Source of variation	Degrees of freedom	Mean square
Between fats	3	53.5*
Between methods	5	265.7**
Methods x fats	15	20.0
Within (error)	335	15.4

* Significant
** Highly significant

variance. There was a significant difference in the four fats and a highly significant difference among the six methods. A non-significant interaction signified that as a whole the rank of the methods was much the same for all fats. For the groups as a whole the four fats differed significantly from each other in the quality of cake which they produced. The method of mixing, however, which is best for one fat can, in general, be expected to produce the highest scoring cake from the other fats. This non-significant difference in the behavior of the fats themselves indicated that variation among the fats had no bearing on their relative response to the various methods used in Buel's study.

BATTER TEMPERATURE

The great range in temperature in Buel's data (table 9) resulted from the intense heat waves which swept over the Middlewest during June and July when the cakes for her study were baked. It was impossible to control the room temperature. James (9) had shown in previous work in this laboratory that the temperature of the cake batter affected the palatability of the resulting cakes. Because the batter temperature in Buel's study varied from 23° to 29.5°C., it was selected as a possible cause for the lack of homogeneity or uniformity in the results obtained from the four fats and six methods. The effect of this factor on the final scores was taken into consideration by adjusting the final score to the same batter temperature. But after taking into consideration the effect of the batter temperature on the final scores, there was still a significant difference among the fats and a highly significant difference among the methods (table 11). The temperature of the batter did not apparently affect the final scores significantly in this study. This fact was also illustrated by the non-significant correlation coefficient between the batter temperature and the final score. This result does not necessarily signify that the batter temperature exerted no effect on the final score. It means that the batter temperature range of 6.5°C. in Buel's study, which was not as great a range as in James' results, was not great enough to significantly affect the final score.

CAKE VOLUMES

The average cake volumes are shown in table 12. The largest average volume is that of group 1, made from prime-steam lard by the Conventional-Sponge method. This group of cakes also received the highest final score. The smallest volume is that for group 21, from hydrogenated lard by the Modified-Conventional method.

With two exceptions, groups 8 and 20 by the Conventional method, the cakes made from prime-steam rendered lard had larger average volumes than the cakes made from the open-kettle rendered and hydrogenated lards.

For all the methods of combining ingredients, with the exception of the Conventional method, the beaten egg either with one-half, one-fourth or no sugar was the last ingredient added. In the Conventional method the egg was added to the creamed mixture before the liquid and flour. Table 12 shows that all these methods by which the egg is added last favor the softer fats, in that the softer fats have larger cake volumes. The largest average cake volume for the Conventional method was 482 cc. in group 20, made with hydrogenated lard.

The smallest variations in volumes were found in the group of cakes mixed by the Conventional and Modified-Conventional methods. The cakes made from the hydrogenated lard showed the widest variation, which was undoubtedly due to the tendency of cakes mixed by the Conventional and Modified-Conventional when removed from the oven.

A greater variation existed in the average volumes of the cakes mixed according to the six methods (19.9 cc., table 12) than in the cakes baked from the four fats (12 cc.).

The rank for the average volumes of cakes baked from the four fats is: 1. Prime-steam lard; 2. butter; 3. open-kettle rendered lard; and 4. hydrogenated lard. Although the hydrogenated lard always gave the largest creaming volume it ranked fourth among the fats in final cake volume.

TABLE 12. AVERAGE CAKE VOLUMES AND RANGE OF THE AVERAGE VOLUMES IN CUBIC CENTIMETERS FOR EACH FAT AND METHOD AND THE DIFFERENCES BETWEEN THE HIGHEST AND THE LOWEST AVERAGE VOLUMES (BUEL).

Fat, group number and group mean	Method of combining ingredients						
	I Conv. sponge	II Conv.	III Mod. Conv.	IV Flour Batter	V No. 26	VI No. 31	Mean for fat for all methods
Prime-steam lard							
Group number	1	2	3	4	5	6	
Mean	484.3	478.7	463.7	483.7	473.0	481.3	477.4
Open-kettle lard							
Group number	7	8	9	10	11	12	
Mean	479.0	480.7	457.3	472.7	459.3	479.0	471.3
Butter							
Group number	13	14	15	16	17	18	
Mean	480.3	475.5	461.3	470.7	466.3	480.0	472.3
Hydrogenated lard							
Group number	19	20	21	22	23	24	
Mean	460.1	482.0	455.0	460.7	463.3	471.3	465.4
Mean for method for all fats	475.9	479.2	459.3	472.0	465.4	477.9	

Highest and lowest fat means .... 477.4—465.4
Range 12.0
Highest and lowest method means .... 479.2—459.3
Range 19.9

The order of average volumes of cakes mixed by the six methods, arranged in decreasing volume is: 1. Conventional; 2. No. 31; 3. Conventional-Sponge; 4. Flour-Batter; 5. No. 26; and 6. Modified-Conventional. Although the cakes made by the Conventional method had the largest average volume, they ranked fifth for final score.

CAKE SCORES

All data on scores refer to the average scores by the five judges.

CRUMB

The means for the scores on crumb are given in table 13. The highest average score for crumb, 25.2, was for prime-steam lard, whereas the lowest score, 24.7, was received by the groups of butter cakes. The differences between the highest and lowest crumb scores (table 13) are interesting because of their smallness for both fat and method, the range for method being slightly greater than for the fats.

VELVETINESS

Velvetiness refers to the softness of the crumb as judged by the tactile sense, i.e., by the finger or palate. The lowest ranking methods were the Conventional and Flour-Batter (table 13) with scores of 15.3 and 15.4, respectively. The top score, 17.1, was received by the Conventional-Sponge method which was followed by method No. 31 with a score of 16.6. The data for the 24 groups of cakes showed the predominance of these last two over the other four methods in producing velvety cakes.

TABLE 13. AVERAGE CAKE SCORES FOR CRUMB, VELVETINESS, EATING QUALITY AND FINAL SCORE OF THE 90 CAKES BAKED FROM EACH OF THE FOUR FATS AND OF THE 60 CAKES MIXED BY EACH OF THE SIX METHODS (BUEL).

	Crumb	Velvetiness	Eating quality	Final score
	(Possible scores)			
	30	20	30	100
Fat				
Prime-steam rendered lard	25.2	16.2	24.2	84.2
Open-kettle rendered lard	25.0	16.1	24.1	83.5
Butter	24.7	16.0	24.3	83.3
Hydrogenated lard	25.0	16.2	24.6	85.1
Method				
Conventional sponge	26.3	17.1	25.0	88.6
Conventional	24.4	15.3	23.7	82.6
Modified Conven.	24.9	16.2	24.7	84.4
Flour-Batter	24.0	15.4	23.2	80.0
No. 26	25.0	16.1	24.8	85.1
No. 31	25.2	16.6	24.8	85.6
Highest and lowest values for fat	25.2—24.7	16.2—16.0	24.6—24.1	85.1—83.3
Range	0.5	0.2	0.5	1.8
Highest and lowest values for method	26.3—24.0	17.1—15.3	25.0—23.2	86.6—90.0
Range	2.3	1.8	1.9	6.6

When the 24 groups were considered from the standpoint of rank for fats, the Conventional-Sponge method produced the highest scoring groups of cakes for the lards and butter. But for hydrogenated lard, methods No. 26 and No. 31 rated above the Conventional-Sponge method. The results emphasize that certain methods for combining ingredients are preferable for a particular fat in producing velvety cakes. The uniform preference of the judges for the Conventional-Sponge method for lard and butter cakes indicates this method is more desirable for the softer fats than for hydrogenated lard.

One striking point for the velvetiness scores is the small range, 0.2, for the fats. The range, 1.8, for the methods is also small. In addition, the range for a given fat by a given method was small. The differences between the highest and lowest scores were greatest for the two lards and the butter. Thus, there was more variation from method to method when these fats were used than when hydrogenated lard was used.

EATING QUALITY

The score for eating quality includes all factors which make the cake desirable or undesirable. The Conventional-Sponge method (table 13) received the highest score, 25.0, for eating quality and the Flour-Batter, the lowest, 23.2. For the fats, the hydrogenated lard ranked highest, followed by butter, prime-steam and open-kettle rendered lard in the order named. When the 24 groups of cakes were considered, the Conventional-Sponge gave higher scoring cakes than the other methods for the two lards and butter but ranked fourth for hydrogenated lard. For all methods with the exception of the Conventional-Sponge, the hydrogenated lard gave the top scoring group. Since the hydrogenated lard received four first ratings in velvetiness this indicates that velvetiness influences the score for eating quality. Hydrogenated lard is practically an odorless and tasteless fat, so that these results emphasize that not flavor alone but also texture or velvetiness, the feel of the crumb in the mouth, is an important factor in determining whether a cake is desirable or undesirable. This conclusion is supported by the simple correlations (table 10) which show the interdependence of velvetiness, eating quality and final scores on each other.

FINAL SCORES

The average final scores are given in table 13, but in table 14, the rank for both fat and method as well as the group mean score for all 24 groups of cakes is given. These average final scores illustrate a number of interesting points as indicated in the statistical analysis.

THE METHODS

The highest scoring of the 24 groups of cakes was group 1, made by the Conventional-Sponge method from prime-steam rendered lard. It was followed closely by group 15, from butter by the same method. The Conventional-Sponge method leads in that the groups of cakes made from prime-steam and open-kettle rendered lard and butter ranked higher than for other methods of combining. For hydrogenated lard, however, the two methods, Nos. 26 and 31, ranked above the Conventional-Sponge. Shrinkage after baking, which was noticeable for cakes made of hydrogenated lard, was far greater by some methods than others. The least shrinkage for cake made from this fat was with method No. 31. Since this was the highest scoring group of cake from hydrogenated lard, there appears to be some relationship between the quality of the cake and the amount it shrinks after being removed from the oven.

On the basis of the ratings for the 24 groups of cakes, the relative value of each method is as follows: 1. Conventional-Sponge; 2. No. 31; 3. No. 26; 4. Modified-Conventional; 5. Conventional; and 6. Flour-Batter.

The greatest ranges in final scores existed in the methods when the two lards and butter were used. In addition, a wide range existed in the fats when the Flour-Batter method was used.

THE THREE METHODS USED BY MINARD

Minard used the Conventional, the Modified-Conventional and the Conventional-Sponge methods for combining ingredients. She used 10 fats, which made 30 different groups. There were 15 cakes for each group, giving a total of 450 cakes. The means for the methods and fat are given in table 15. As can be seen by the means the method of combining ingredients had a decided effect on the final scores, the averages being 61.2, 67.9 and 75.7 for the Conventional, Modified-Conventional and Conventional-Sponge methods, respectively. Minard's cakes were definitely of poorer quality than Buel's. This is shown in the mean scores. Although Minard found in her preliminary work that hand-creaming produced higher scoring cakes, she used machine creaming because of the saving in human energy in making 450 cakes. The analysis of variance of Minard's data showed that the differences in the scores caused by using different methods of combining and different fats were both highly significant.

THE TWO METHODS USED BY MYERS

Myers used the Conventional and Conventional-Sponge methods for combining ingredients. In addition, she used three fats and two temperatures of the ingredients when combined.

TABLE 14. THE MEANS FOR FINAL SCORES FOR 24 GROUPS OF CAKES, EACH MEAN BEING THE AVERAGE OF SCORES OF FIVE JUDGES FOR 15 CAKES (BUEL).

Fat, group mean, and rank for fat and method	Method					
	I Conv.-Sponge	II Conv.	III Modif. Conv.	IV Flour-Batter	V No. 26	VI No. 31
Prime-steam rendered lard:						
Group number	1	2	3	4	5	6
Mean	87.6	82.1	84.9	80.3	84.7	85.7
Rank for fat	1st	3rd	1st	2nd	3rd	2nd
Rank for method	1st	5th	3rd	6th	4th	2nd
Open-kettle rendered lard:						
Group number	7	8	9	10	11	12
Mean	86.3	81.5	84.2	80.2	84.6	85.1
Rank for fat	3rd	4th	3rd	3rd	4th	3rd
Rank for method	1st	5th	4th	6th	3rd	2nd
Butter:						
Group number	13	14	15	16	17	18
Mean	87.5	83.2	83.8	75.9	84.9	84.7
Rank for fat	2nd	2nd	4th	4th	2nd	4th
Rank for method	1st	5th	4th	6th	2nd	3rd
Hydrogenated lard:						
Group number	19	20	21	22	23	24
Mean	85.2	83.7	84.8	83.8	86.2	86.2
Rank for fat	4th	1st	2nd	1st	1st	1st
Rank for method	3rd	6th	4th	5th	2nd	1st

This gave 12 groups of cakes, which with 25 cakes in each group, made a total of 300 cakes.

THE SCORES

An analysis of Myers' scores showed that the differences due to the methods of combining ingredients, the temperature of the ingredients when combined and the fats used were all highly significant. Of these three factors, the method of combining the ingredients produced the greatest difference. (Tables 17, 18 and

TABLE 15. THE MEANS FOR FINAL SCORES FOR 30 GROUPS OF CAKES, EACH MEAN BEING THE AVERAGE OF SCORES OF SIX JUDGES FOR 15 CAKES AND THE MEANS FOR ALL CAKES MADE BY EACH METHOD AND FOR EACH FAT (MINARD).

Fat used	Method for combining			Mean for each fat for all methods
	Conventional	Modified Conventional	Conventional Sponge	
Butter	72.8	75.4	84.0	77.4
Drip rendered lard, lot 4	55.0	64.7	75.7	65.1
Open-kettle rendered lard:				
Grainy	68.2	72.2	76.9	72.4
Smooth	50.9	64.5	71.3	62.2
Drip-rendered lard, lot 3:				
Grainy	58.3	67.5	77.7	67.8
Smooth	65.8	71.6	79.3	72.2
Prime-steam lard, No. 1:				
Grainy	67.8	72.3	74.1	71.4
Smooth	58.3	66.1	75.0	66.5
Prime-steam lard, No. 2:				
Grainy	60.7	64.9	72.3	66.0
Smooth	53.9	60.2	71.2	61.8
Mean for each method for all fats	61.2	67.9	75.7	....

19.) The average total scores for all cakes made by the Conventional and Conventional-Sponge methods were 64.1 and 78.2, respectively.

CAKE VOLUMES

The average cake volumes of all cakes made by the Conventional and Conventional-Sponge methods were 486.2 and 490.3 cc., respectively. The analysis of the data showed that the variations due to methods and fats were both highly significant, but the differences in volumes between the cakes combined at the two temperatures were not significant.

IMPORTANCE OF METHOD OF COMBINING INGREDIENTS

All the data obtained in this 4-year investigation emphasize the effect and importance of the method of combining ingredients on the texture and palatability of the cake as shown by the cake scores. The method of combining ingredients produced highly significant results in Buel's study, but the effect of the different fats was only significant, whereas in the last two investigations both the method of combining and the fat had highly significant effects on scores. Martin's study suggested the importance of method of combining ingredients on cake texture and palatability. Buel's work confirmed Martin's results and showed conclusively the great influence of method of combining on cake quality. Minard's and Myers' work further substantiated the work of the two previous investigators.

Berrigan (1) reported that lard and egg white have an antagonistic reaction in white cake batter, the effect of which results in poor cake volume and quality, if these two ingredients are mixed simultaneously with the other ingredients.

Swartz (21) in "How to use lard in bakers' cakes" gives a method by which the lard is blended with three-fifths of the flour. The eggs beaten with about five-sevenths of the sugar to a sponge are added to the cake batter last. This method, judging by consumer preferences, produces a very acceptable product.

In this series of investigations herein reported, the methods by which the egg was added to the milk or added last (either without or with a portion of the sugar as a sponge) to the batter have been outstanding in improving the quality and palatability of cakes made with oils, and the improvement in cakes made with lards has been nearly as marked as the improvement of the cakes made with oils. Even cakes made with butter have ranked higher when the egg was added last than when it was added to the creamed mixture. Some of these methods have even produced better cakes with the hydrogenated lard than did the Conventional method.

Of the methods tried, the Conventional-Sponge (in which one-half of the sugar is beaten into the egg to form a light, fluffy sponge and is folded into the cake batter last) has been outstanding in producing palatable cakes, particularly with oils, lards and butter. The cakes made with hydrogenated lard have scored higher by some other methods (No. 26 and No. 31) used by Buel, but the Conventional-Sponge did produce higher scoring cakes than the Conventional method.

These studies indicate that egg, if added early in the mixing process to the cake batter containing soft fats, exerts an unfavorable effect on the distribution of the fat in the batter. This is detrimental to cake quality as shown by palatability scores. It is further discussed under the section "Miscroscopical Examination of Fat Distribution in Cake."

THE FATS

Because of the variables in the different units of the investigations, it is difficult to entirely separate different parts of the study such as the methods of combining ingredients and the kind of fats used. Some of the results for differences in cakes because of kind of fat used have previously been given. But it seems worthwhile to concentrate in one section the most outstanding results obtained with different fats.

MARTIN'S RESULTS

Martin, by the Standard method (tables 7 and 16), found that the fats she used ranked, on the basis of total or final score, as follows: 1. Hydrogenated lard; 2. butter; 3. hydrogenated vegetable oil; 4. open-kettle rendered lard; 5. A. H. Individual lard; 6. A. H. Composite lards; 7. prime-steam rendered lard; and 8. corn oil.

But with the other methods this order changed, although the number of cakes Martin made by these methods was too few to draw definite conclusions. For the Flour-Batter method (tables 7 and 16), the order was: 1. Prime-steam rendered lard; 2. hydrogenated vegetable oil; 3. open-kettle rendered lard; 4. butter; 5. hydrogenated lard; and 6. corn oil. For the Conventional-Sponge method, Martin again found that the order of preference for fat varied. The hydrogenated lard ranked first, followed by the open-kettle rendered lard, prime-steam rendered lard, butter, hydrogenated vegetable oil and corn oil.

From these results Martin suggests that certain methods ap pear to be superior for certain kinds of fats. The Conventional-Sponge appears to favor the softer fats and the oil, the flavor being decidedly less distinct for these fats by this method and the texture and volume of the cake good.

The lards themselves vary in texture, degree of softness or firmness, flavor and other characteristics. It might be possible that softer lards would be better combined by one method and the firmer ones, by another. But the high scores with all fats by the Conventional-Sponge method suggest that in general it is the best method yet tried for all fats.

BUEL'S RESULTS

Buel (tables 9 to 15 inclusive, summary in table 1) compared a smooth prime-steam rendered lard, a grainy open-kettle rendered lard, a hydrogenated lard and butter. She also used six methods of combining ingredients, and the order (though on the whole the ratings of the methods were uniformly the same for all fats) varied somewhat when each fat was used by different methods. In the final averages for the six methods, the hydrogenated lard cakes ranked first in eating quality and final score, tied for first in velvetiness and ranked fourth in final cake volume. The prime-steam rendered lard cakes ranked first in volume, tied for first in velvetiness and ranked second in both eating quality and final score.

For all methods the prime-steam rendered lard cakes had higher final scores than the cakes made from open-kettle rendered lard. (Table 15.) The variation, though not great, was consistent, and as a whole the same relationship existed among the crumb, velvetiness and eating quality scores. The uniformity of this variation suggests a difference in the culinary value of these two lards in so far as their use in cake is concerned. It must be remembered, however, that the prime-steam was a smooth lard, whereas the open-kettle lard was grainy. A subsequent study by Myers showed that in cakes the smooth was preferable to the grainy form of lard. Hence, this variation in the two lards in Buel's results may be attributed to the consistency of the two fats rather than the method of rendering. The prime-steam lard in this unit had a less desirable odor than the open-kettle rendered lard.

Difference in fats is significant. Of the 24 groups of cakes made by Buel, the group receiving the highest score was that made from prime-steam lard by the Conventional-Sponge method (table 14). This was closely followed by the group of butter cakes made by the same method. The Conventional-Sponge method also gave the highest ranking group for open-kettle rendered lard as well as for prime-steam lard and butter. When hydrogenated lard was used, two other methods ranked above the Conventional-Sponge.

For four of the six methods either open-kettle or prime-steam lard or both ranked above butter in the average final scores, the prime-steam lard ranking first for two of the six methods.

For four of the six methods the hydrogenated lard ranked first in final score. This rating bore a definite relationship to the placing received by this fat in crumb, velvetiness and eating quality.

After taking into consideration the effect of the batter temperature on the final scores, there was still a significant difference in the fats (table 11). This significant variation may be partially explained as being due to one group, the scores of which vary quite widely from those of the other groups. This is group 16 of the butter cakes (table 14) made by the Flour-Batter method. Its score is 4.3 points lower than the next lowest scoring group made by this method. The variation among the other three fats mixed by this method is only 3.5 points. In no other

TABLE 16. THE RANK FOR DIFFERENT FATS USED IN DIFFERENT UNITS OF THIS STUDY

Fat	Method of mixing batter		
	Standard	Flour-Batter	Conventional-Sponge
Martin's results*			
Hydrogenated lard	1st	5th	1st
Butter	2nd	4th	4th
Hydrogenated vegetable oil	3rd	2nd	5th
Open-kettle lard	4th	3rd	2nd
A. H. Individual lards	5th	......	......
A. H. Composite lards	6th	......	......
Prime-steam lard	7th	1st	3rd
Corn oil	8th	6th	6th

	Method of mixing batter					
	Conventional sponge	Conventional	Modified Conventional	Flour batter	No. 26	No. 31
Buel's results						
Prime-steam lard	1st	3rd	1st	2nd	3rd	2nd
Butter	2nd	2nd	4th	4th	2nd	4th
Open-kettle lard	3rd	4th	3rd	3rd	4th	3rd
Hydrogenated lard	4th	1st	2nd	1st	1st	1st

	Method of mixing batter		
	Conventional Sponge	Conventional	Modified Conventional
Minard's results			
Butter	1st	1st	1st
Drip lard, lot 3	5th	7th	8th
Open-kettle lard, grainy	4th	2nd	3rd
Open-kettle lard, smooth	9th	9th	9th
Drip lard, lot 4, grainy	3rd	6th*	5th
Drip lard, lot 4, smooth	2nd	4th	4th
Prime-steam lard, 1, grainy	7th	3rd	2nd
Prime-steam lard, 1, smooth	6th	6th*	6th
Prime-steam lard, 2, grainy	8th	5th	7th
Prime-steam lard, 2, smooth	10th	8th	10th

	Method of mixing batter	
	Conventional-Sponge	Conventional
Myer's results		
Butter	1st	1st
Smooth lard	2nd	2nd
Grainy lard	3rd	3rd

* Two fats with the same score.

method is the range for the group scores more than 2.3 points. Apparently in so far as the other five methods are concerned, a very small difference existed in the cakes made from the four fats.

The comparatively close relationship among the final scores of the cakes by each method further verifies the statistical analysis in which the non-significant interaction was interpreted to mean that the relative value of the methods was uniform for the fats. However, in a later study, Myers found that when temperature, as well as method of combining, and kind of fat were considered, the interaction was significant.

From the standpoint of the ratings received by all methods on their final scores the fats could be placed in the following order: 1. Hydrogenated lard; 2. prime-steam rendered lard; 3. butter; and 4. open-kettle rendered lard.

MINARD'S RESULTS

Minard states that the type of fat affects the cake texture and flavor but affects the eating quality of the cake to a greater degree than the texture.

Minard (table 16) found that for total scores, butter cakes ranked highest, regardless of the method of mixing used. This rank was received primarily on eating quality or flavor, because some of the lards scored higher than butter in velvetiness. The prime-steam, grainy lard, No. 1, was second; the open-kettle rendered, grainy lard and a smooth drip-rendered lard received about the same scores for the third place. The other prime-steam rendered lard and the other drip-rendered lards had lower ranks. The smooth form for most lards ranked lower than the grainy form.

MYERS' RESULTS, SMOOTH VS. GRAINY LARD

Myers (table 16) using butter and two forms of the same lard, i.e., a grainy and a smooth form (tables 17 and 18) found that butter ranked first in texture, velvetiness, eating quality and total scores, smooth lard second and the grainy lard third. But in the highest scoring group of cakes, those made by the Conventional-Sponge method at 25°C., this order was true only for eating quality and total scores. For texture and velvetiness scores, smooth lard ranked first and butter second.

THE FAT AND THE METHOD ARE BOTH IMPORTANT

These four studies suggest that the choice of a particular fat for use in plain cake may largely depend upon how the ingredients are combined, their temperature, the technic of the maker and other factors. Even when compared with butter, hydrogenated lard and hydrogenated vegetable oil, the lards can compete with these fats, producing desirable, palatable cake—in fact, may produce cakes with higher scores than other fats, provided a satisfactory method of combining ingredients is used.

The outstanding characteristic of lard in cake making appears to be its ability to impart a soft, velvety texture. The consistent successful use of lard in cake seems to depend on adding the egg or the egg white late in the mixing process.

TEXTURE OF THE FAT

Both Martin and Buel observed that commercial smooth lard creamed better and seemed to give better results in cake than did the commercial grainy lard.

Minard found that cakes made from grainy lard in general had higher scores than cakes made from the smooth forms of the same lard. With one drip-rendered lard Minard obtained higher scoring cakes with the smooth than with its grainy form. But this smooth lard, due to the method of cooling, was softer than the other smooth lards used. Three of the four smooth lards used by Minard were so waxy and firm, because of too rapid cooling, that they were not typical of commercial smooth lard, and it remained for Myers to continue the work with this factor.

TEXTURE OF THE FAT AND CAKE VOLUME

Myers found that the differences in cake volume (tables 17 and 7) due to the kind of fat used were highly significant. Cakes made from smooth lard had a larger average volume than cakes made of grainy lard, though both the smooth and grainy lards were made from the same original lard.

TEXTURE OF THE FAT AND CAKE SCORES

The smooth lard cakes not only scored higher than cakes made from grainy lard in texture and velvetiness but also in eating quality and total score. Flavor and the tactile sensation in the mouth are the most important factors in determining the score for eating quality. Under certain conditions flavor would carry the most weight, whereas under other environments the tactile reaction would predominate. Thus, the groups of smooth lard cakes which ranked higher in texture and velvetiness scores than the butter cakes ranked lower in eating quality. Here flavor was probably the most important factor. But with the smooth and grainy lards the cakes made from grainy lards scored definitely lower than the cakes from smooth lards, although both lards were originally from the same source. In this instance, a combination of the two factors probably caused the variation in scores. Although the cakes made of grainy lard had decidedly lower scores for texture and velvetiness, those made from smooth lard appeared to have a smaller concentration of lard flavor. However, there was also less difference in the eating quality scores from the two lards when the cakes were made by the Conventional-Sponge method than when made by the Conventional method. The distribution of smooth and grainy lard in the cake crumb is discussed under microscopical examination of the fat distribution in cake.

TEMPERATURE OF THE INGREDIENTS WHEN COMBINED

James (9) found that cake ingredients combined at 40°C. gave cakes that were definitely inferior in palatability to those combined at 25°C. In Myers' study, in addition to using smooth and grainy lard and two methods of combining the ingredients (Conventional and Conventional-Sponge), it seemed desirable also to use the ingredients at two different temperatures. Since the fats would be softer at the higher temperature, it gave an opportunity to study the effect, if any, of temperature of ingredients on the distribution of fat in the cake crumb.

Ingredients were combined at 25° and 30°C. The ingredients were incubated overnight at the desired temperature and the room temperature kept as nearly as possible at these temperatures during the time of combining. For fats, Myers used butter, and a smooth and grainy form of the same lard.

EFFECT OF TEMPERATURE OF INGREDIENTS ON CAKE VOLUME

A summary of the average cake volumes is given in table 17. The average range in volumes for all 12 groups is only 30.8 cc. with an average volume of 488 cc. for the entire group. The analysis of variance (table 7) showed highly significant differ-

TABLE 17. AVERAGE CAKE VOLUMES EXPRESSED IN CUBIC CENTIMETERS (MYERS).

Method and fat	Temperature of ingredients when combined		Average
	25°C.	30°C.	
Conventional-Sponge			
Butter	508.6	501.2	504.9
Smooth lard	485.6	485.2	485.4
Grainy lard	482.0	479.8	480.9
Conventional			
Butter	501.0	479.4	498.7
Smooth lard	477.8	483.4	480.6
Grainy lard	481.2	478.4	479.2
Average for all cakes	489.2	487.3	488.3
Average for each method of combining			
Conventional-Sponge			490.3
Conventional			486.2
Average for all cakes made of each fat			
Butter			501.8
Smooth lard			484.0
Grainy lard			480.4

ences due to methods and fats but no significant variation between the volumes of cakes combined at the two temperatures. This is further verified by the means, the volumes of all cakes mixed at 25°C. averaging 489.2 and those at 30°C. averaging 487.3 cc. The greatest variations were due to the fats used; butter cakes had the largest volume, smooth lard next and the grainy lard the lowest. The Conventional-Sponge cakes had greater volume than those made by the Conventional method.

EFFECT OF TEMPERATURE OF INGREDIENTS ON CAKE SCORES.

The figures given in table 18, for the 12 groups of cakes are averages for 25 cakes and each cake was scored by five judges. Although there was considerable range in the scores of the individual judges, all were quite consistent, in that they agreed on the quality of individual cakes.

TEXTURE SCORES

At 25°C. the smooth lard gave as good or better textured cakes than butter, but at 30°C. the cakes made from butter scored higher than those made from smooth lard. Grainy lard gave the least desirable texture of all the fats at both temperatures. The texture of all cakes was more desirable at 25°C. than under the same conditions at 30°C.

VELVETINESS SCORES

The velvetiness scores for all groups of cakes are definitely higher when mixed at 25°C. than for similar groups mixed at 30°C. Texture and velvetiness are interdependent to a certain extent as evidenced by the fact that cakes having the highest texture scores have the highest velvetiness scores. It is also quite evident that the temperature of the ingredients at the time of mixing had a decided effect upon the velvetiness of the cake. In all cases there was a wider variation in the group scores for velvetiness at the two different temperatures than for the texture scores.

EATING QUALITY AND TOTAL SCORES

The scores for eating quality and total scores are definitely higher at 25°C. (table 18) than at 30°C. The analysis of variance (table 7) shows that variations in total scores due to temperature of combining, methods of mixing and the kinds of fats used were all highly significant. The interactions of "temperature-method," "temperature-fat," "method-fat" and "temperature-method-fat," are also all highly significant. This means that not all of the variations can be explained by the sum of the variation due to temperature, method and fat taken individually. There is an increase in efficiency as measured by the variation

TABLE 18. AVERAGE SCORES OF TEXTURE, VELVETINESS, EATING QUALITY AND TOTAL SCORE OF TWELVE GROUPS, EACH GROUP BEING THE AVERAGE OF 25 CAKES (MYERS).

Temperature, method and fat used	Scores: Texture	Velvetiness	Eating quality	Total
(Possible score)	30	30	40	100
At 25°C.				
Conventional-Sponge				
Butter	25.1	25.7	31.7	82.5
Smooth lard	25.1	26.2	29.9	81.2
Grainy lard	24.1	24.7	28.1	76.9
Conventional				
Butter	22.9	22.8	29.1	74.8
Smooth lard	23.2	23.4	28.2	74.8
Grainy lard	18.0	16.9	21.6	56.5
At 30°C.				
Conventional-Sponge				
Butter	25.0	24.8	31.8	81.6
Smooth lard	23.7	23.9	27.4	75.0
Grainy lard	23.0	22.3	26.7	72.0
Conventional				
Butter	20.8	19.4	25.8	66.0
Smooth lard	19.9	17.9	22.8	60.6
Grainy lard	17.4	15.4	19.3	52.1
All cakes by Conventional-Sponge method				78.2
All cakes by Conventional method				64.1
All cakes when ingredients at 25°C.				74.5
All cakes when ingredients at 30°C.				67.9
All cakes made from butter				76.2
All cakes made from smooth lard				72.9
All cakes made from grainy lard				64.4

when they are used in certain combinations. Practically, this appears possible. For instance, the plasticity of fat varies with temperature, and the creaming quality of the fat, that is, the possibility of incorporating air, varies with its plasticity. It has been shown in this series that creaming quality and volume have an effect on the cake scores. Hydration of the flour proteins is more rapid at higher than at lower temperatures. Sugar is more soluble at higher temperatures. Egg has an undesirable effect on the quality of cake made with some fats, if the two ingredients are added to the batter at the same time. Hence, it is not surprising that certain combinations of method, fat and temperature tend to increase cake quality.

MICROSCOPICAL EXAMINATION OF FAT DISTRIBUTION IN CAKES

Although Minard made 450 cakes, histological sections were made for only 68 of these cakes. She states that when the slides were examined tendencies toward characteristic appearances due to the method of combining ingredients could be discerned. In general, the fat distribution varied less between fats than between methods. The cakes made by the Conventional-Sponge method tended to have more of the fat distributed at the edge of the air/cake crumb interface than the cakes made by the Conventional or Modified-Conventional methods.

TABLE 19. HIGHEST AND LOWEST SCORES AND RANGE OF SCORES OF TEXTURE, VELVETINESS, EATING QUALITY, AND TOTAL SCORES FOR THE 12 GROUPS OF CAKES (MYERS).

Temperature, method and fat used	Scores			
	Texture	Velvetiness	Eating quality	Total
At 25° C.				
Conventional-Sponge				
Butter	23.6—27.2 3.6	23.0—27.4 4.4	23.0—34.6 8.6	76.0—85.8 9.8
Smooth lard	23.0—27.4 4.4	24.4—27.6 3.2	23.2—34.8 11.6	73.8—88.8 15.8
Grainy lard	21.2—26.8 5.6	20.8—27.2 6.4	25.2—32.4 7.2	69.0—84.8 15.8
Conventional				
Butter	19.8—25.2 5.4	20.2—26.8 6.8	25.8—35.0 9.2	68.8—87.0 18.2
Smooth lard	21.2—25.6 4.4	20.6—26.4 5.8	23.6—31.4 7.8	65.6—82.0 16.4
Grainy lard	18.8—20.6 4.8	13.6—22.0 8.4	16.8—26.0 9.2	47.8—64.8 17.0
At 30° C.				
Conventional-Sponge				
Butter	22.2—26.4 4.2	22.0—27.0 5.0	27.0—36.0 9.0	74.0—89.2 15.2
Smooth lard	21.0—26.2 5.2	20.2—26.2 6.0	22.8—31.8 9.0	68.0—83.6 12.6
Grainy lard	19.6—25.8 6.2	17.4—26.6 9.2	19.4—32.0 12.6	56.4—84.0 27.6
Conventional				
Butter	18.4—24.4 6.0	15.4—23.0 7.6	21.6—31.6 10.0	57.4—76.8 19.4
Smooth lard	14.8—24.6 9.8	11.0—23.6 12.6	16.4—28.4 12.0	44.8—76.6 31.8
Grainy lard	8.2—23.6 15.4	4.4—22.2 17.8	9.6—29.0 19.4	22.2—73.0 50.9

The director of these investigations, after making a microscopical examination and study of slides prepared from nearly 300 cakes by Myers, then examined the 68 slides prepared by Minard and found that in the majority of instances the cakes made by the Conventional-Sponge method could be identified correctly before checking with the record. After examination of Minard's slides, the director classified them as follows:

Conventional method:
- Fat distributed mostly within crumb .... 19 slides
- Fat distributed mostly at edge of crumb .... 1 slide
- Fat distributed within and at edge .... 5 slides

Modified-Conventional method:
- Fat distributed mostly within crumb .... 15 slides
- Fat distributed mostly at edge of crumb .... 2 slides
- Fat distributed within and at edge .... 4 slides

Conventional-Sponge method:
- Fat distributed mostly within crumb .... 1 slide
- Fat distributed mostly at edge of crumb .... 11 slides
- Fat distributed within and at edge .... 10 slides

The foregoing classification shows there was considerable variation of fat distribution in the cakes made by a particular method. However, there was also considerable variation in the scores for the individual cakes. There was more uniformity of fat distribution for the cakes made by the Conventional-Sponge method than for the other members. The scores for the cake made by this method were also more uniform than for the Conventional and Modified-Conventional methods.

Because histological sections were made of only part of the cakes, Minard could draw no definite conclusions concerning the relation of velvetiness and total scores of the cake to fat distribution. She suggested that conclusions could be made only after numerous observation of fat distribution in both high and low scoring cakes.

From observations of the slides prepared by Myers, a great difference was found between the cakes mixed at 25°C. and those combined at 30°C. These differences were so great that it is preferable to consider the two temperatures separately.

One slide was chosen from each of the 12 groups of cakes, and photomicrographs at approximately 350 magnifications were taken. The slide which was chosen was as nearly typical of the group as could be found. Also, as nearly as possible, these slides were from cakes whose total scores were near the mean of the group. By doing this it was hoped to obtain an idea of the relation between fat distribution and the cake quality as measured by the scores, as well as to determine the specific effect, on the fat distribution, of the two temperatures, the two methods of combining ingredients and the three fats used. The scores in the group of 12 cakes of which photomicrographs were taken ranged from 59.6 to 85.8, so that it was found possible to trace to a greater or lesser degree the relation of decreased cake scores to a change in fat distribution.

FAT DISTRIBUTION ACCORDING TO KIND OF FAT

Figures 2, 3 and 4 show no marked difference in fat distribution because of the kind of fat used at a given temperature, except for the grainy lard. At 25°C. for the Conventional-Sponge method, the butter and smooth lard are very similar, whereas at the same temperature for the Conventional method the smooth lard is more evenly distributed at the edge of the cake crumb than the butter. The grainy lard is not so evenly or well distributed at the edge of the cake crumb in any instance. It is interesting to compare the mean scores for texture (table 18) with fat distribution. When the fat is more uniformly distributed at the edge of the crumb, the texture scores are higher. The grainy lard was inferior throughout the study in producing good cakes, particularly with the Conventional method. This was probably because the grainy lard had considerable oil separated from the more solid portion at 25°C. and still more at 30°C.,

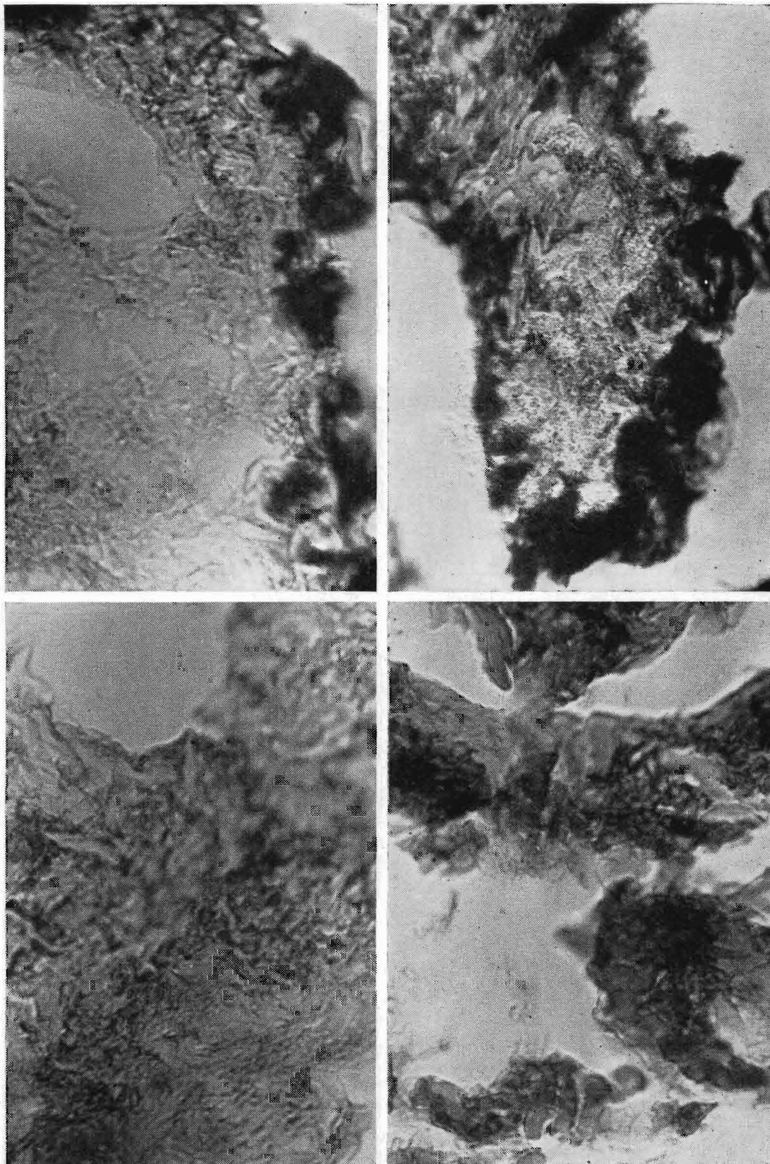

Fig. 2. The effect of temperature of ingredients and method of combining upon fat distribution in plain cake. Butter:

Upper left, Conventional method at 25° C. Score 76.6.
Upper right, Conventional-Sponge at 25° C. Score 85.8.
Lower left, Conventional at 30° C. Score 64.8.
Lower right, Conventional-Sponge at 30° C. Score 79.4.
(Magnification approximately 350 diameters)

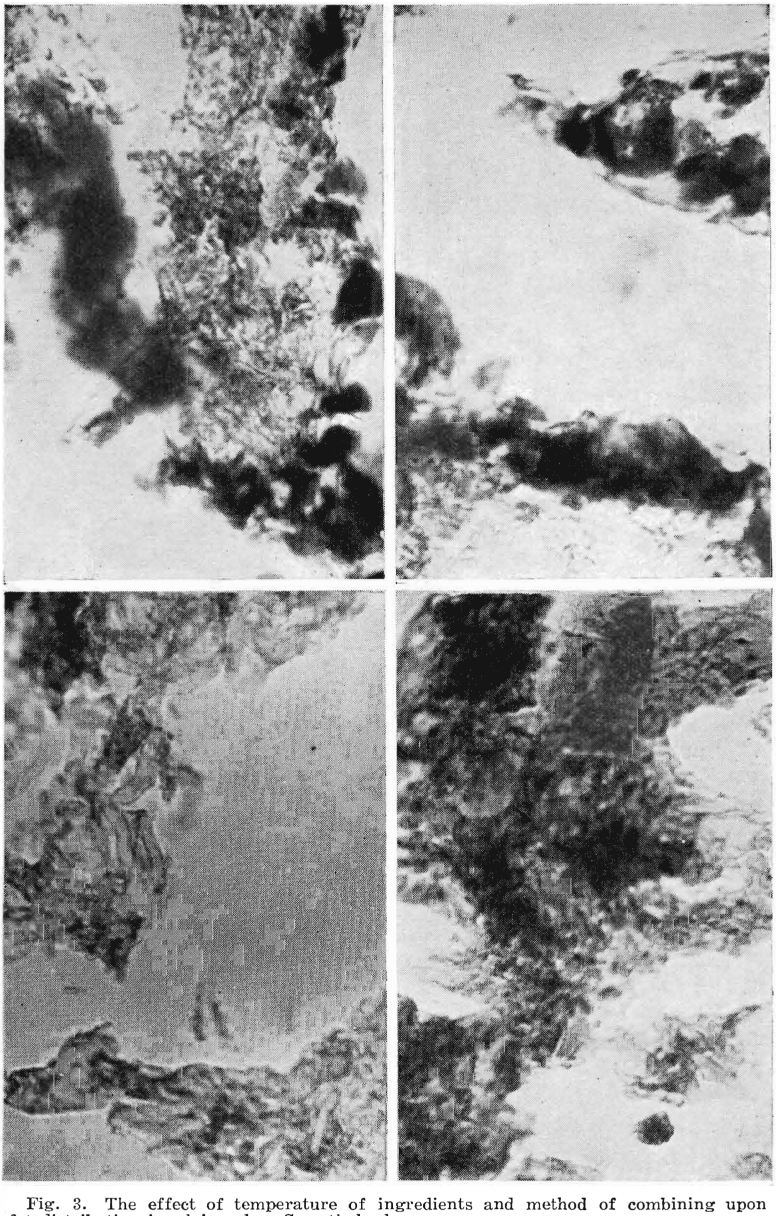

Fig. 3. The effect of temperature of ingredients and method of combining upon fat distribution in plain cake. Smooth lard:
Upper left, Conventional method at 25°C. Score 75.0.
Upper right, Conventional-Sponge at 25°C. Score 80.4.
Lower left, Conventional at 30°C. Score 58.2.
Lower right, Conventional-Sponge at 30°C. Score 77.4.
(Magnification approximately 350 diameters.)

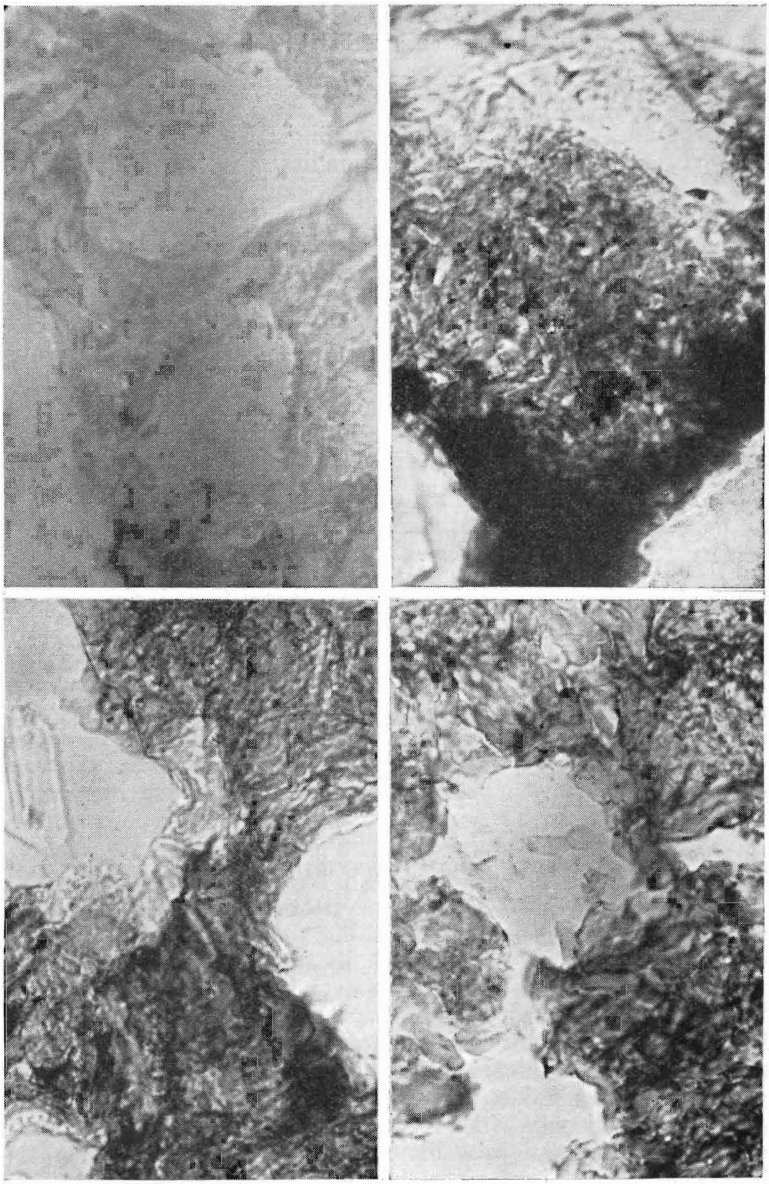

Fig. 4. The effect of temperature of ingredients and method of combining upon fat distribution in plain cake. Grainy lard:
Upper left, Conventional method at 25°C. Score 58.6.
Upper right, Conventional-Sponge at 25°C. Score 80.4.
Lower left, Conventional at 30°C. Score 54.2.
Lower right, Conventional-Sponge at 30°C. Score 72.0.
(Magnification approximately 350 diameters.)

and this oil tended to be dispersed largely as an oil-in-water emulsion when the egg was creamed with the fat and sugar.

FAT DISTRIBUTION ACCORDING TO TEMPERATURE

When the ingredients were combined at 25°C., the slides showed the characteristic distribution described by Minard when she states that the "lard cake . . . typically showed a concentration of the fat in layers of varying thickness around holes of the cake crumb." However, this layer of fat does not always appear as a distinct line but as a margin made up of particles, spheres or grains of uneven shapes and sizes. Sometimes a portion of the fat is dispersed very finely in the crumb structure. Sometimes there are areas of greater concentration of the fat within one crumb, as if it were in pools, films or layers. The amount and distribution of the fat within the crumb varies greatly. It should be remembered in looking at the photomicrographs that they showed two dimensions only, whereas the cake crumb was three dimensional, and in a few instances what appears as a pool or film throughout the crumb may really be a marginal layer. The sections of the cake were cut 20 microns in thickness, and because of the diffraction of the light through the crumb, the crumb appears more like a liquid than if the sections had been cut 10 microns in thickness.

The cakes combined at 30°C. show none or very little of the layers or margins of fat at the air/cake crumb interface, which are typical of the cakes combined at 25°C. At 30° the fat particles are smaller and more uniformly dispersed throughout the cake crumb. As with the fats and methods of combining, there is considerable variation in the concentration and distribution in the different cakes.

DISTRIBUTION OF FAT ACCORDING TO METHOD

Figures 2 to 4 show that the fat distribution is definitely affected by the method of combining the ingredients. The fat distribution for the cakes made by the Conventional-Sponge method was more uniform at the margins of the cake crumb than for the Conventional. The scores for the cake crumb also varied less for the Conventional-Sponge than for the Conventional method, which checks Minard's results. The scores of the Conventional-Sponge cakes ranked higher for each fat at both 25° and 30°C. The egg, which is the best oil-in-water emulsifier of the cake ingredients, probably affected the fat distribution, as it was added last in the Conventional-Sponge method. At 25° there is a more even distribution of the adsorbed margin of fat at the cake crumb surfaces than for the Conventional method. At 30° the cakes made by the Conventional-Sponge method show more tendency to have spots of greater concentration and less fat dispersed in tiny spheres within the crumb.

DISCUSSION

Fat distribution has a relation to the cake scores. Though an important one, it is not the only factor affecting cake quality and cake scores. In some instances, it was impossible to predict from the microscopical examination whether a cake would be high or low scoring. If from the fat distribution it appeared that the cake should have a high score, yet had a low one, it seemed that the size of the cells and the thickness of the cell walls had some relation to the cake scores. In other cases inspection of the slide of the baked cake gave no clue to the score. No study was made of the distribution of fat and sugar in the cake batter in these investigations, but from other work done in this laboratory, it seems that the distribution and size of the sugar crystals has some relation to the palatability of cake. This will be considered later.

In the majority of cases in which there was a decrease in the cake scores, the margin of fat around the air/cake crumb interface of cakes combined at 25°C. became more uneven and broken and thus covered a progressively smaller proportion of the surface of the cell walls. From this it appears that if the fat is divided evenly enough so that the cake cells have quite a distinct margin or layer of fat, the cake is likely to be fine textured and velvety. On the other hand, cakes of poor texture which lack velvetiness have many surfaces at which no fat is adsorbed and at other surfaces have an excess of adsorbed fat. (See fig. 4, photomicrograph of the cake made by the Conventional-Sponge method at 25°C.) The average total scores for all cakes mixed at 25°C. was 74.5, of those mixed at 30°, 67.9.

The cakes combined at 30°C. showed only a few or none of the marginal layers of fat at the edge of the cake crumb. If this distribution did occur the cakes usually had high scores. For the majority of cakes mixed at 30°, the higher scoring ones were those with a good, yet not too even nor too fine a dispersion of the fat within the crumb. The photomicrographs for butter and grainy lard (figs. 2 and 4) at 30°C. are typical.

The possibilities for the dispersion of the fat within the cake crumb are as follows: 1. Oil-in-water emulsion, 2. water-in-oil emulsion, 3. films adsorbed on cake ingredients, i.e., starch, proteins and sugar crystals, and 4. at cake/air interfaces.

Possibly more than one or all of these distributions are found in the cake crumb. Microscopic examination of the slides tends to confirm this. The distribution of fat in the cake probably is affected to a certain extent by the distribution in the creamed mixture and the cake batter.

Lowe (10) found that fat is adsorbed very strongly by sugar crystals during creaming. In fact, the fat is adsorbed so strongly, that even after the liquid and flour are added to the creamed mix and the sugar is partially dissolved as shown by the rounding off and decrease in size of the sugar crystals, a layer of fat still clings to the sugar. Additional work has shown that the distribution of these sugar crystals is an important factor in obtaining velvety cakes. If these sugar crystals are bunched so that they look like a cluster of grapes, the texture of the cake is not so velvety as when the sugar crystals are evenly distributed.

FAT IN THE CREAMED MIXTURE

When plastic fats and sugar are creamed, a foam is formed. A large portion of the fat is of course adsorbed by the sugar. When egg is creamed with the fat and sugar, an emulsion also may be formed. Grewe (8) has reported that the creaming of butter, sugar and egg together produces an air-in-oil foam and a water-in-oil emulsion. It was also shown that this emulsion was more stable if the egg was added gradually to the creaming mixture. However, all of Grewe's ingredients were at 25°C. or below when combined, and the final distribution of the fat in the cake batter and the cake are not known. The most stable emulsion for the samples of butter used was at 22°C.

An oil-in-water emulsion may be formed (a) at temperatures at which the fat is very soft yet not quite melted, (b) when considerable oil has separated as in grainy lard, (c) when the fat is melted or (d) an oil is used. As the fat becomes softer or is melted, it is more mobile, hence the force the emulsifying agent (the egg) exerted without much effort at 25° when the fat was firmer or even formed another type of emulsion, is now sufficient to emulsify the more mobile fat as an oil-in-water emulsion. The emulsifier is adsorbed on the surface of the fat or oil and exerts a squeezing effect dispersing the fat in small spheres. Thus, at higher temperature there is a tendency for the proportion of oil-in-water emulsion to increase. Microscopic study of the creamed mixture supports this supposition. It is, of course, possible for both water-in-oil and oil-in-water emulsion to occur in the same mixture. If egg is not creamed with the fat and sugar, only a foam is formed, unless some water is present as when butter is used.

FAT IN THE CAKE BATTER

When milk and flour are added to the creamed ingredients, the mixture becomes still more complex. Seifritz (19) has reported that olive oil stabilized with albumen (found in egg white and in milk) and lecithin (found in egg yolk) forms an oil-in-water emulsion, but the same oil stabilized with casein (found in milk) and gliadin (found in flour) forms a water-in-oil emulsion. Hence, with the addition of the liquid and flour other emulsifying agents are found in the mixture, some of which may exert antagonistic tendencies. With the addition of the last two ingredients curds are often formed in the cake batter. Grewe (8) thinks the cake texture is better if these curds do not form and attributes their formation to the breaking of the water-in-oil emulsion. The observation of the director of these studies with the formula used in these investigations is that the texture of the cake is improved if fine curds are formed, but these curds should not be too large. The texture is definitely not good with the formula used in these investigations, if the fat is melted or an oil is used, and the cake is combined by the "Muffin" method of mixing. In these cases, no curds are formed, the batter is smooth, runny instead of viscous, and the cake is rubbery, tougher and with unpalatable crumb. The formation of these curds may be due to the breaking of a water-in-oil emulsion and to partial reversal of this type of emulsion, or it may be the breaking of the foam with adsorption of the fat on new surfaces such as starch and flour proteins. Mention has been made of the fact that the undissolved sugar carries a film of fat into the batter. The dissolving of part of the sugar after the addition of milk or liquid may also aid in forming the curds. The partial dispersion of the fat by the sugar may partially explain why cake textures are better if the proportion of sugar is not too small. With a smaller proportion of sugar, 1 cup instead of 1½ cups in the formula used, the cake texture is definitely inferior in quality. With the smaller proportion of sugar, more sugar dissolves before the batter starts baking, leaving pools of fat which possibly may combine as the batter is stirred.

The fat distribution may again change in baking. Plastic fats are melted during baking and gas is evolved by the leavening agent. The sugar dissolves completely, probably leaving its film of adsorbed fat in a pool, layer or sphere. This fat may be adsorbed at the surface of the gas phase produced by the release of the carbon dioxide from the baking powder in the dough. The increasing temperature of the dough not only increases the release of carbon dioxide but melts the fat.

FAT DISTRIBUTION IN CAKES

When two or more substances that lower the surface tension are in a sol (in this case the batter), by Gibb's law the one that lowers the surface tension the most occupies the surface layer. In baking, as the fat melts, it has an opportunity to take this surface, and it is evident that the distribution of fat in the batter affects the distribution in the cake to a certain extent, for the method of combining the ingredients and the temperature of combining both affect the fat distribution in the finished cake.

The rate of baking also may affect the fat distribution somewhat. It has been shown in this laboratory by Stone (20) that baking portions of the same batter at different temperatures produces decidedly different textured cakes, those at lower than optimum temperatures being coarser textured, harsher and less velvety. The fat distribution in these cakes has not been studied microscopically, however.

The photomicrographs show that the fat in the cake is distributed at the edge of the air/cake crumb interface and within the crumb. The former would hardly be classed as an emulsion but as adsorbed layers. It is of course possible that oil-in-water or water-in-oil emulsions or both are present within the cake crumb, and in addition some pools or layers of adsorbed fat also are found. The type of emulsion which predominates within the cake crumb also may partially determine the velvetiness and texture of the cake. All the dark, round spots in the photomicrographs do not appear alike. Some are dark throughout, whereas others have a dark margin with a lighter color in the center. The latter occur more often in the butter cakes combined at 25°C. than in the lard cakes and may be water-in-oil emulsions. The histological sections show that even at 25°C. some of the fat is dispersed as an oil-in-water emulsion.

When the ingredients are combined at 30°C. there is no question but that most of the fat in cakes is dispersed as an oil-in-water emulsion, but there are also some pools or layers throughout the crumb that are not well dispersed, and only occasionally is there a layer of fat at the air/cake crumb interface. Certainly the cakes are not as desirable nor palatable if practically all the fat is distributed as an oil-in-water emulsion, as is shown by the scores of the cakes combined at 30°C. by the Conventional method.

Additional evidence that an oil-in-water emulsion is being formed at the higher temperatures is shown by the fact that these cakes are less tender and velvety than those mixed at a lower temperature. If the fat is dispersed within a protein film, like egg protein, which coagulates on baking, it would cover less surface of the flour, and its shortening power would be decreased.

Smooth lard had no oil separated from the main mass of the fat at 25° and 30°C., but grainy lard had considerable oil. This oil, being more mobile, would be more readily emulsified than the plastic fat.

Butter, because it has a lower melting point than lard, might be more easily emulsified than lard at 30°C. This tendency is shown in the photomicrographs of the butter cakes (fig. 2) by the presence of tiny stained spheres in certain parts of the structure. Butter cakes contain only about 80 percent as much fat as the lard cakes, because part of the weight of the butter is water, curd and salt. The curd may tend to form water-in-oil emulsions instead of oil-in-water. Whatever the explanation, cakes made of butter combined at 30°C., scored higher for texture than the lard cakes combined at the same temperature in Myers' study.

The question was raised as to whether the cake sections actually represent the fat distribution of fresh cake. After the cake sample was stained with osmic acid, it was dried overnight to keep the sample from disintegrating in the warm paraffin. In natural staling a definite change in the colloidal structure of the cake takes place. If this did occur, it might have altered the fat distribution as it existed in the fresh cake to the fat distribution of stale cake. In that case the photomicrographs would show the fat distribution of a partly or wholly stale cake which might be different from that of fresh cake. However, the deposition of a compound of the heavy metal osmium with each fat particle seemed to stabilize the fat and perhaps the entire cake structure. The blackening of the fat in staining is due to the reduction of osmium tetroxide to a lower oxide, such as osmium dioxide, by the unsaturated molecules of true fats and lipids. A difference in the percentage of unsaturated molecules would result in a different rate and depth of blackening for a given time of exposure. This may have prevented staling, for in cutting the sections those which were well stained did not crumble and break as much as those which were not well stained. It has not been shown conclusively, however, that staling did not take place.

SPECIAL TESTS

TEXTURE INDEX

The values obtained by Myers from the technic described under the procedure for taking tests, "Texture index," were correlated with the texture scores. There was a highly significant negative correlation of —0.459. This negative correlation indicates that a small texture index is obtained from a cake with a high texture score. The cakes with good textures have finer cells with finer walls and therefore retain a smaller amount of sand in the cells.

This correlation is sufficiently high to encourage further work to develop it as a reliable objective test for estimating the texture of cakes. The need for objective tests to replace or supplement scoring has long been evident. This test seems to offer real promise. Although very careful technic is required, little extra equipment is necessary .

BREAKING ANGLE

Through an oversight Myers' cakes were not scored for tenderness, as they should have been. But in looking over data obtained from eight previous studies for the tenderness, velvetiness, texture and eating quality, tenderness seems most nearly related to velvetiness. Therefore, the data from the breaking angle test were correlated with velvetiness scores. Myers obtained a small but highly significant negative correlation of —0.181. Although the test is probably not well enough refined at present, as indicated by the small figure, the relation between the two values is enough to suggest the possibility of a satisfactory test and to relate it to tenderness scores.

It would have been interesting to have compared tenderness scores instead of velvetiness scores with the results of the breaking angle tests. However, in studying the tenderness scores for the eight investigations in plain cake series, it was found that little differentiation was made in tenderness.

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APPENDIX

TABLE A. CREAMING DATA FOR INDIVIDUAL ANIMAL HUSBANDRY LARDS.

Lard	Highest temperature reached by creamed mix (°C.)	Time to reach maximum volume (min.)	Volume of 25 grams of creamed mix: At end of 2 minutes (cc.)	Volume of 25 grams of creamed mix: Maximum (cc.)	Volume of 25 grams of creamed mix: Percent of maximum volume as air	Time maximum volume was maintained (min.)	Iodine number (Wijs)
43	30.5	120	22	31	38.2	10	58.6
2	27.0	55	21	30	30.0	65	59.4
40	30.0	25	22	27	18.5	65	59.9
29	30.0	55	22	33	33.3	10	60.3
12	29.5	35	22	32	31.2	30	60.7
1	28.0	55	22	33	33.3	25	61.4
27	29.5	55	22	32	31.2	5	61.4
13	29.5	45	22	31	29.0	35	61.7
11	30.0	30	23	30	23.4	35	61.9
20	29.5	55	23	34	32.3	85	63.0
32	30.5	40	22	34	35.2	5	63.1
14	30.5	50	20	31	35.4	20	63.3
30	31.0	50	22	34	35.2	5	64.1
31	30.5	35	22	32	31.2	30	64.1
19	29.5	30	22	30	26.6	45	64.3
4	31.0	40	23	32	29.1	15	64.3
7	31.0	120	22	33	33.3	5	64.4
37	29.5	70	21	33	36.3	40	64.5
38	31.0	140	21	34	38.2	20	64.8
3	32.0	40	22	31	29.0	15	65.0
25	30.0	40	22	33	33.3	40	65.0
24	30.5	90	22	34	35.2	60	65.1
15	30.5	35	22	34	35.2	5	65.4
26	29.0	55	23	33	30.3	65	65.6
6	32.0	55	21	34	38.2	45	65.6
16	31.5	35	23	34	32.3	20	65.9
18	29.0	40	22	30	26.6	5	65.9
92	28.0	40	22	33	33.3	60	66.0
17	29.5	35	23	34	32.3	15	66.3
45	30.0	35	22	31	29.0	10	66.4
5	28.0	30	22	30	26.6	10	66.8
67	29.0	40	22	34	35.2	5	68.2
28	28.0	40	22	32	31.2	80	68.7

Total creaming time 260 minutes (KitchenAid at low speed); full amount of recipe used; proportions of fat to sugar by weight, 1:2.6.; room temperature varied considerably; initial temperatures of ingredients 24.5° to 26°C. Arranged according to increasing iodine number (Martin).

TABLE B. ANIMAL HUSBANDRY INDIVIDUAL LARDS GROUPED ACCORDING TO INCREASING TEMPERATURE OF THE CREAMED MIXTURE AT POINT OF MAXIMUM VOLUME, WITH SOME DATA FOR TEMPERATURE, TIME AND VOLUME OF THE CREAMED MIXTURE. PERIOD FOR CREAMING 260 MINUTES (MARTIN).

Temperature of creamed mixture at maximum volume (°C.)	Lards, number	Initial room temperature (°C.)	Room temperature at maximum volume (°C.)	Average time to reach maximum volume (min.)	Average maximum volume 25 gms. creamed mixture (cc.)	Average iodine numbers of lards
24.5	25, 40	23.5	23.5	32.5	30	62.4
25.0	4, 5, 19, 28, 30	22.4	23.4	38.0	31.6	64.6
25.5	2, 3, 11, 17	22.5	23.9	40.0	31.2	62.1
26.0	12, 15, 16, 20, 26, 27, 31, 67, 92	22.8	24.1	42.2	32.7	64.5
26.5	13, 32, 45	22.8	24.6	40	32	63.7
27	1, 6, 14, 18, 37	24	25.1	54	33	64.1
27.5	7, 24, 29	20.8	23.8	85	33	63.2
29	38	24	24	140	34	64.8
29.5	43	24	25	120	34	58.6

TABLE C. ANIMAL HUSBANDRY INDIVIDUAL LARDS GROUPED ACCORDING TO INCREASING TEMPERATURE OF THE CREAMED MIXTURE, WITH SOME DATA FOR TEMPERATURE, TIME AND VOLUME OF THE CREAMED MIXTURE. PERIOD FOR CREAMING, 30 MINUTES (MARTIN).

Temperature of creamed mixture at maximum volume (°C.)	Lards, number	Average initial room temperature (°C.)	Average room temperature at 30 minutes (°C.)	Average volume 25 gms. creamed mixture at 30 minutes (cc.)	Average iodine numbers of lards
25.5	15	24.0	24.0	29	65.4
26.5	1, 5, 16, 28	24.0	24.2	29.7	65.7
27.0	2, 6, 11, 19, 20, 25, 27, 29, 30, 32, 45, 67	24.2	24.2	29.7	64.6
27.5	3, 7, 24, 26, 37, 40, 92	24.4	24.6	30.3	64.4
28.0	4, 17, 31, 38. 43	24.4	24.5	30.4	63.6
28.5	12, 18	24.7	25.5	31.5	63.3
29.0	13	25	25	32	61.7
29.5	14	25	25	32	63.3

TABLE D. ANIMAL HUSBANDRY INDIVIDUAL LARDS WITH AVERAGE CREAMED VOLUMES AND IODINE NUMBERS, GROUPED ACCORDING TO INCREASING GRADE OF FIRMNESS OF CARCASS FROM WHICH THE LARDS CAME, AS JUDGED BY THE ANIMAL HUSBANDRY DEPARTMENT (MARTIN).

Grade of carcass as judged by A. H. Department	Lard numbers	Average maximum volume of 25 grams creamed mixture cc.	Average iodine number of lards
Soft	15	33	65.4
Medium hard	4, 5, 6, 7, 16, 17, 18, 20, 26 27, 36, 67, 92	32.9	65.1
Hard	1, 2, 3, 11, 12, 13, 14, 19, 24, 25, 28, 29, 30, 32, 37, 38, 40, 43, 45	31.9	63.1

TABLE E. CHEMICAL AND PHYSICAL CONSTANTS OF ANIMAL HUSBANDRY COMPOSITE LARDS. FIRMNESS OF CARCASS AND OBSERVED FIRMNESS OF LARDS (MARTIN).

Lard	Iodine number of lard (Wijs)	Average iodine number of back fat samples	Free fatty acids as oleic %	Melting point °C.	Kreis test at 3 weeks	Carcass firmness as judged by A. H. Dept.	Firmness of lards as observed by Martin
F	63.6	68.7	0.80	47.0	......	Very hard	Very firm
D	67.5	75.1	0.41	47.5	....	Hard	Quite soft
E	68.1	74.5	0.34	47.0	....	Medium hard	Quite firm
A	70.6	73.2	0.40	46.0	......	Hard	Firm
B	70.6	75.6	0.30	47.0	....	Hard	Firm
C	75.4	82.1	0.59	47.0	....	Soft	Soft
I	76.8	84.0	0.28	46.5	......	Medium soft	Quite soft
G	81.5	87.2	0.43	47.0	......	Very soft	Very soft
H	83.4	90.2	0.20	50.0	....	Very soft	Softest

TABLE F. SCORE CARD FOR CAKE.

Date..

Number of cake	Volume in cc. of 25 gms. creamed batter	Temperature			Volume in cc. of cake
		Room	Creamed batter	Cake batter	
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

	Number						
	Perfect score						
Crumb: 1. Texture, cell walls thin and fine. 2. Cells rather small in size but not too compact or too large. 3. Crumb, springy and elastic	30						
Tenderness: Tender, not tough or gummy	20						
Velvetiness Smoothness, softness like velvet to tactile sense; (finger or palate)	20						
Eating quality: This includes aroma, flavor, velvetiness and all the qualities that make the cake agreeable or disagreeable for eating. Not rancid, not too sweet, not too much of any one ingredient. Texture soft and pleasing.	30						
Total	100						

Scorer ....