CHOCOLATE CAKE I. OPTIMUM BAKING TEMPERATURE

by

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INTRODUCTION

Many people believe that a lower baking temperature is required for a batter containing chocolate, honey, molasses, or fruit than for a plain cake batter of the same general formula. Stone (10) found that the optimum temperature for baking plain cake in a loaf pan was 185°C. With too low a temperature a marked decrease in volume and poor texture resulted. Likewise, too high an oven temperature produced a cake of more close, compact texture and of less volume than a similar cake baked at 185°C. However, no accurate scientific information is available relative to the optimum baking temperature for chocolate cake.

Because of the scarcity of experimental work on the effect of baking temperature on chocolate cake, this present investigation was undertaken to determine the effect of oven heat on cakes of different formulae. Thus the purpose of one part of the study was to determine whether cakes having a higher ratio of sugar would require a higher baking temperature. In addition, since many people add hot rather than warm chocolate to the cake batter, this practice was also studied to determine its effect on the volume, texture, tenderness, and velvetiness of the baked cake.

REVIEW OF LITERATURE

Grewe (3) believes that prevention of breaking the fat-sugar-egg emulsion is one of the important problems in cake making. The persistence of a stable emulsion after the milk, flour, and other ingredients are added is of major importance also. As a result of her study, Grewe reports that emulsions were much more stable when small portions of the beaten egg were added at intervals of 0.25 minutes rather than at 0.10 minute intervals. With more rapid addition of the egg, more air was occluded in the emulsion and thus it was not nearly as stable.

According to Grewe (2), the ingredients which may affect the color of chocolate cake are milk, soda, baking powder, egg yolk and the kind and quantity of chocolate. Cake made from sweet milk is the darkest and that from strongly acid milk the lightest in color. The variety of cocoa beans and the various processes which they undergo during manufacture, are important factors in the color of chocolate. Naturally, an increase in the amount of chocolate used will give an increase in color in the baked cake. Cakes made with pale yellow eggs will be lighter in color than similar cakes made with darker colored egg yolks; the difference, however, is not great.

Grewe (2) states that "the color constituent of chocolate has the properties of an indicator over the range in which chocolate cake has desirable eating quality." Chocolate is yellow at pH 5.0 and is increased in value to red at pH 7.5. Therefore any variation in the formula which resulted in a change in the hydrogen-ion concentration, such as the amount of soda or baking powder used, or the variation in the pH of the egg white, would be responsible for a change in the color of the baked cake.

Shank (9) found that when the sugar was decreased too much in the recipe a compact texture and somewhat dry cake resulted. With too great an increase in sugar she states that the cake "has a wrinkled appearance; has a tendency to fall, and the texture is too loose."

For a layer cake nine inches in diameter, with an original batter weight of 468 grams, Shank (9) determined that the best baking temperature was 350°F. for 35 minutes. With a lower temperature, she found that the texture of the cake was loose and dry. With baking temperatures above 350°F., the center of the cake was rounded with uneven texture.

By means of graphs, Lowe (4) indicates that the volume for a rich chocolate cake, i.e. with a high ratio of sugar and fat, increases with an increase in baking temperature up to 215°C. With a less rich batter the volumes also show a steady increase from 165°C. to 205°C.

Lowe (4) also shows that a palatability score increased with baking temperatures from 165°C. to 205°C. for a rich chocolate cake. With a less rich formula, a gradual increase in scores was observed for cakes baked at 175°C. to 205°C. with a decrease for those baked at 215°C.

Schaal (8) states that "in baking chocolate goods a good solid heat with a good solid bottom and no flash is best." He indicates that the cake should be baked at a moderate temperature (about 380°F.) until barely done as overbaking impairs the flavor as much as a temperature which is uneven or very high.

EXPERIMENTAL PROCEDURE

General Plan

For this study a total of 270 small loaf cakes was made. Series A with the regular formula had the melted chocolate added at 40°C. The same proportions were used for Series B with the chocolate added at 60°C. and the last series, also a variation of Series A, had the sugar increased to 450 grams. Each mix was divided into six cakes each of which was baked at a different temperature.

The cakes were baked over a period of seven weeks from April 18 to June 2. Usually only six cakes were baked daily, although occasionally two sets consisting of 12 cakes were made in one day. The cakes were always scored and tested the day after they were baked. The series were alternated so that all three groups were finished at approximately the same time. The order in which they were baked was also randomized. In this way the scoring for each series was more valid since the judges did not score any one series long enough to acquire a distinct preference or dislike for it.

All the ingredients, with the exception of the milk and chocolate, were incubated in a thermostatically controlled box at a temperature of approximately 27°C. for at least twelve hours before mixing. The temperature of the room in which the mixing was done varied from 25° to 26°C. with an average of 25.08°C. for the entire period.

The conventional method of mixing was used. For a description of the process see Section C, Part 2 of the Experimental Procedure.

Materials and Equipment

Ingredients

All staple ingredients were obtained in sufficient quantities for the entire experiment. The finely granulated beet sugar and cake flour* were each stored in a tightly covered galvanized can in the laboratory. Two pounds of salt were placed in a covered glass container at the beginning of the experiment. Two cases of chocolate, a sixteen ounce bottle of vanilla, and five pounds of tartrate baking powder were also purchased for this experiment. Milk and eggs were obtained fresh daily from the store room, and butter fresh weekly.

Equipment

Three thermometers with calibrations as nearly the same as possible were used. One was suspended from a ring stand near the electric mixer; another was used to obtain the temperature

*Swansdown.

of ingredients and of the batter; the third was placed in the constant temperature box.

An electric mixer was used for all of the creaming process. Other equipment included Hygrodeik, slotted wooden spoon, rotary egg beater, double boiler for melting chocolate, two large mixing bowls, four smaller mixing bowls, rubber scraper, 25 cc. graduate, 100 cc. graduate, a flour sieve of medium fine mesh, six small loaf pans 2½ inches deep and 3½ x 6 inches at the top and 3 x 5¼ inches at the bottom, wire racks, and stop watch.

The temperature of the gas ovens* was controlled not only by the automatic regulator but also by thermometers inside the ovens.

Recipe and Procedure

Recipe

Series A.

Butter	1 cup	224 grams
Sugar	2 cups	400 "
Eggs	4	192 "
Chocolate	4 squares	113 "
Cake flour	3 cups	300 "
Milk, whole	1 cup	244 "
Baking powder	5 teaspoons (Approximately)	17.5"
Vanilla	1 teaspoon	5 cc.
Salt	½ teaspoon	2 grams

*Clark Jewel Type oven with Lorain heat control.

The melted chocolate was added at 40°C.

Series B.

The proportions were the same for this series as for A, the variable being that the chocolate was added at 60°C.

Series C.

For this group the sugar was increased to 450° grams with the other proportions remaining the same. Like the first series, the chocolate was added at 40°C.

Weighing and storing of ingredients

1. Weighing in advance.

Sufficient sugar, butter, salt, grated chocolate, baking powder, and flour were weighed on a Cence trip balance for a week in advance. The butter and grated chocolate were wrapped in waxed paper while white wrapping paper was used for the other ingredients. The butter was kept in the refrigerator. The weighed flour and baking powder were sifted together three times and then weighed into three equal portions.

2. Incubation.

The sugar, butter, salt, vanilla, eggs, and flour mixture were placed in the constant temperature box over night.

3. Other preparation.

a. In the morning the eggs were beaten a total of 125 strokes with a rotary beater. They were weighed and then placed in the incubator until time to be used.

b. The fresh milk was thoroughly mixed to make it as homogeneous as possible and quickly weighed. It was then heated in a pan of lukewarm water to 25°C. and likewise placed in the incubator.

c. The grated chocolate was melted in the top of the double boiler over hot water.

Combining

1. Special techniques.

   a. The relative humidity and room and incubator temperatures were recorded.

   b. The volume of the creamed mixture was recorded before adding the eggs, after adding the eggs, and after adding the chocolate; the volume of the batter was also taken. These volumes were obtained by alcohol displacements as described by Myers (7). Great care had to be exercised to always get the mixture as nearly as possible on the same place on the waxed paper and also to have the same amount of paper within the alcohol. This volume could then be changed into specific gravity by this formula:

$$\text{Specific gravity} = \frac{\text{weight}}{\text{volume}}$$

   c. The temperature of the creamed mixture was taken after adding the chocolate and that of the batter was taken just before putting it in the pans.

d. The bottom of each cake pan was covered with waxed paper and 240 grams of batter were added to each pan.

2. Method of mixing. Though this method varies considerably from those used by former investigators, preliminary work with more than 150 small cakes seemed to indicate that this was the best procedure.

a. The butter, sugar, salt and vanilla were creamed on low speed in the Kitchen Aid mixer for two minutes and scraped down. The speed of the machine was changed to medium and this was used for the remainder of the mixing period. The mixture was creamed for three minutes more, and scraped down.

b. Gradually the beaten eggs were added within a minute and a half as mixing continued. At the end of two minutes the mixture was scraped down. Creaming was continued for two more minutes and the mixture was again scraped down from the sides of the bowl.

c. The melted chocolate was added, creaming was continued for one minute and the mixture was again scraped down. The mixture was creamed for another minute.

d. The milk and flour mixture was added by hand. One-third of the flour mixture and one-third of the milk by volume were mixed with 15 rather light strokes with a slotted wooden sppon to mix the loose flour into the mixture and then with 60 additional vigorous strokes. The other two portions of milk and flour were added in the same way.

3. Baking.

Table I gives the time and temperature used for each of the six cakes. The pans were rotated in the ovens so that those weighed out last and therefore receiving more mixing were never baked in the same oven on two successive days. There were only five oven thermometers. Since the three high temperature ovens varied the least, one of the ovens was used for two days without a thermometer. On the third day a thermometer was taken from one of the other two ovens. Such rotation checked the setting of the automatic regulators.

Table I. Baking Times and Temperatures

Oven number	°C.	°F.	Baking time in minutes
1	175	347	39
2	185	365	36
3	195	383	33
4	205	401	30
5	215	419	27
6	225	437	24

Special Techniques after Baking

Volume

The volume of the cakes was taken by seed displacement according to the method and with the same equipment as that described by Buel (1).

Scoring

The cakes were cut, scored and tested the day after they were baked. To give uniform pieces of cake, they were sliced in the miter box for all of the scoring and mechanical tests. Each judge received identical half slices from each cake to eliminate the variables of position in the oven and portion of the cake. Slices too near either end could not be used since they were much drier than the center portions. Each piece was carefully wrapped in waxed paper with the number of the cake plainly visible. A sample of the score card used is indicated in the Appendix.

Breaking angle

The tenderness of the cake was tested with the breaking angle apparatus as described by Myers (7). A slice of cake one-half inch thick was cut with a cookie cutter measuring 1.5 x 2.5 inches.

As the movable holder of the breaking angle apparatus was very gradually moved away from the operator, the pointer showed the number of degrees required for the angle of breakage. The readings were recorded at the point where the slice of cake just began to break. These readings ranged from 8° to 36°.

o slices of cake, one from the end and the other from
ter, were tested from each cake and the scores totaled.
are had to be taken in slicing the cake, so that the
as the same thickness at the bottom as it was at the
definite technique had to be developed in revolving
able portion slowly and steadily.

index

an attempt to quantitatively measure the texture of
method was used as described by Myers (7). A similar
had been suggested to Myers by Swartz and Swartz (11)
published her method of procedure. Rounds $1\frac{1}{2}$ inches in
er were cut with a cookie cutter from two one-half inch
slices. Each round was generously sifted with sand
just went through an 80 mesh sieve. The sample was then
two complete revolutions on a 45° incline to permit
sand to fall off which was not retained in the pores
cake. The round was weighed, inverted and shaken five
to remove as much of the sand as possible from the pores.
the round was weighed and the difference in weight was
ed as an indication of the texture.

and was used in measuring the texture because of its
y, accessibility, density, and ease of sifting to uniform
le size.

Moisture index

According to Swartz (11) "At least part of the eating character of cake is due to the ability of the cake to become moistened with saliva in the first few seconds of chewing." Since this moisture absorbing property seems to be inherent in fresh cake, greater water absorbing ability would seem to be a desirable quality.

Samples of the same size and shape as for the texture index were used. Each round was quickly weighed and then dropped by means of a two-tined fork into a $3\frac{1}{4}$ inch Petri dish containing 30 cubic centimeters of water, which had been in the incubator overnight. After five seconds the round was quickly removed and immediately weighed. It was hoped that the difference in the two weights could be used to determine the relationship of ease of moisture absorption to eating quality.

RESULTS AND DISCUSSION

General

The room and incubator temperatures were standardized as well as possible to 25°C. and 27°C. respectively. In the early part of the experiment several attempts were made to adjust the temperature of the incubator to 25°C., but since this was impossible the slightly higher temperature was taken as the standard. The average room temperature was 25.08°C. and that for the incubator was 27.02°C. Inspection of the data showed that the room and incubator temperatures did not vary enough to warrant an analysis of these data.

Relative Humidity

In general, the relative humidity was very high throughout the entire experiment (see Table II). The mean humidities for the three series did not vary greatly, from 91.2 to 93.3. In addition, the humidities during the time that the fifteen cakes within each series were made did not vary greatly and neither of these differences in humidity between series nor for mixes within a series varied significantly.

Table II. Means and Mean Totals for Three Series of Chocolate Cakes for Relative Humidity, Temperature of Creamed Mixture after Adding the Melted Chocolate, and for the Cake Batter Temperature

Variable	Series A Chocolate 40°C.	Series B Chocolate 60°C.	Series C Chocolate 40°C.	Mean Totals
Relative humidity	92.7	93.3	91.2	92.4
Temperature of creamed mixture after adding chocolate	25.0	26.2	25.2	25.5
Temperature of cake batter	25.5	26.1	25.2	25.6

Temperatures

The mean temperature for the creamed mixtures and the cake batter are given in Table II. The mean temperatures of the creamed mixture of the two cake series in which the chocolate was added at 40°C. were 25.0 and 25.2. Whereas for the series in which the chocolate was 60°C. when added the mean temperature was 26.2. Throughout the study the temperature of the creamed mixture varied but slightly for a given series. This was verified by the analysis of variance which showed the difference in these series temperatures to be highly significant.

Specific Gravity Taken at Four Different Stages during the Mixing Process

The data indicated that the specific gravity of the mixture increased consistently throughout the mixing period as seen in

Table III. In other words, with further mixing and addition of ingredients the volume of a given weight of the mixture decreased. A highly significant difference was noticed between the four stages at which the specific gravity was taken.

Table III. Means and Mean Totals for Specific Gravity Taken at Four Different Stages during the Mixing Process

Series	Specific gravity of creamed mixture before adding eggs	Specific gravity of creamed mixture after adding eggs	Specific gravity of creamed mixture after adding chocolate	Specific gravity of cake batter	Mean totals
A	.733	.743	.758	.786	.755
B	.720	.742	.780	.799	.760
C	.767	.771	.782	.825	.786
Mean totals	.740	.752	.773	.803	.767

Between the three series the data also indicated a marked variability. Series A had the smallest mean total specific gravity of .755 and Series C the largest, .786. The specific gravity of the creamed fat and sugar taken before the other ingredients were added was lower for B than for A. With the addition of egg to the creamed mixture the specific gravity of Series A and B were approximately the same. With the addition of chocolate, the specific gravity of Series B increased decidedly over that of Series A. There was no doubt that the high temperature of the chocolate added to Series B softened the fat sufficiently to permit loss of enough air to lower the specific gravity of the B series. This also affected the cake

Table IV. Mean Totals for Specific Gravity of Baked Cakes

Series	Baking temperatures, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	.534	.504	.450	.417	.410	.409	.454
B	.537	.498	.440	.412	.402	.404	.449
C	.561	.528	.477	.443	.433	.422	.477
Mean totals	.544	.510	.456	.424	.415	.412	.460

The cakes baked at the lower temperatures had a higher specific gravity than those baked at higher temperatures because the former group had much smaller volumes. During the baking process, all the cakes seemed to rise about the same amount, but at the end of the baking period and during cooling the low temperature ones shrank considerably.

In the preceding section it was shown that the specific gravity of the mixtures after creaming the fat and sugar, after adding the egg and later the chocolate varied greatly in the three series and the explanation for these differences was attributed to the high temperature of the chocolate in Series B and the large proportion of sugar in Series C. Since the specific gravity of the cakes of these three series also differed to such a great extent, it seemed evident that the same factors that affected the specific gravity of the creamed mixtures also affected the specific gravity of the cakes.

Another factor that might have affected this result was the fact that the volumes for Series C were the smallest. This series, as shown later (Table VII), also had the least moisture loss in baking, hence the cakes in this series were relatively heavier for given volumes. The means show that in general the specific gravity for the cakes in Series B was lower than for the other two series. In this series the moisture loss was higher than for Series C and approximately the same as for Series A, but the cake volumes were larger.

The analysis of variance showed that the specific gravity of the fifteen cakes within a given series varied greatly. The same result was obtained with the specific gravity of the creamed mixtures within a series. Although the analysis of variance data indicated differences in specific gravity of the cakes, they did not show whether batters of low specific gravity gave cakes of low or high specific gravity. Correlation showed this relationship. Simple correlations were determined on the data for one baking temperature only, namely 195°C., between the specific gravity of the creamed mixture after the egg was added and the baked cake, and between the specific gravity of the cake batter and the baked cake. The first correlation, -.12, was non-significant. The second correlation, -.40, that between specific gravity of the cake batter and the baked cake, was highly significant. Since the correlation was negative, this indicated that the batters of the lowest specific gravity produced cakes of the greatest specific gravity and vice versa. In other words, batters of the greatest volume within a series produced smaller cakes. This is contrary to the claim that large cake volume is dependent upon a large creamed volume. The results in this study for cakes baked at 195°C. are substantiated by other work in this laboratory. Martin (5) and Buel (1) found a tendency for smaller cake volume to be obtained from greater creaming volumes, though their correlations were non-significant. However, Minard's (6) correlation for this factor was highly significant.

Cake Volume

Highly significant differences in volume between the six baking temperatures, between the three cake series and between the fifteen mixes within each series were obtained (see Table VI). With increased baking temperature there was an increase in cake volume. The largest average volume, as seen in Table V, was obtained with the highest temperature, though there was very little difference in the mean volumes for the cakes baked at 215°C. and 225°C. for series A and B. As was noted under the discussion on specific gravity of baked cakes, the cakes baked at low temperatures shrank very badly before they finished baking and while they were cooling.

Table V. Means and Mean Totals for Cake Volumes in Cubic Centimeters

Series	Baking temperatures, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	423	443	499	537	545	549	499
B	420	450	509	543	554	556	505
C	403	426	471	507	518	533	476
Mean totals	416	440	493	529	539	546	494

Series C had the lowest average cake volume perhaps because it contained more sugar than the other two series. All the cakes were mixed the same amount even though cakes containing greater amounts of sugar require more mixing. If Series C had been mixed longer, the cake volumes might have been greater. Sugar takes up some of the liquid which might have been used for the development of the gluten so that longer mixing would be required for improved texture and larger volume.

Table VI. Analysis of Variance of Cake Volumes.

Source of variation	Degrees of freedom	Mean squares	Due to regression: Degrees of freedom	Mean square	Remainder: Degrees of freedom	Mean square
Between baking temperatures	5	135176**	1	624448**	4	12858**
Between series	2	21244**				
Temperature x series	10	340				
Mix in series	42	1272**				
Error	210	194	210	194		

**Highly significant.

Series B, in which the chocolate was 60°C. when added to the creamed mixture, had the best average cake volume. This result was obtained in spite of the fact that the specific gravity of the creamed mixture after the chocolate was added and the specific gravity of the cake batter (Table III) were greater than for the specific gravities of corresponding mixtures of Series A. However, attention is called to the fact that the specific gravity of the creamed fat and sugar was lowest for Series B, Table III.

In order to determine whether all the variation in cake volume was due to difference in baking temperature, the regression, as seen in Table VI, was computed. After removing this variation, a highly significant difference still remained thus indicating that part of the variation was due to differences in series and to mixes within each series. The specific gravity of the cake batter, as shown for the cakes baked at 195°C., did have an effect on the specific gravity of the baked cakes. Though correlations were not determined between the specific gravity of the cake batter and the specific gravity of the cakes baked at the other temperatures, such a relationship might also exist. As indicated in Table II, the room and incubator temperatures as well as the relative humidity did not vary significantly throughout the entire study. The temperatures of the creamed mixture after adding the chocolate and of the batter did vary significantly between series, but not within a given series.

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Therefore this remaining variation in cake volume must have been due to differences in specific gravity of the batter, to differences in series, i.e., to the amount of sugar used in the formula or the temperature at which the chocolate was added, or to some unknown factor or factors.

This analysis, as seen in Table VI, gives another indication that the mixes within the series varied widely.

Moisture Loss

The average moisture loss in grams is given in Table VII. The cakes baked at 175°C. lost the least moisture and, in general, those baked at 215°C. lost the most. The mean scores show that the cakes baked at 225°C. lost less moisture than any except the very low temperature (175°C.) ones. The total means for the cakes baked at 185°, 195° and 205°C. are identical.

Table VII. Means and Mean Totals for Moisture Loss in Grams

Series	Baking temperature, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	14.6	16.8	16.6	16.5	17.3	15.7	16.3
B	14.4	16.4	16.8	16.8	17.3	15.7	16.2
C	13.8	15.7	15.6	15.8	16.5	15.2	15.4
Mean totals	14.3	16.3	16.3	16.3	17.0	15.5	16.0

In all cases the means for moisture loss are less for Series C than for either of the other series. Apparently the increased sugar was an aid in moisture retention. The average moisture loss for Series A and B is practically the same.

The statistical analysis of these data indicated highly significant differences for moisture loss between the six baking temperatures, between the three cake series and in addition between the 15 mixes within a given series. This analysis gave a further indication that identical mixes could not be duplicated.

Objective Tests

Breaking angle

The data as tabulated in Table VIII indicate that with increasing baking temperature up to 215°C. there was a similar increase in the amount of pressure necessary to break the cake. The cakes baked at a low temperature, though gummy, were very crumbly so that they broke more easily than those baked at higher temperatures. A comparison of the average breaking angle, 27.98 for the cakes baked at 175°C. to 35.86, the mean for those baked at 215°C., would indicate this.

Table VIII. Means and Mean Totals for Breaking Angle

Series	Baking temperatures, °C.						Mean
	175°	185°	195°	205°	215°	225°	totals
A	29.13	31.57	30.80	33.53	38.67	35.07	33.13
B	26.87	29.40	31.70	32.13	34.47	35.30	31.64
C	27.93	28.93	31.73	30.87	34.43	35.73	31.60
Mean totals	27.98	29.97	31.41	32.18	35.86	35.37	32.12

The cakes in Series C broke slightly easier than those in the second series. Undoubtedly the increased sugar was responsible for the lower breaking angle of Series C in comparison with Series A. In Series B the breaking angle was probably less because the high temperature chocolate gave a better volume; with the more compact cake from Series A more pressure would be required to break the sample.

An analysis of variance indicated highly significant differences for the breaking angle between the six baking temperatures, between the three cake series, and between the fifteen mixes within a given series.

Texture index

The mean scores, as given in Table IX, seemed to have no consistent relationship so far a s baking temperature was concerned. Series B, with a mean of .930, had a higher texture score than either Series A with an average of .843 or C with a mean of .866. Probably, this higher mean for Series B was due to its having the largest volume which gave coarser pores and thus greater sand retention.

The analysis of variance for the texture index also showed that there were highly significant differences between the six baking temperatures, between the three cake series and between the fifteen cake mixes within each series.

Table IX. Means and Mean Totals for Texture Index or Sand Retention in Grams

Series	Baking temperature, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	.803	.750	.887	.883	.873	.860	.843
B	.897	.860	.957	.920	.933	1.017	.930
C	.867	.807	.920	.863	.853	.887	.866
Mean totals	.856	.806	.921	.889	.887	.921	.880

Moisture index

As can be observed from Table X, the cakes baked at 185°C. absorbed less moisture in five seconds than the cakes baked at 175°C. This would seem to indicate that the cakes baked at 185°C. were drier which is verified by moisture loss, Table VII, and had thus lost some of their ability to absorb water.

Table X. Means and Mean Totals in Grams for Moisture Index, or Water Absorption in Five Seconds

Series	Baking temperature, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	10.97	10.35	11.61	12.17	11.92	11.99	11.50
B	11.29	10.46	11.50	12.41	11.96	11.98	11.60
C	12.89	12.06	13.27	13.15	12.92	13.58	12.98
Mean totals	11.72	10.96	12.13	12.58	12.26	12.52	12.03

A similar observation could be noted with cloth, bread, etc. If a cloth were too dry it would not absorb as much moisture in a given time as one which was partially wet. Of course, if sufficient time was given, the dry one would absorb

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B	11.29	10.46	11.50	12.41	11.96	11.98	11.60
C	12.89	12.06	13.27	13.15	12.92	13.58	12.98
Mean totals	11.72	10.96	12.13	12.58	12.26	12.52	12.03

A similar observation could be noted with cloth, bread, etc. If a cloth were too dry it would not absorb as much moisture in a given time as one which was partially wet. Of course, if sufficient time was given, the dry one would absorb more moisture. In this test, however, only five seconds were allowed for each round of cake to absorb water, so that the cakes baked at 185°C. did not absorb as much water as those baked at 175°C.

However this does not explain why moisture absorption was greater for all other temperatures than at 175°C. and 185°C. The cakes baked at the two lowest temperatures had textures nearly alike. These cakes were less velvety, more compact and more gummy than cakes baked at the four highest temperatures. It would seem probable that this difference in texture as well as the dryness affected the amount of moisture absorbed. Moisture absorption was considerably higher for the more velvety cakes, i.e., those baked at the four highest temperatures, though absorption did not increase progressively with increase in baking temperature.

The mean totals for the cakes baked at 215°C. indicate drier cakes than for those baked at 205° or at 225°; this fact is borne out in the moisture loss determinations for the cakes baked at the two highest temperatures.

In all cases the averages for Series C indicate greater absorption of moisture than the other two series. Naturally, one would expect such a result since sugar has a high power for water absorption. Little difference could be noted between Series A and B.

Since moisture absorbing ability is often associated with eating quality, a correlation was computed but it was found that for this study no relationship existed.

Cake Scores

The cakes were scored for four characteristics: texture, tenderness, velvetiness, eating quality and total score, the last being the sum of the first four. (See score sheet in Appendix.) The scores for each cake were the total of the scores given by the five individual judges. The range of the scores given by the various judges varied rather widely, but all seemed to be consistent throughout the entire period. Scores were the best available estimates of cake quality.

Texture scores

A cake of good texture is described on the score card as one having a fine, even texture with rather small cells and thin, elastic cell walls.

With an increase in baking temperature a similar increase in the texture scores seemed to follow as seen in Table XI. The low temperature cakes shrank so much before they had finished baking that a compact gummy cake resulted. The high temperature cakes rounded very noticeably in the center with a tendency toward tunnels.

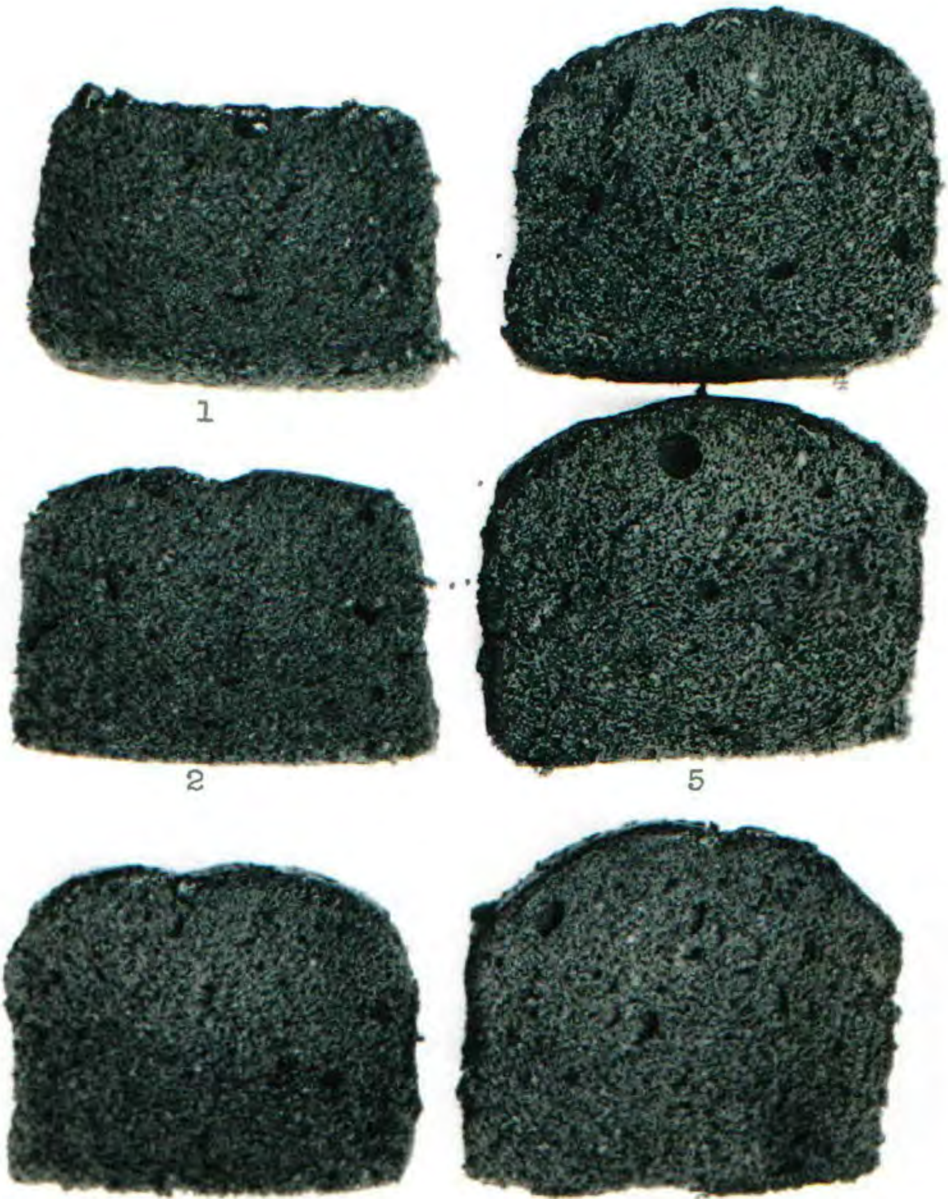

Plate I.
Series A. 400 grams sugar. Chocolate 40°C.
Baking temperatures:

1. 175°C.	4. 205°C.
2. 185°C.	5. 215°C.
3. 195°C.	6. 225°C.

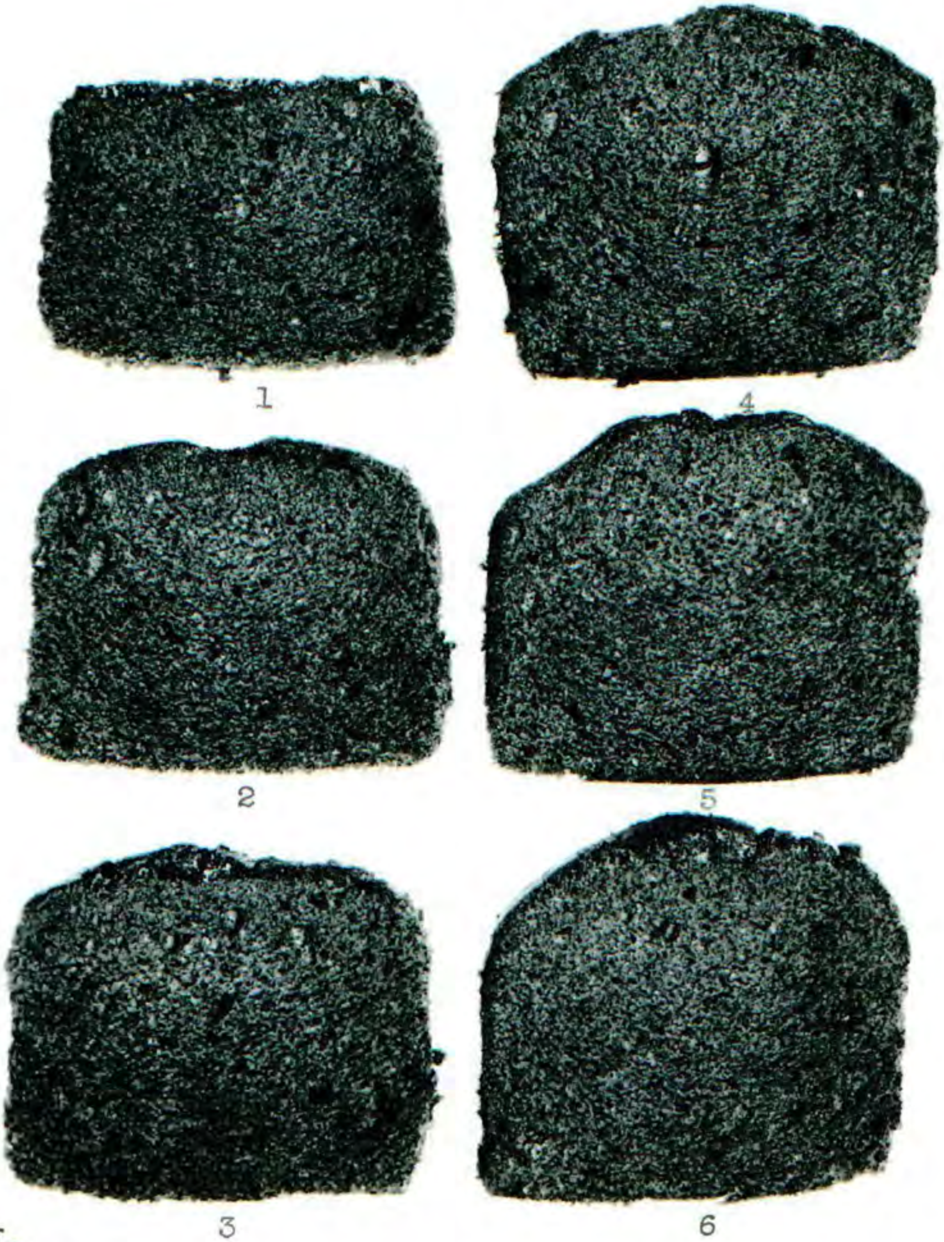

Plate II.
Series B.

400 grams sugar. Chocolate 60°C.
Baking temperatures:

1. 175°C.	4. 205°C.
2. 185°C.	5. 215°C.
3. 195°C.	6. 225°C.

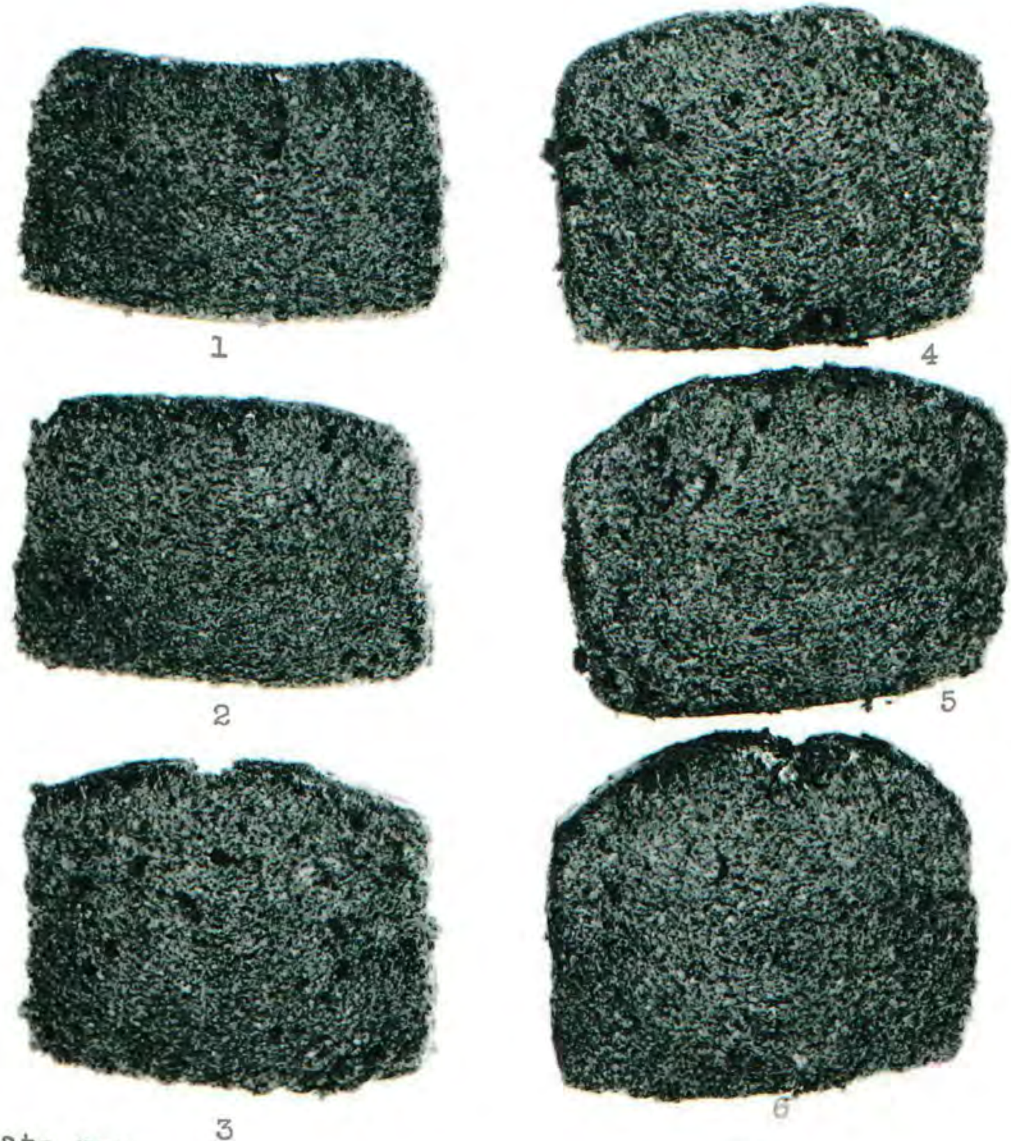

Plate III.
Series C. 450 grams sugar. Chocolate 40°C.
Baking temperatures:

1. 175°C.
2. 185°C.
3. 195°C.
4. 205°C.
5. 215°C.
6. 225°C.

Table XI. Means and Mean Totals for Texture Scores. (Highest possible score 150)

Series	Baking temperatures, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	83.5	90.3	102.7	115.3	119.3	121.5	105.4
B	82.0	89.1	103.2	115.0	121.2	121.1	105.2
C	80.9	87.0	100.2	111.7	115.7	121.1	102.8
Mean totals	82.1	88.8	102.0	114.0	118.7	121.2	104.5

Series C, since it contained more sugar than the other two series and was mixed the same amount as they were, had lower texture scores.

Tenderness scores

According to the score card the cakes were scored high in tenderness if they were not tough or gummy. The judges scores showed a positive correlation with baking temperatures. With the exception of the cakes baked at 185°C., the tenderness scores increased consistently from 75.0 for the cakes baked at the lowest temperatures to 88.3 for the cakes baked at the highest temperature. The cakes baked at the two lowest temperatures were very tender and crumbly, but the judges scored them low in this characteristic because they were gummy and had an undesirable tenderness. The range in tenderness scores was comparatively small.

There seems to be little difference, so far as tenderness was concerned, between Series A and B, the former with a mean total of 81.1 and the latter of 81.5. Series C, since it was a richer cake, was scored higher for tenderness than the other two series. The range in mean scores can be observed in Table XII.

Table XII. Means and Mean Totals for Tenderness Scores. (Highest possible score 100)

Series	Baking temperatures, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	73.0	74.0	79.8	86.1	85.9	87.8	81.1
B	74.8	74.5	80.3	85.3	86.5	87.5	81.5
C	77.3	76.3	81.2	85.1	86.0	89.6	82.6
Mean totals	75.0	74.9	80.4	85.5	86.1	88.3	81.7

Velvetiness scores

Velvetiness, according to the score sheet is "smoothness, softness like velvet to the tactile sense." The velvetiness scores were in the same order as the texture and tenderness scores. The velvetiness scores for each series increased directly with an increase in baking temperature.

The range between the velvetiness scores, i.e., 66.0 to 86.1, was relatively small compared to the wide variations of the texture, eating quality, and total scores.

The velvetiness scores were directly proportional to the baking temperatures with a gradual increase in average scores from 66.0 for the cakes baked at 175°C. to 86.1 for the cakes baked at 225°C. Little variation was found between the three cake series. So far as velvetiness was concerned, the three series were very similar with scores of 76.8, 77.0 and 76.8 for Series A, B and C respectively.

The relationship between velvetiness scores and baking temperature can be seen in Table XIII.

Table XIII. Means and Mean Totals for Velvetiness Scores. (Highest possible score 100)

Series	Baking temperatures, °C.						Mean
	175°	185°	195°	205°	215°	225°	totals
A	65.7	67.3	75.0	82.2	84.7	85.8	76.8
B	65.7	67.6	77,2	80.8	84.5	86.3	77.0
C	66.5	67.9	75.6	79.9	84.4	86.3	76.8
Mean totals	66.0	67.6	75.9	81.0	84.5	86.1	76.8

Eating quality scores

All the factors which make a cake either desirable or undesirable for eating were included in the eating quality score. The two most important factors determining the score given by the judges was cake flavor and the effect on the tactile sense in the mouth.

Table XIV shows that the judges like Series C with a total mean score of 111.3 best for eating quality, probably because of increased sugar. The eating quality scores for the first two series were quite similar, i.e., 110.6 for Series A and 109.1 for Series B.

The eating quality scores increased with higher baking temperatures; the total mean scores for 215° and 225°C. varied only slightly, i.e., 122.6 for the former and 123.0 for the latter.

Table XIV. Means and Mean Totals for Eating Quality Scores. (Highest possible score 150)

Series	Baking temperatures, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	93.1	96.5	108.5	119.3	122.9	123.4	110.6
B	90.9	96.4	108.8	116.2	121.3	120.9	109.1
C	94.5	97.6	108.3	119.1	123.6	124.7	111.3
Mean totals	92.8	96.8	108.5	118.2	122.6	123.0	110.3

Total Scores

The total means for the total cake scores, 373.9, 372.8 and 373.4 for Series A, B and C, respectively, do not vary greatly (see Table XV). Apparently then when the scores for texture, tenderness, velvetiness and eating quality were totaled amd averaged, the results were very much the same for each of the cake series.

Table XV. Means for total cake scores. (Highest possible score 500)

Series	Baking temperatures, °C. 175°	185°	195°	205°	215°	225°	Mean totals
A	315.3	328.1	366.1	402.9	412.7	418.5	373.9
B	313.3	327.5	369.5	397.3	413.5	415.7	372.8
C	319.3	328.7	365.2	395.8	409.7	421.7	373.4
Mean total	316.0	328.1	366.9	398.7	412.0	418.6	373.4

However, there was considerable difference between the six baking temperatures for the total scores. Increased baking temperatures, at least up to 225°C., gave higher total cake scores as indicated by the consistent increase from 316.0 for cakes baked at 175°C. to 418.6 for cakes baked at 225°C.

Analysis of Variance for Cake Scores

The analysis of variance for cake scores is shown in Table XVI. The mean squares between the six baking temperatures for texture, tenderness, velvetiness and eating quality were highly significant. The mean square for total scores, however, was non-significant. Since total score was the sum of the four individual scores, it would seem that scores for texture, tenderness, velvetiness and eating quality varied enough from day to day so that the mean square of total scores for baking temperature did not differ greatly.

The scores varied sufficiently between series to give highly significant mean squares for texture, tenderness, eating quality and total scores. As was noted in Section III under Cake Scores, there seemed to be little difference in velvetiness between the three series and these differences according to the statistical analysis were non-significant.

Highly significant variations in the mixes within a given series were found for the mean squares for texture, tenderness, velvetiness, eating quality and total scores. This indicated

Table XVI. Analysis of Variance for Cake Scores

Source of variation	Degrees of freedom	Mean squares: Texture scores	Tenderness scores	Velvetiness scores	Eating quality scores	Total scores
Between baking temperatures	5	11,924.00**	1525.0**	3307.80**	7787.00**	86,093.00**
Between series	2	198.00**	53.0**	2.00	116.00**	27.00
Series X temperature	10	16.60	14.6*	8.90	12.90	119.00
Mix within series	42	114.24**	56.8**	111.52**	118.36**	1188.00**
Error	210	15.15	7.08	10.50	19.38	98.88

*Significant.
**Highly significant.

that there was a great difference in the individual mixes for each of the cake series.

Regressions were also computed to determine whether all of the differences in scores for texture, tenderness, velvetiness and eating quality, as well as total scores, were explained by variations in baking temperatures. After this relationship between baking temperature and cake scores was removed, highly significant differences still remained. The remainder indicated that part of this variation was due to differences in the three cake series and to the fifteen mixes within a given series. As was indicated in the discussion of results for cake volume, this highly significant remainder was probably due to differences in specific gravity of the cake batter for mixes within a given series, or to differences in series, i. e., to variations in the cake formula, differences in the amount of sugar used, temperature at which the chocolate was added or to some unknown factor or factors.

SUMMARY AND CONCLUSIONS

A total of 270 cakes was baked of which one-third contained 400 grams of sugar and had melted chocolate added at 40°C., a second group of the same number with the same proportions had the chocolate added at 60°C. and the remaining group, a variation of the first series, had the sugar increased to 450 grams. Sufficient batter was prepared in one mix for six small loaf cakes, each of which was baked at a different temperature from 175° in 10° intervals to 225°C.

The data recorded were room, incubator, creamed mixture, and batter temperatures; relative humidity; creaming and batter volumes, cake weight and volume, breaking angles (in duplicate), texture and moisture indices (also in duplicate) and the scores of the five judges.

For evaluating results averages were determined and analyses of variance computed for: temperature of creamed mixture and of batter, relative humidity, specific gravity of creamed mixture at four different stages during the mixing process, specific gravity of the baked cake, cake volumes, moisture loss, objective tests, scores for texture, tenderness, velvetiness, eating quality and for total scores. Correlations were computed for moisture index and eating quality and for the specific gravity of the creamed mixture at different stages of mixing with the specific gravity of the baked cakes.

From the data recorded in this study the following results were obtained:

1. The temperature of the creamed mixture after adding the melted chocolate was higher for Series B. A similar increase in temperature was noted for the batter in Series B.

2. The specific gravity of the creamed mixture increased after the addition of the eggs and chocolate. A similar increase in specific gravity was obtained for the cake batter. The specific gravity of the cakes baked at 195°C. was inversely proportional to that of the batter. (The last data were determined only for those baked at 195°C.).

3. The cake volume was directly proportional to the baking temperature. The cakes with increased sugar gave the smallest cake volume; the cakes in Series B with chocolate added at a higher temperature had the largest average volume.

4. In general the cakes baked at 175°C. lost the least moisture and those baked at 215°C. lost the most. The mean scores show that the cakes baked at 225°C. lost less moisture than any except the very low temperature ones. The scores for moisture loss were less for Series C than for either of the other series.

5. The angle of breakage was least for Series C and greatest for Series A.

6. Moisture absorption (index) did not vary directly with an increase in baking temperature. The cakes baked at 185°C.

absorbed the least, followed in order of increasing amount by those baked at 175°C., 195°C., 215°C., 225°C., and 205°C.

7. The scores for texture, tenderness, velvetiness, and eating quality as well as the total scores were directly proportional to baking temperatures. Series C scored lowest for texture, but highest in tenderness and eating quality.

It is concluded from this study that baking temperatures higher than those usually recommended will give more palatable cakes. However a temperature of 225°C. is not recommended to the homemaker because such a high temperature would give a very brown crust for cakes larger than those baked in this study. For a seven inch square layer consisting of 480 grams of batter (approximately one-third of entire cake batter), a baking temperature of 205°C. (400°F.) for 26 minutes is recommended to the homemaker. A baking temperature of 195°C. (380°F.) gives a cake of more compact texture than a temperature of 205°C. However, the cakes baked at the lower temperature lost less moisture than those baked at the higher temperature. The higher scores given by the judges for the cakes baked at 205°C. more than offset the greater moisture loss. If the depth of the batter in the cake pan were greater than an inch and a quarter or an inch and a half the baking temperature would probably need to be lower than 205°C.

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SCORE CARD FOR CAKE

Date ____________

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

	Number / Perfect score						
Crumb 1. Texture, cell waslls 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 ____________