SOME FACTORS AFFECTING THE QUALITY OF ANGEL FOOD CAKE

by

SARA JANE REED

B. S., Colorado Agricultural College, 1925

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

KANSAS STATE COLLEGE

OF AGRICULTURE AND APPLIED SCIENCE

1931

TABLE OF CONTENTS

INTRODUCTION

A study of the literature on angel food cakes, combined with general observation, reveals a wide variation in kinds of pans, baking temperatures, proportions of ingredients, and methods of mixing used. The extent to which these factors influence such cakes is a question. Because of uncertainty concerning this matter, this investigation was made with the hope that methods might be devised to measure more exactly the effects on the cake of some of these variations.

REVIEW OF LITERATURE

The importance of the kind of pan used in culinary processes has long been recognized. Good (3), testing light-weight aluminum and enamel stew kettles, found their relative thermal efficiencies to be 38.4 and 43.1 per cent, respectively. These figures were obtained when water was heated in the pans over a gas burner.

Cornehl and Swartz (1), observed that the efficiency of aluminum utensils ranged from 13.6 to 16.7 per cent, according to the weight and finish, whereas enamel averaged 19.2 per cent and glass 21.9 per cent. They believed the differences lay in the ability of the material to reflect or absorb heat and that this property was related to the degree of polish on the utensil. They could detect no relation between their results and the specific heat or the specific thermal conductivity of the materials used.

Sullivan of the Corning Glass Works Laboratory (10), reports that glass baking dishes do not reflect radiated heat as easily as do metal ones. He further states that such dishes, as a consequence, absorb the heat more readily and therefore bake more rapidly. In further tests reported from this laboratory it was found that in a gas oven a tin and an aluminum pan took up 50 and 66 per cent as much heat, respectively, as a glass dish. This was believed to be due to the higher reflecting power of the metals which overbalanced their advantage in conductivity.

Eggs, which are an important constituent of angel food cake, show much individual variation in composition when fresh, and develop marked changes when stored. Sharp (9), reports that as soon as an egg is laid the pH of the white begins to increase, due to the loss of carbon dioxide. The change in pH ranges from about 7.6 in a fresh egg, to 9.7 as the egg becomes stale. This increase in alkalinity occurs more rapidly at high temperatures.

Individual eggs also show a difference in the proportion of thick to thin white. According to Romanoff (8), a fresh hen's egg is composed of 3 distinct layers of albumin, an outer, a middle, and an inner layer, averaging respectively, 11.59, 12.45, and 14.55 per cent of dry matter. However, the proportion of each of these in a single egg may vary greatly. Watery white also increases as the pH is increased. Thus a stale egg white becomes thinner, less viscous, and correspondingly less desirable for a leavening agent since it holds less air when beaten.

According to MacLeod and Nason (7), the colloidal nature of the albumin in the egg white permits it to hold air upon beating, each air bubble being surrounded by a film of egg protein. If the egg whites are beaten too much, they acquire a great number of very small air bubbles and all the protein may then be used to surround the air leaving none to combine with other ingredients. Such eggs are said to be beaten "dry" and their use is not generally recommended. These authors also suggest that the value of sodium chloride in the whipping of egg whites may be due to the fact that it decreases the alkalinity to some extent.

The general opinion is that a specially prepared pastry flour is particularly desirable for cake making. According to the statements of its manufacturers (11), a well known cake flour is prepared from a carefully selected soft wheat, which is so ground and sifted that it is 27 times as fine as other flour. They claim that it contains a maximum of starch with just enough gluten to bind the ingredients without affecting the tenderness and fluffiness of the cake.

Bread flour, which is coarser, and contains more gluten with less starch, is thought to give a darker, and somewhat tougher cake. For this reason it is frequently recommended (2, 5), that the amount be decreased when it is substituted for pastry flour or that a certain amount of the bread flour be replaced by cornstarch.

Grewe and Child (4), in their work with acid potassium tartrate, conclude this acid increases the hydrogen-ion concentration of the cake, making a finer grained, whiter product and, without it, the cake is yellow and coarse. They suggest that since egg whites differ in hydrogen-ion concentration that this also may be a factor affecting the color of the cake. MacLeod and Nason (7), agree with the above authors as to the effect of cream of tartar on color. They state further that cakes containing cream of tartar shrink less in baking with the possible explanation that the egg albumin may coagulate more readily with the increase in hydrogen-ion concentration.

No material is available on the viscosity of angel food cake batter. Loeb (6), suggests that viscosity in general may be affected by many factors. As a rule, acids and alkalies tend to increase it until certain limits are reached. Salt has a depressing effect due to the chlorine-ion. Non-electrolytes, as sugar, have little or no effect. Temperature, time of standing, and methods of manipulation are known to change this property.

Considerable variation exists in the weight suggested for any given unit of food material. Woodruff (12), has developed a table of weights for a number of common food materials which is of particular value in the standardization of recipes.

PROCEDURE

The experimental work was divided into 4 distinct parts. These were as follows:

Part I - Variation of the pan.

For this series of experiments the same ingredients and method of mixing were used and the cakes were all baked 60 minutes with the oven regulator set at 325° F. The pans were varied as to:

A. Kind of material.

Round pans of uniform size made of 5 different materials - aluminum, tin, stove pipe iron, enamel, and pyrex glass were used. They were constructed without tubes.

B. Structure.

Information was desired concerning the effect on the cake of a tube in pans made of various materials. Therefore aluminum, tin, and stove pipe iron pans with and without tubes, but otherwise practically identical, were used.

Part II - Variation of the time and temperature for baking the cakes.

Ingredients and method of mixing were kept the same throughout this part of the problem. A basic recipe, described later, and an aluminum tube pan were used.

The temperature and time for baking were varied as follows:

A. Cake started in a preheated oven

Regulator Reading degrees F.	Time minutes
325	60
325	45
300	60

B. Cake started in a cold oven

Regulator Reading degrees F.	Time minutes
325	60
300	45

C. Cake started in a preheated oven containing a pan of water (500 cc.)

325	60
325	50

Part III - Variation of the different ingredients used in the cake.

Again the basic recipe, the same method of mixing, and the aluminum tube pan were used. The oven regulator was set at 325° F. and, as a result of the findings in Part II, all cakes were baked 45 minutes.

The following variations were made:

A. Substitution of bread flour for pastry flour.

Bread Flour

Weight gm.	Approximate measure cups
113	1
99	1 less 2 tablespoons

B. Substitution of varying amounts of cornstarch for bread flour.

Bread flour Weight gm.	Bread flour Approximate measure tablespoons	Cornstarch Weight gm.	Cornstarch Approximate measure tablespoons
99.0	14	7.8	1
99.0	14	11.7	$1\frac{1}{2}$
84.8	12	31.2	4
70.7	10	46.8	6

C. Varying the amount of sugar.

Sugar Weight gm.	Sugar Approximate measure cups
200	1
250	$1\frac{1}{4}$
300	$1\frac{1}{2}$

D. Varying the amount of egg whites.

Egg whites Weight gm.	Egg whites Approximate measure cups
243	1
303	$1\frac{1}{4}$
364	$1\frac{1}{2}$
425	$1\frac{3}{4}$

E. Varying the amount of cream of tartar.

Cream of Tartar

Weight gm.	Approximate measure teaspoons
230.3	$\frac{3}{4}$
4.7	$1\frac{1}{2}$
6.2	2

F. Varying the amounts of water.

1. Addition of water.

Egg whites		Water	
Weight gm.	Approximate measure cups	Weight gm.	Approximate measure tablespoons
243	1	28.2	2
243	1	56.4	4

2. Substitution of water for egg whites.

182.8	$\frac{3}{4}$	28.2	2
121.5	$\frac{1}{2}$	56.4	4

These substitutions were made according to the cook book rule that 1 tablespoon of water may be substituted for each egg white (2). The average egg white approximates 1/8 cup by weight.

Moisture was determined for all cakes in this series as it was believed that they were somewhat more moist than the control. Samples approximating 5 grams were weighed accurately and dried at 80° C. in a Freas oven. Loss in weight was taken as the moisture content and calculated as per cent.

Part IV - Variation of the methods of mixing.

The recipe evolved from the preceding work formed the basis of this part of the experiment.

The methods of mixing were varied as follows:

A. Combining sugar and flour, sifting together 3 times and folding in at the last.

B. Beating 1 cup of the sugar sifted once, into the eggs with a spoon; combining remaining $\frac{1}{2}$ cup with the flour, sifting together 3 times and folding in at the last.

C. Same as (B) except sugar was beaten into eggs with a Dover egg beater and the beating continued 2 minutes.

D. Same as (C) but the folding continued for 2 minutes after all ingredients were added.

E. Making sugar into a syrup with 119 cc. water ($\frac{1}{2}$ cup), cooking to 119° C. (firm ball), pouring slowly over stiffly beaten egg whites and beating with a spoon until cold.

F. Same as (C) except a whip was substituted for the Dover egg beater.

G. Same as (C) except the cream of tartar was added to the flour-sugar mixture.

Throughout Parts III and IV, the pH of both egg whites, and cake mixture was determined as it was hoped that some relation might be established between the pH of the cake and its quality. At the same time and for the same reason, viscosity tests were made on both egg whites and cake batter. The pH was determined electrometrically using the hydrogen-electrode and viscosity with an Eimer and Amend viscosimeter.

Two cakes were made to test each variation. If these showed practically the same characteristics it was thought safe to assume that any different properties might be attributed to the point being investigated. When the results were in doubt more cakes were made as necessary. A slice of each cake was photographed so a picture of the grain was available for comparison.

Approximate increase in volume was determined by marking on the pan the depth of the batter and of the finished cake. The amount of water required to fill the pan to the mark was then taken as a measure of the volume. While this is not an accurate method for cakes in general, it is less subject to error when applied to angel food cakes, because of their flat and regular contour. It appeared to meet the needs of this experiment satisfactorily.

From each of these cakes, 66 grams of batter were removed for pH and viscosity determinations. The volume of the cakes was therefore smaller than the recipe would indicate.

A popular recipe known to give a good product was chosen for the beginning of this work. It was as follows:

Ingredient	Weight gm.	Approximate measure
Flour (Swansdown)	100.0	1 cup
Sugar	250.0	$1\frac{1}{4}$ cup
Egg whites	243.0	1 cup
Cream of tartar	2.3	$\frac{3}{4}$ teaspoon
Salt	1.0	$\frac{1}{4}$ teaspoon
Vanilla	5.6	1 teaspoon

All ingredients were weighed on a Harvard trip balance. The sugar was sifted once and the flour 3 times after weighing. The egg whites were beaten until frothy. The salt and cream of tartar were then added after which the beating was continued until mixture was stiff enough to hold its shape. The sugar was beaten in, approximately 2 tablespoons at a time, after which the vanilla was added in the same way. Lastly the flour was folded in; it, too, being added gradually. Every effort was made to standardize and control the working conditions.

In order that there might be the minimum of variation with respect to ingredients, all supplies, with the exception of eggs, were obtained in quantity at the beginning of the experiment and stored at room temperature.

The brands chosen were those commonly used in this section of the country.

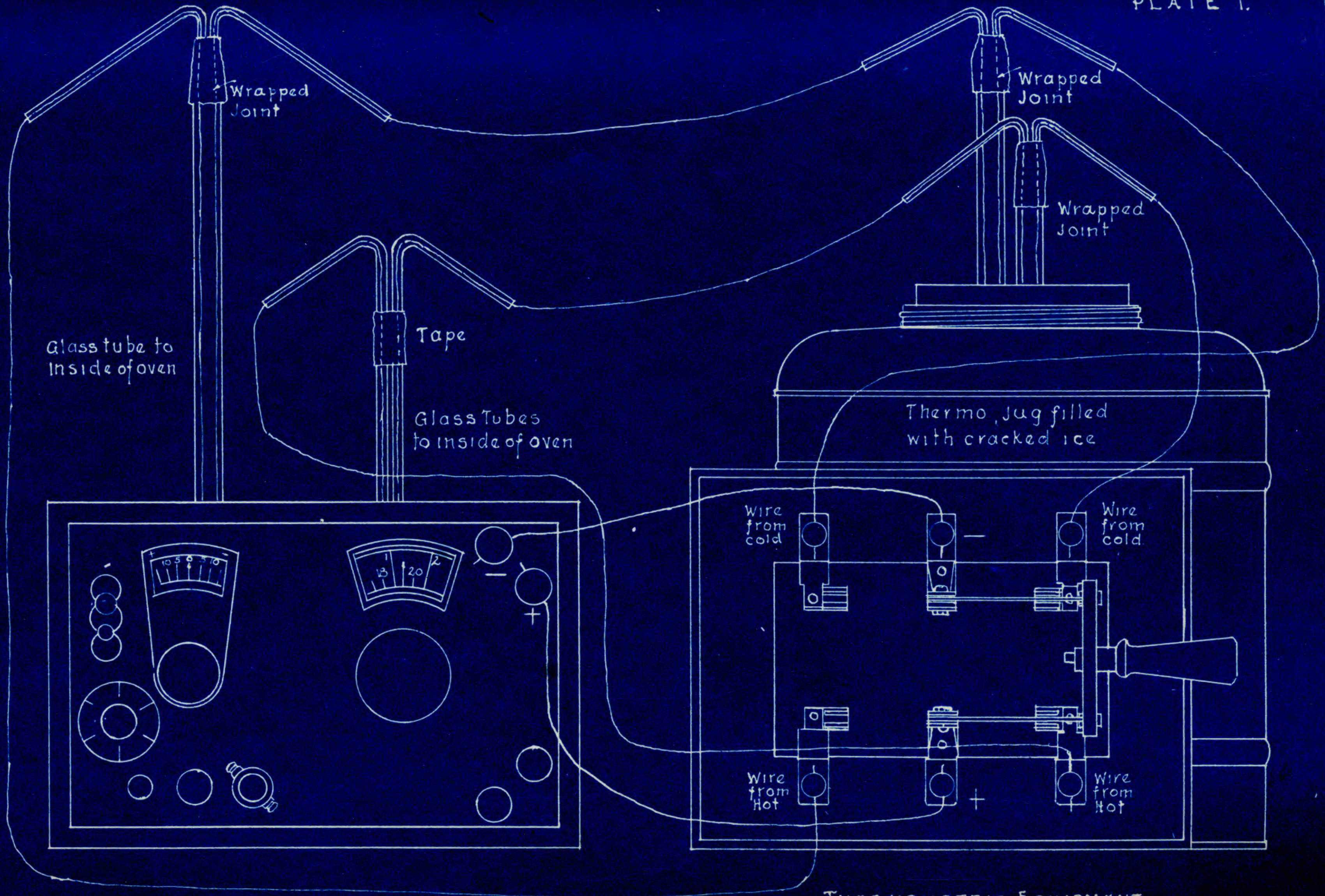
Eggs were obtained from the College farm. The aim was to secure them when 3 hours old and store them immediately at 59° F. until used sometime on the third day. Slight deviation from this plan was necessary, however, on Sundays and on a few other occasions.

The same utensils were used throughout the period. The cakes were mixed in an earthen mixing bowl unless otherwise stated. Eggs were beaten with a Dover egg beater rather than an electric one, since it was desired to reproduce the average home equipment.

The cakes, except as indicated in Part I, were baked in a medium-weight aluminum tube pan of 3500 cc. capacity.

A Clark-Jewell gas oven fitted with a Lorain regulator and a glass door was used for this investigation. In order to measure temperature more accurately than the regulator permitted, a system of electric thermometers (Plate 1), was devised. Two thermocouples made of Leeds and Northrup iron and constantan wire, No. 24, were used. The milli-

PLATE I.



THERMOMETRIC EQUIPMENT.

H.C.A.

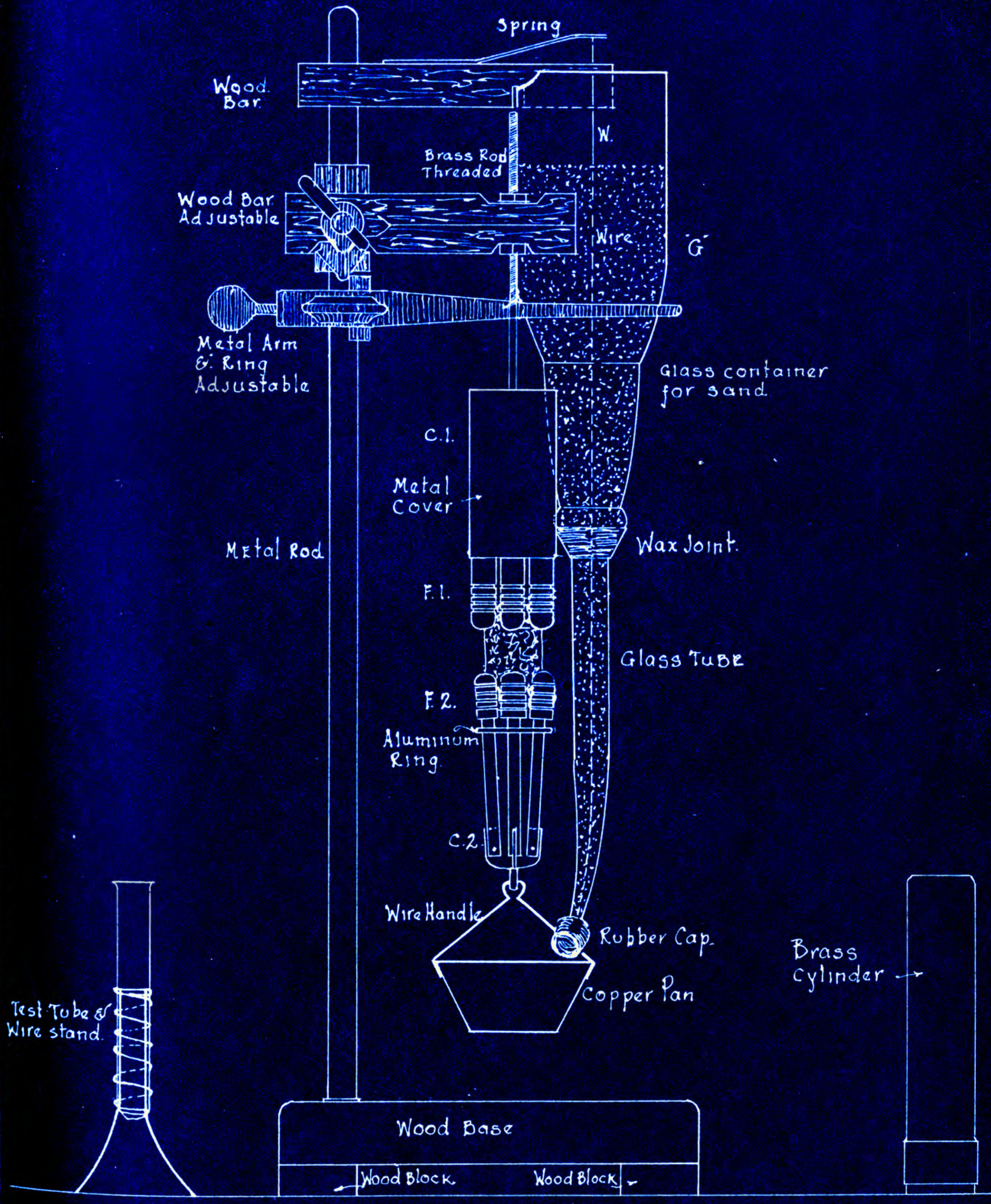
volts were registered with a Leeds and Northrup double-range portable potentiometer and the temperatures determined from standard conversion tables. The accuracy of the thermocouples was tested with a calibrated mercury-glass thermometer.

In order to fit the thermocouples into the oven, 2 holes were drilled through the top, one, exactly in the center, into which one thermocouple, hereafter designated as No. I, was placed. The other hole was made 2 inches directly back of the first one. The second thermocouple, No. II, occupied this space.

Thermocouple No. I was enclosed in a thermometer-like glass sheath. Instead of sheathing No. II it was placed in a small glass test tube held in position in the cake by a wire tripod which rested on the bottom of the pan (Plate 2). This device made it easy to remove the thermocouple without injury to the cake.

In case pans with tubes were used, thermocouple No. I was adjusted to register the temperature of the center of the pan, and thermocouple No. II that of the inside of the cake. With pans without tubes the thermocouples were rearranged, the order being reversed to permit thermocouple No. II to be placed in the center of the cake. In both

PLATE 2.



BREAKING FORCE DEVICE

H.C.A.

cases it was desired to have the end of thermocouple No. II midway between the top and bottom of the cake so the temperature at the center of the latter could be secured.

The oven regulator was set at 325° F. (the temperature most often recommended for baking angel food cakes) and checked for accuracy by thermocouple readings which were taken every 5 minutes. After careful adjustment of the regulator it was possible for the readings to agree within 3 per cent. The 2 thermocouples did not, as a rule, register exactly the same temperature. This showed that the heat in the oven was not uniform.

When the same reading was secured twice in succession for each of the thermocouples the temperature was considered stationary, and the oven ready for use. The cake was then placed in position and the thermocouples adjusted. Readings were made at 5 minute intervals throughout the baking period. Temperature and time were plotted for both sets of readings for each cake.

An estimate of the cake quality was obtained by scoring. In each case the same three people working individually, judged the finished product. The following score card was used:

Name:
Date:
Cake No.:

SCORE CARD FOR ANGEL FOOD CAKE

	Perfect Score	Actual Score
I. General Appearance - External	15	
1. Shape - 5 Regular Evenly rounded Without hollows		
2. Size - 5 Suitable to ingredients Light in proportion to		
3. Crust - 5 Color Even Light brown Texture Tender Not sticky Not sugary		
II. General Appearance - Internal	35	
1. Texture - 15 Tender Moist Silky Resilient		
2. Grain - 10 Small uniform cells Thin cell walls Free from large air space		
3. Color - 5		
4. Crust - 5 Thin		
III. Flavor		
1. Taste - 35 2. Odor - 15	50	

In addition, a mechanical device served to test the breaking force of the cake and thus to measure its tenderness. This apparatus was designed and made by Professor E. V. Floyd of the Department of Physics of the College. It is shown in Plate 2.

The device consisted of a ring stand, the rod of which supported a short horizontal beam from which was suspended a clamp, C_1 F_1, for holding one end of the cake sample. A similar clamp, C_2 F_2, supported a very lightweight pan secured to the lower end of the cake sample. The clamps consisted of 3 fingers of wood hinged at the outer ends. A metal ring was adjusted to enclose the fingers enabling them to hold the cake sample.

The samples for testing were cut from the cake by means of a sharpened cylinder resembling a cork borer, the bottom area of which was 1 square inch. The samples were so placed in the clamps that 2 inches of the cake were exposed.

The ring stand also supported a glass container, G, from which a flow of dustless sand could be released or checked at will. This was controlled by means of the spring, S, which was connected with the cork stopper, R, by a thin steel wire, W. When not in use the wire was held taut by the spring. When pressure was applied to the spring it caused the sand to pour slowly into the scale pan, P, until the sample was broken. The weight of the sand, pan, and the lower clamp represented the breaking force or tenderness of 1 square inch of cake. Three such samples were tested for each cake and the mean recorded as its breaking force.

RESULTS AND DISCUSSION

Part I. Variation of the pan.

A. The effect on cake quality of varying the material in the pan.

The results for this portion of the experiment are shown in Table I.

While it appears that the temperature of the oven varied with the material used in the pan, particularly in the case of glass, there is little proof that the pan was the cause of this difference. However, it is believed that glass absorbs radiant heat more readily than tin, and since radiant heat is abundant in a gas oven, this may have been a factor in the figures indicated for glass since the ones in the oven were low and those in the cake were high when this material was used.

Table I. The Effect on Cake Quality of Varying the Material of the Pan.[1]

Cake No.	Pan Material	Oven Temperature: Initial degrees F.	Oven Temperature: Baking Average degrees F.	Oven Temperature: Final degrees F.	Cake Temperature: Rise degrees F.	Cake Temperature: Final degrees F.	Breaking Force gm./sq.in.	Volume Increase cc.	Results
7	Aluminum	332.6	316.0	317.6	78.0	220.1	68.2	1180	Light brown crust
8	"	332.4	316.0	317.6	75.8	222.4	68.7	1135	Tender
Average		332.5	316.0	317.6	76.9	221.3	68.4	1157	
9	Tin	329.7	316.0	319.6	85.0	221.0	65.2	1050	Light brown crust
10	"	327.7	317.0	318.5	68.0	220.4	65.8	1140	Tender
Average		328.7	316.5	319.1	76.5	220.7	65.5	1045	
11	Enamel	330.8	317.0	320.0	83.0	226.0	73.7	850	Brown crust
12	"	330.8	319.0	321.2	78.0	226.4	72.0	728	Tough
Average		330.8	318.0	320.6	80.5	226.2	72.9	789	Hard to remove from pan
17	Stove pipe Iron	332.6	317.0	318.5	81.0	223.3	73.1	1010	Brown crust
18	" " "	332.4	319.0	319.2	57.0	224.9	71.7	1010	Tough
Average		332.5	318.0	318.9	69.0	224.1	72.4	1010	
19	Glass	324.0	314.0	317.3	86.0	231.8	68.7	1110	Brown crust
20	"	326.0	313.0	316.0	74.7	229.2	67.7	1100	Tender
Average		325.0	313.5	316.7	80.4	230.5	68.7	1105	Hard to remove from pan

1. All cakes were baked 60 minutes in pans without tubes with oven regulator set at 325° F.

Studying the reaction of the different materials in the pans with regard to the rise in temperature during baking, it is observed that when the average is considered, (1), tin and aluminum give similar results as do enamel and glass. However, the latter show a greater average rise in temperature than tin and aluminum. They also show a higher final temperature in the cake. Stove pipe iron is an exception in all cases registering, on the average, the lowest rise in temperature, a medium final temperature in the cake and a high breaking force.

In comparing the effect of the kind of material in the pan on the final temperature reached in the cake, some differences are to be noted. Arranged in ascending order as to inside cake temperature obtained, the materials rank as follows:

1. tin
2. aluminum
3. stove pipe iron
4. enamel
5. glass

The differences between tin and aluminum are less than individual differences in the cakes, but when the other materials are used they suggest noticeably higher inside cake temperatures. Experimental data (10), indicate that tin takes up heat somewhat less efficiently than aluminum. The thermal efficiency of enamel ware is definitely higher than aluminum as is that of glass. No figures are available for stove pipe iron but if one may judge from the results obtained in this experiment it, too, has a higher thermal efficiency than either tin or aluminum.

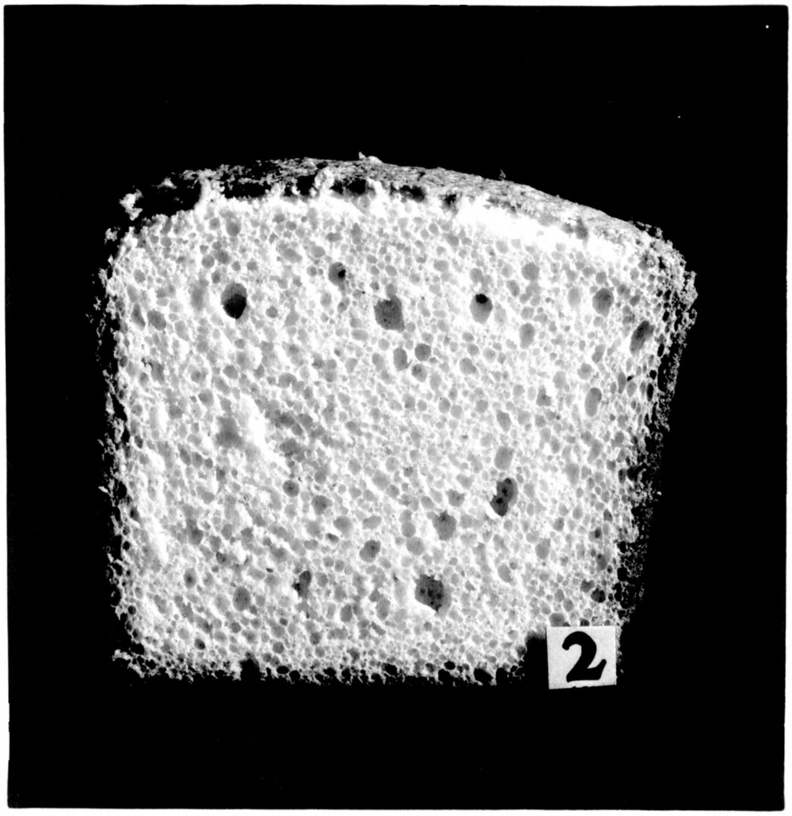
Some correlation possibly may exist between the final temperature obtained in the cake and the breaking force. With a lower temperature, a lower breaking force tends to occur though the differences are not consistent, nor are they convincing, and exceptions occur. Glass in which the highest temperature was registered did not give the toughest cake as tested by its breaking force and by human judgment.

Differences in crust corresponding to those of temperature are noted. When the material absorbs heat readily as in enamel and glass, the crust is browner and thicker as shown in Plate 3.

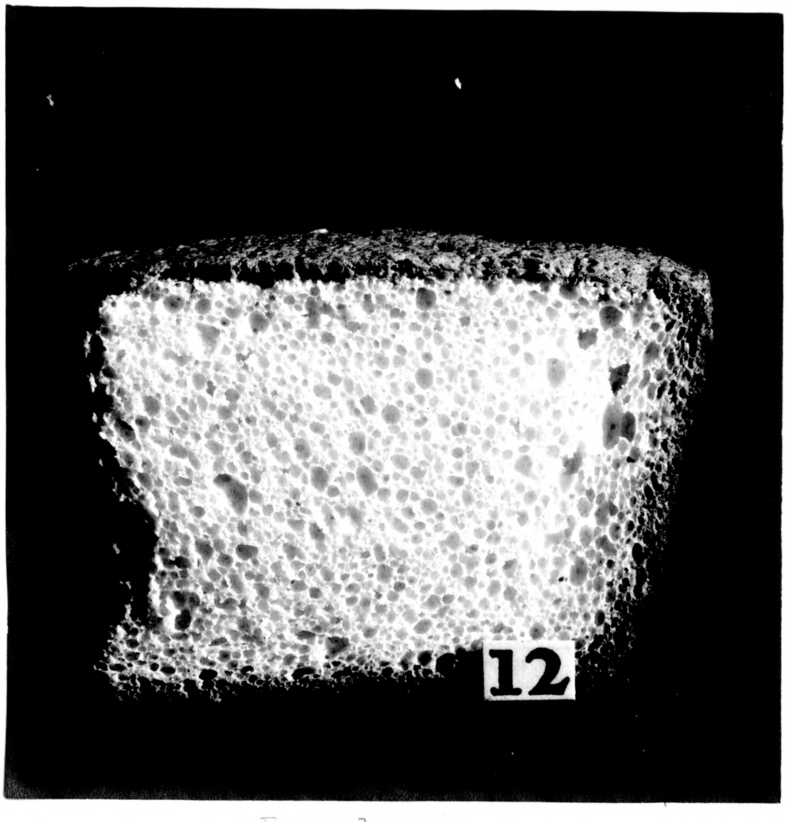
B. The effect on cake quality of tube pans of different materials.

In comparing the three materials, aluminum, tin and stove pipe iron, (Table II), it was found that the rise in temperature in cakes baked in tube pans appeared to be less in the case of aluminum and tin than in the pans without

Plate 3. Effect of Varying Material in Pan



Aluminum pan



Enamel pan

Table II. The Effect on Cake Quality of Tube Pans of Different Materials.[1]

Cake No.	Pan: Material	Pan: Construction	Oven Temperature: Initial	Oven Temperature: Baking Average	Oven Temperature: Final	Cake Temperature: Rise	Cake Temperature: Final	Breaking Force	Volume Increase	Results
			degrees F.	degrees F.	degrees F.	degrees F.	degrees F.	gm./sq.in.	cc.	
1	Aluminum	With tube	325.4	312.0	314.4	73.7	216.5	66.9	1040	Brown crust
2	"	" "	324.1	315.0	318.2	73.5	219.2	67.7	1050	Tender
Average			324.7	313.5	316.3	73.6	217.8	67.2	1045	
7	Aluminum	Without tube	332.6	316.0	317.6	78.0	220.1	68.2	1180	Brown crust
8	"	" "	332.4	316.0	317.6	75.8	222.4	68.7	1135	Tender
Average			332.5	316.0	317.6	76.9	221.2	68.4	1157	
3	Tin	With tube	340.5	320.0	324.8	78.1	216.5	67.3	1010	Brown crust
4	"	" "	333.3	318.0	321.6	68.6	217.4	67.7	950	Tender
Average			336.9	319.0	323.2	73.3	216.9	67.5	980	
9	Tin	Without tube	329.7	316.0	319.6	84.5	221.0	65.2	1050	Brown crust
10	"	" "	327.7	317.0	318.5	78.0	220.4	65.8	1140	Tender
Average			328.7	316.5	319.0	82.2	220.7	65.5	1090	
15	Stove Pipe Iron	With tube	327.3	316.0	318.5	73.8	226.0	71.7	1160	Very brown crust
16	" " "	" "	332.4	319.0	321.8	74.9	226.0	73.1	1200	Tough
Average			329.8	317.5	320.1	74.3	226.0	72.4	1180	
17	Stove Pipe Iron	Without tube	332.6	317.0	318.5	80.8	223.3	73.1	1010	Very brown crust
18	" " "	" "	332.4	319.0	319.2	57.2	224.9	70.0	1010	Tough
Average			332.5	318.5	318.8	69.0	224.1	71.5	1010	

1. All cakes were baked 60 minutes with oven regulator set at 325° F.

tubes. The opposite was true with stove pipe iron. Disregarding the kind of material used in the pan the average oven rise in temperature for cakes in tube pans during the baking period was 73.7° F., and 75.7° F. for those without tubes. The difference of 2° suggests that the rise in temperature may be slightly greater when pans without tubes are used. Stove pipe iron pans, however, as noted above, are an exception to this statement.

Observation of the curves showing the rise in temperature within the cakes during the baking period indicates that when a tube pan was used the rise was more uniform in the aluminum and tin pans which suggests that the tube may permit of a more even and uniform distribution of heat with these materials (Figures 1 and 2). However, no such difference could be detected for stove pipe iron.

The rate of temperature rise immediately following the placing of the cake in the hot oven was nearly twice as fast and not nearly so steady in the pans without tubes. The aluminum pan with a tube showed a remarkably even rise of temperature during baking when the cake was started in a cold oven. Since the pans made of other materials were not tested in this way it is not known whether this is true only of aluminum or whether it holds for other materials as well.

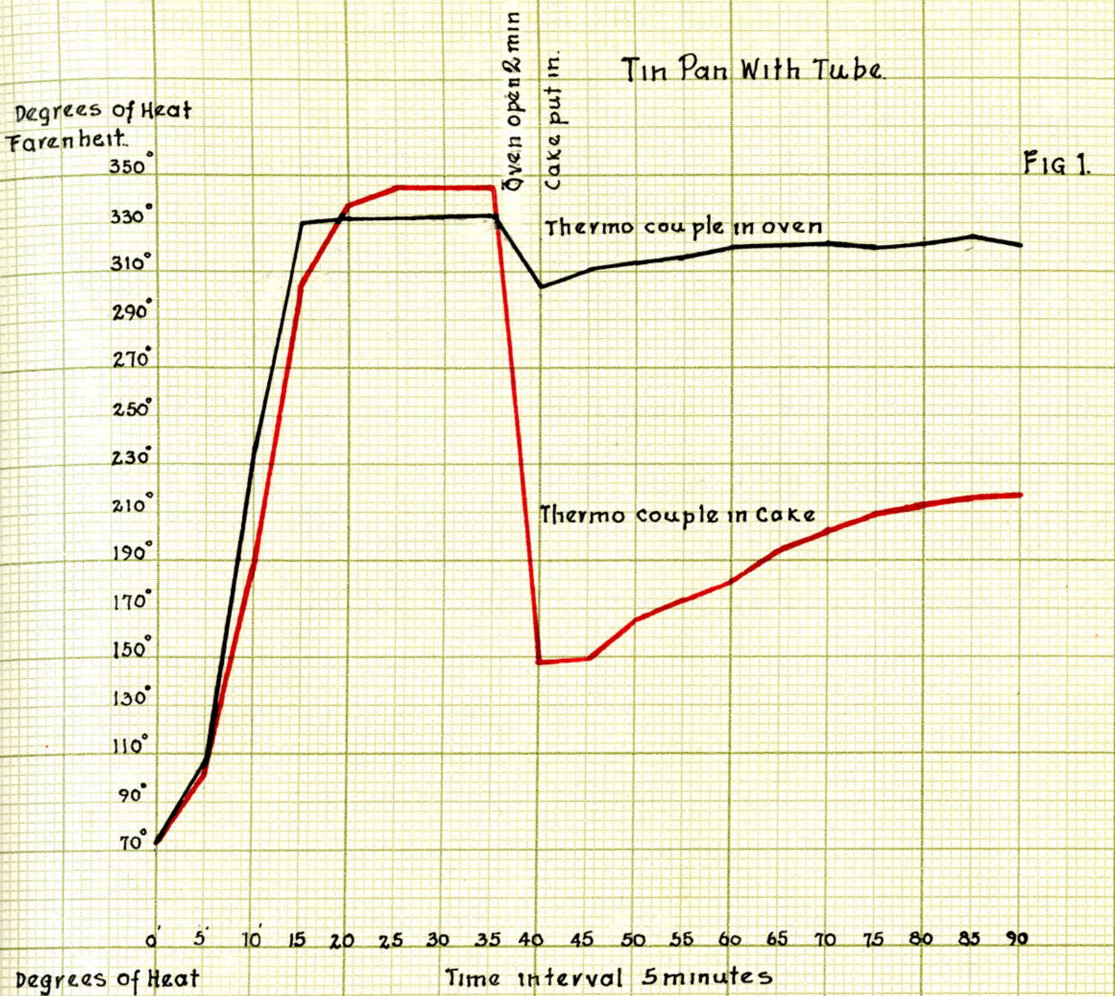

Tin Pan With Tube.
Degrees of Heat Farenheit.
350°
330°
310°
290°
270°
250°
230°
210°
190°
170°
150°
130°
110°
90°
70°
Oven open 2 min
Cake put in.
Thermo couple in oven
Thermo couple in cake
0' 5' 10' 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Time interval 5 minutes

FIG 1.

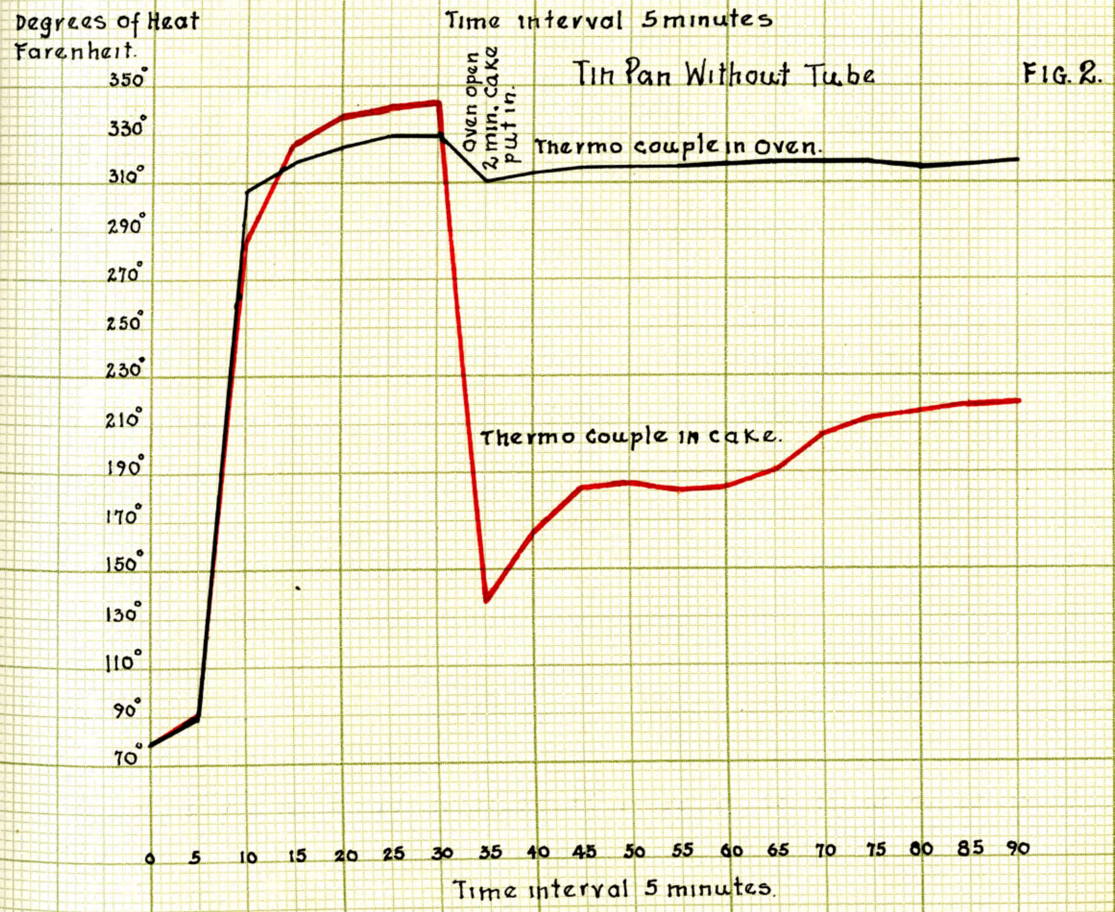

Tin Pan Without Tube
Degrees of Heat Farenheit.
350°
330°
310°
290°
270°
250°
230°
210°
190°
170°
150°
130°
110°
90°
70°
Oven open 2 min. Cake put in.
Thermo couple in Oven.
Thermo couple in cake.
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Time interval 5 minutes.

FIG. 2.

This suggests an interesting problem for further research.

It was desired also to learn the final temperature which was reached within the cake and to see if it varied when a pan with a tube was used. Again no correlation could be observed for pans with and without tubes, a higher final temperature being obtained with aluminum and tin pans when no tube was present, whereas with stove pipe iron the reverse was true.

Since no significant differences in temperature within the cake could be detected whan a tube pan was used, differences in breaking force could not be expected nor were they obtained. The average breaking force for cakes baked in tube pans was 69.0 and for the pans without tubes it was 68.5 grams per square inch. The tubes apparently made no difference in this case.

The above results are, in general, contrary to expectations as it was believed that the tube would probably cause not only a quicker distribution of heat in a given baking period but that a greater degree of heat would be registered. It cannot be said that the tube makes any appreciable difference upon the temperature at which a cake starts to bake, in the rise of baking temperature, or in the final temperature obtained within the cake with its consequent effect upon breaking force. It may, however, tend to cause a more uniform rise in temperature because of a better distribution of heat.

The change in volume of the cake apparently cannot be correlated with the kind of pan used, or the temperature recorded in the cake. Probably the differences observed were too slight to show any marked effects. Neither did the breaking force appear to show any relation to the small differences obtained in volume.

The tubes are apparently a small factor in cake quality so far as these tests were carried. In both (A) and (B) it is to be noted that the initial oven temperature as registered by thermocouple No. I, ranged from 324.0 to 336.9° F. - a difference of 12.9° F. This indicates that the oven temperature is not uniform from time to time and that the variation from the temperature indicated by the regulator may be considerable even when the latter has been carefully adjusted.

Another interesting point is that the average, as well as the final temperature, for the baking period is always less than that indicated by the regulator even over a period as long as 1 hour. The range for the average baking temperature for this series of cakes is from 313-319° F. and for the final temperature is 316.0-323.2° F. It thus appears that the fall of temperature following the placing of the cake in the oven is so great that the oven is never able to return to the original temperature in this length of time. We therefore conclude that the cake actually bakes below the expected temperature.

Part II. Variation of time and temperature for baking the cakes.

The results showing the effects of varying time and temperature for baking appear in Table III.

Variations (b), (c), (d), and (f) gave good products without appreciable differences in tenderness and volume.

When the oven regulator was set at 325° F. a decrease of 15 minutes in the baking time appeared to be desirable. The cake was larger in volume than the control as seen in Plate 4. It was also much more tender though the crust was thin and somewhat pale in color.

With the regulator set at 300° F. no decrease was necessary. This indicates that with the higher temperature a shorter baking period is preferable.

Variations (b) and (c) gave very similar products which when compared with the control (a), showed marked improvement in tenderness, color of crust, and volume.

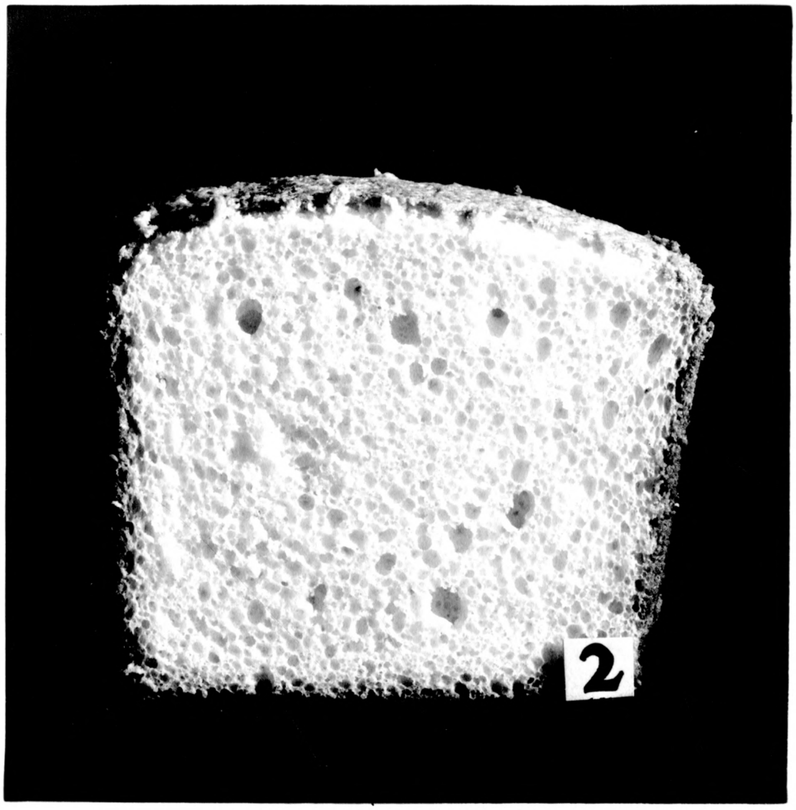
Although variation (d) gave a product similar to (b)

Table III. The Effect on Cake Quality of Varying the Time and Temperature of Baking.[1]

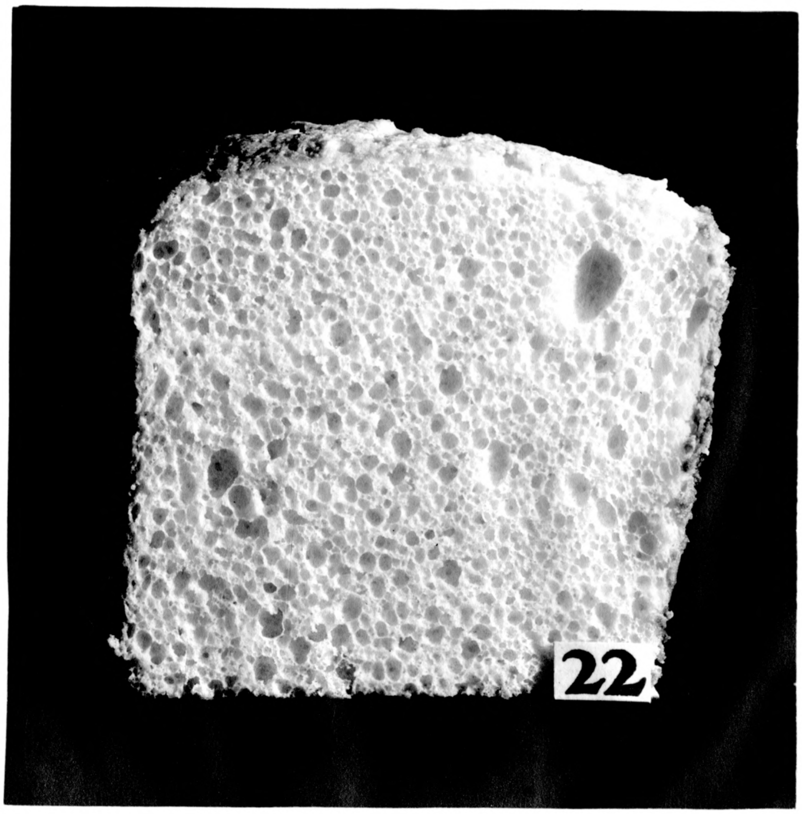
Cake No.	Variation Oven	Baking Time minutes	Oven Temperature: Regulator degrees F.	Oven Temperature: Initial degrees F.	Oven Temperature: Baking Average degrees F.	Oven Temperature: Final degrees F.	Cake Temperature: Rise degrees F.	Cake Temperature: Final degrees F.	Breaking Force gm./sq.in.	Volume Increase cc.	Results
1	(a) Preheated	60	325	325.4	312.0	314.4	73.7	216.5	66.9	1040	Brown crust
2				324.1	315.0	318.2	73.5	219.2	67.7	1050	Somewhat tough
Average[2]				324.7	313.5	316.3	73.6	217.8	67.3	1045	Small volume
21	(b) Preheated	45	325	331.3	311.0	312.9	77.9	214.8	61.7	1310	Light brown crust
22				331.3	311.0	316.9	70.0	213.2	60.7	1400	Very tender
Average				331.3	311.0	313.9	73.9	214.0	61.2	1350	Large volume
25	(c) Preheated	60	300	303.6	290.0	292.4	60.3	212.1	60.3	1200	Same as (b)
26				303.6	290.0	293.0	80.5	209.3	63.7	1222	
Average				303.6	290.0	292.7	70.4	210.2	62.0	1211	
29	(d) Cold	60	300	66.5	276.0	294.9	142.8	209.3	63.2	1150	Same as (b)
30				76.6	278.0	294.4	131.9	208.5	63.7	1050	
Average				71.5	277.0	294.6	137.3	208.9	63.4	1100	
31	(e) Preheated with water[3]	60	325	318.5	307.0	312.0	72.2	213.6	63.0	1150	Brown crust
32				315.6	302.0	305.6	100.5	214.1	64.0	1170	Fairly tender
Average				317.0	304.5	308.8	86.3	213.8	63.5	1160	Large volume
33	(f) Preheated with water	50	325	317.6	308.0	316.9	86.9	213.2	61.7	1110	Same as (b)
34				314.7	303.0	306.1	78.4	213.2	61.2	1150	
Average				316.1	305.5	311.5	82.6	213.2	61.4	1130	

1. All cakes baked in an aluminum tube pan.
2. Control
3. 500 cc. of water in oven.

Plate 4. Effect of Varying Time of Baking



Baked 60 minutes



Baked 45 minutes

and (c) there appeared to be no advantage so far as cake quality was concerned in starting the baking in a cold oven. However, there might be a saving of time and fuel and less danger of over-baking.

Variation (f) seemed to prolong the time required for baking but with an unregulated oven it might serve to keep the temperature down and thus prevent over-baking.

From the above results, variation (b) was selected for use in the remainder of this work. It gave one of the best products and saved 15 minutes on the baking time.

Part III. Variation of the different ingredients used in the cake.

The results of the effect of varying the different ingredients appear in Tables IV-IX inclusive.

A. The substitution of bread flour for pastry flour.

The bread flour used was a long patent, about 95 per cent straight grade, so perhaps did not represent the best flour of this type for the purpose. However, with this grade, certain results are to be noted.

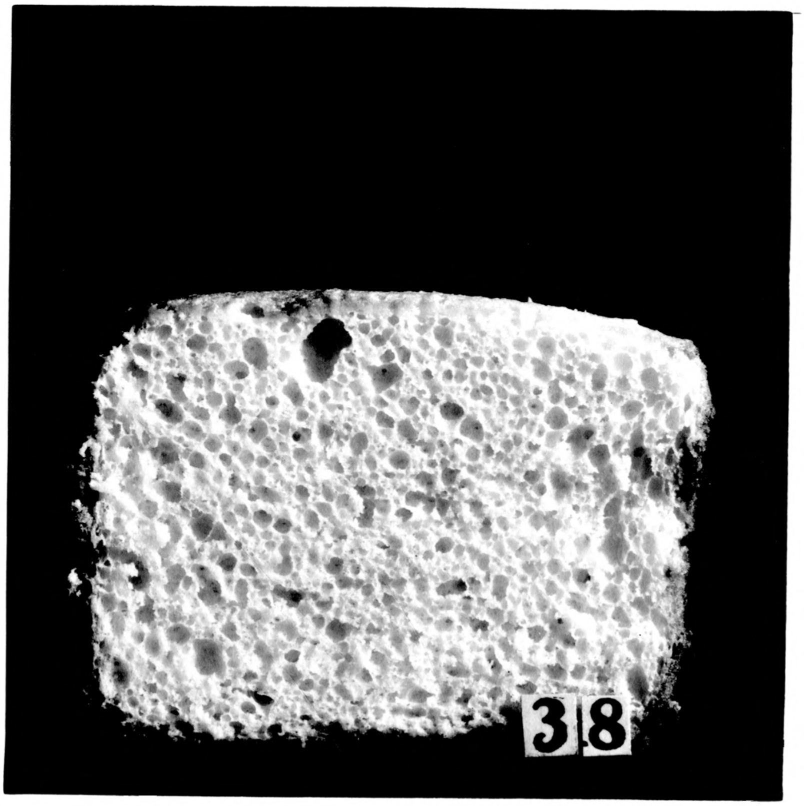
The inside temperature and breaking force of the cakes were higher when bread flour was used, and a corresponding decrease of volume was observed as seen in Plate 5. The average relative viscosity of the batter was also higher. The flavor was less desirable and the color of the interior

Table IV. The Effect on Cake Quality of Varying the Kind of Flour.[1]

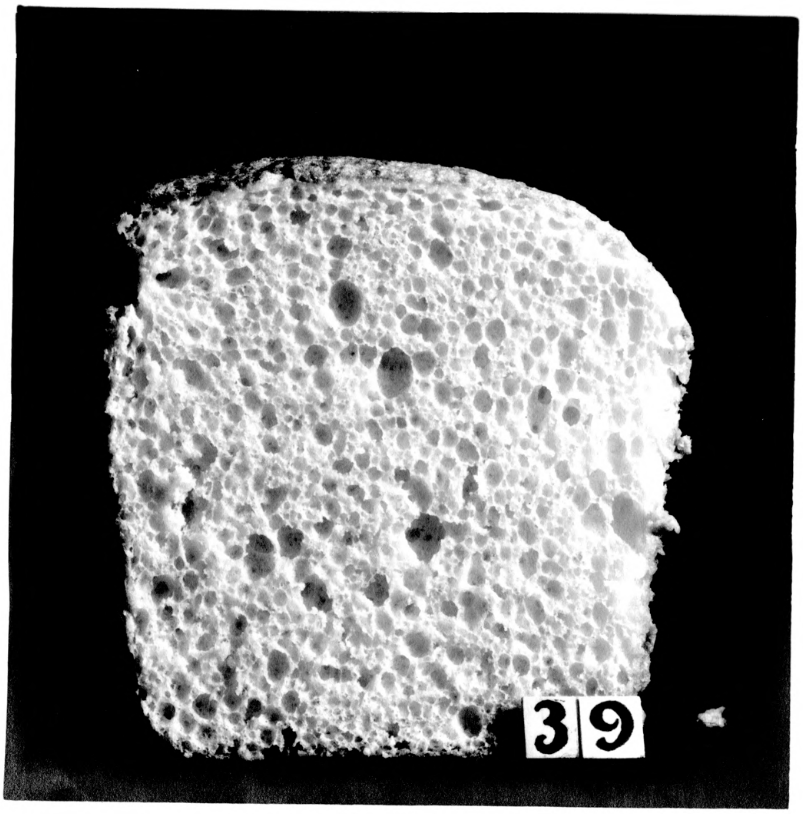
Cake No.	Variation: Pastry Flour gm.	Variation: Pastry Flour cups	Variation: Bread Flour gm.	Variation: Bread Flour cups	Oven Temperature: Initial degrees F.	Oven Temperature: Baking Average degrees F.	Oven Temperature: Final degrees F.	Cake Temperature: Rise degrees F.	Cake Temperature: Final degrees F.	Breaking Force gm./sq.in.	Volume Increase[2] cc.	Relative Viscosity Batter (water = 1)	Results
35			113	1	326.4	310.0	312.0	71.5	215.6	68.2	900	2.31	Light brown crust
36			113	1	324.1	309.0	312.4	57.7	215.7	67.7	900	2.36	Creamy interior Tough Bread flour odor
Average			113	1	325.2	309.5	312.2	64.6	215.6	67.9	900	2.33	
37			99	1-2T.[3]	321.0	308.0	311.3	82.4	219.3	66.2	900	2.63	Light brown crust
38			99	1-2T.	324.1	305.0	307.9	84.1	217.4	67.2	940	2.68	Less creamy interior
Average			99	1-2T.	322.5	306.5	309.6	83.2	218.3	66.7	920	2.65	Tough Bread flour odor less evident
39	100	1			328.4	308.0	311.6	91.9	210.9	61.7	1050	1.47	Light brown crust
40	100	1			320.9	307.0	310.8	54.0	210.5	63.2	1050	2.89	White interior Tender
Average[4]					324.6	307.5	311.2	72.9	210.7	62.4	1050	2.18	Pleasant odor

1. All cakes baked 45 minutes in an aluminum tube pan with oven regulator set at 325° F.
2. 66 gm. of batter were taken out for viscosity determinations.
3. T. equal tablespoon.
4. Control.

Plate 5. Effect of Substituting Bread for Pastry Flour



Bread flour



Pastry flour

was darker.

The results suggest that a better cake is obtained with this grade of bread flour when the amount is decreased 2 tablespoons to the cup. In no case is it so desirable as the pastry flour control. A high patent flour probably would have shown more favorable results.

B. The substitution of varying amounts of cornstarch for bread flour.

The amount of cornstarch substituted for bread flour varied from 1-8 tablespoons by weight. The physical measurements of viscosity, breaking force and temperature differed so much that no conclusions can be drawn. It is believed that the factors which could not be controlled had a greater effect on the results than the ones that were to be measured.

Judging from the scores and the results as shown in Table V, the substitution of cornstarch to the extent of 4 tablespoons to the cup was desirable in the case of the grade of bread flour used in this experiment. The cake had a finer grain, a whiter color, and was larger than the bread flour control though somewhat smaller than the cakes made of pastry flour (Nos. 39 and 40, Table IV). A greater substitution did not give a satisfactory product

Table V. The Effect on Cake Quality of Substituting Varying Amounts of Cornstarch for Bread Flour.[1]

Cake No.		Variation: Bread Flour gm.	Variation: Corn-Starch gm.	Oven Temperature: Initial degrees F.	Oven Temperature: Baking Average degrees F.	Oven Temperature: Final degrees F.	Cake Temperature: Rise degrees F.	Cake Temperature: Final degrees F.	Breaking Force gm./sq.in.	Volume Increase[2] cc.	Relative Viscosity Batter (water = 1)
41	(a)	99	7.8	316.5	308.0	313.3	68.6	209.3	70.7	1080	2.89
42	"	"	"	321.8	308.0	310.1	71.6	208.0	67.7	1080	2.10
Average				319.1	308.0	311.7	70.1	208.6	69.2	1080	2.49
43	(b)	99	11.7	321.8	309.0	311.3	78.1	215.7	65.7	1065	2.10
44	"	"	"	320.9	308.0	309.7	85.0	210.0	63.7	1065	2.36
Average				321.3	308.5	310.5	81.5	212.8	64.7	1065	2.23
45	(c)	84	31	320.9	307.0	307.7	70.2	210.9	63.7	1025	2.10
46	"	"	"	316.5	302.0	303.6	94.0	212.0	63.7	1000	2.63
Average				318.7	304.5	305.6	82.1	211.4	63.7	1012	2.36
47	(d)	70.7	46.8	321.8	307.0	308.8	74.4	208.4	63.7	990	3.15
48	"	"	"	319.2	304.0	306.8	69.6	214.1	64.7	1000	4.21
Average				320.5	305.5	307.8	72.0	211.2	64.2	995	3.68
49	(e)	56.5	61.4	314.4	304.0	306.8	52.3	208.5	65.7	1010	3.94
50	"	"	"	317.3	302.0	304.2	40.5	208.9	66.7	1010	4.40
Average				315.8	303.0	305.5	46.4	208.7	66.2	1010	4.17
35	(f)	113		326.4	310.0	312.0	71.5	215.6	68.2	900	2.31
36	"	"		324.1	309.0	312.4	57.7	215.7	67.7	900	2.36
Average[3]				325.2	309.5	312.2	64.6	215.6	67.9	900	2.33

1. All cakes baked 45 minutes in an aluminum tube pan with oven regulator set at 325° F.
2. 66 gm. of batter were taken out for viscosity determinations.
3. Control.

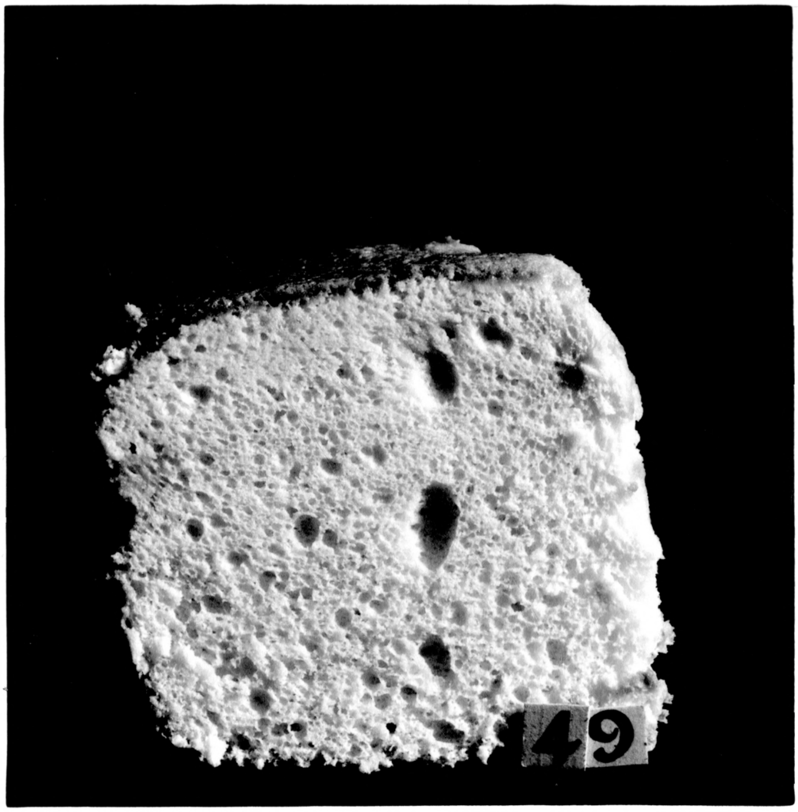
in these experiments resulting in a fairly fine grain but a smaller and heavier cake as Plate 6 indicates.

C. Varying the amount of sugar.

When the sugar was varied from 1 to $1\frac{1}{2}$ cupfuls there was an increase in tenderness as shown by breaking force (Table VI). The greatest difference was observed between $1\frac{1}{4}$ and $1\frac{1}{2}$ cups. It seems that the use of the larger amount of sugar is desirable, not only from the standpoint of tenderness, but also from that of flavor and volume.

Beginning with this series of experiments, viscosity was determined for both beaten egg whites and cake batter. Previous work indicated that probably the egg whites varied in this respect so much that they obscured the factors to be measured. The figures shown here suggest that while egg whites do vary considerably in this respect they probably do not account entirely for the results obtained. Other variables that could not be controlled doubtless also played a part. It seems impossible to correlate cake quality with the viscosity of the batter as measured in this experiment. However, for the sake of interest these figures are included throughout this part of the study.

Plate 6. Effect of Substituting Cornstarch for Part of Bread Flour



8 tablespoons of cornstarch and 8 tablespoons of bread flour used

Table VI. The Effect on Cake Quality of Varying Amounts of Sugar.[1]

Cake No.	Variation: Sugar gm.	cups	Oven Temperature: Initial degrees F.	Oven Temperature: Baking Average degrees F.	Oven Temperature: Final degrees F.	Cake Temperature: Rise degrees F.	Cake Temperature: Final degrees F.	Breaking Force gm./sq.in.	Volume Increase[2] cc.	Relative Viscosity: Batter (water = 1)	Relative Viscosity: Egg Whites (water = 1)	Results
51	300	1½	317.3	303.7	306.1	62.9	210.2	45.0	1300	3.94	1.31	Light brown crust
52	"	"	316.4	303.1	305.7	60.8	211.2	42.8	1300	4.21	1.31	Tenderest
Average			316.3	303.4	305.9	61.8	210.7	43.9	1300	4.07	1.31	Largest volume
53	200	1	317.3	300.0	302.5	63.0	210.2	66.4	700	2.63	0.78	Light brown crust
54	"	"	320.9	306.6	306.5	80.6	213.2	68.4	1120	2.63	1.31	Somewhat tough
Average			319.1	303.3	304.5	71.8	211.7	67.4	910	2.63	1.04	Small volume
39	250	1¼	328.4	308.0	311.6	91.9	210.9	61.7	1050	1.47	1.05	Light brown crust
40	"	"	320.9	307.0	310.8	54.0	210.5	63.2	1050	2.89	1.05	More tender
Average[3]			324.6	307.5	311.2	72.9	210.7	62.4	1050	2.18	1.05	Larger volume

1. All cakes baked 45 minutes in an aluminum tube pan with oven regulator set at 325° F.
2. 66 gm. of batter were taken out for viscosity determinations.
3. Control.

D. Varying the amount of egg whites.

From Table VII, it is noted that tenderness and volume are increased when more egg whites are used. It is interesting to observe that the greatest volume was obtained when the eggs were increased 50 per cent (Plate 7). When raised beyond this point the change in volume was not correspondingly great but the cake was more tender, and voted more desirable. Therefore this amount of eggs was used in the remainder of the experiment.

E. Varying the amount of cream of tartar.

It was expected that some toughening of the cake would result from increasing the acid due to its action on the egg albumin and possibly on the gluten of the flour. However, such differences in breaking force could not be noted as all cakes were about equally tender (Table VIII).

The shape of the cake was definitely improved with increase in cream of tartar which is scarcely in accord with the above data though it does suggest some action of the acid on the protein in the mixture.

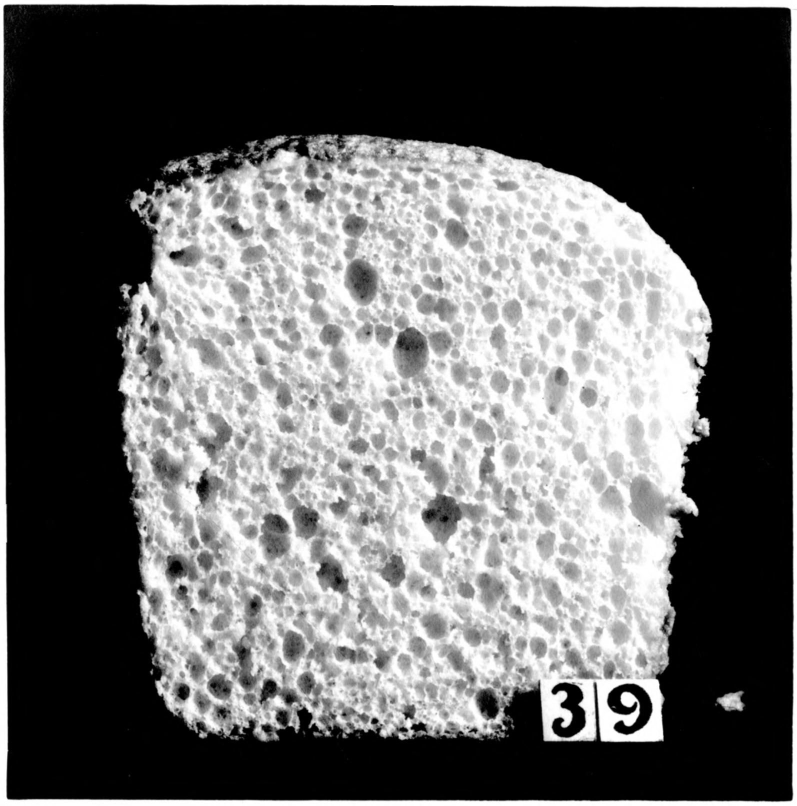
Some increase in hydrogen-ion concentration occurred when more acid was used, although it was not definitely proportional to the amount. The pH of the egg whites with one exception, which suggests a possibility of error, was

Table VII. The Effect on Cake Quality of Varying Amounts of Egg White.[1]

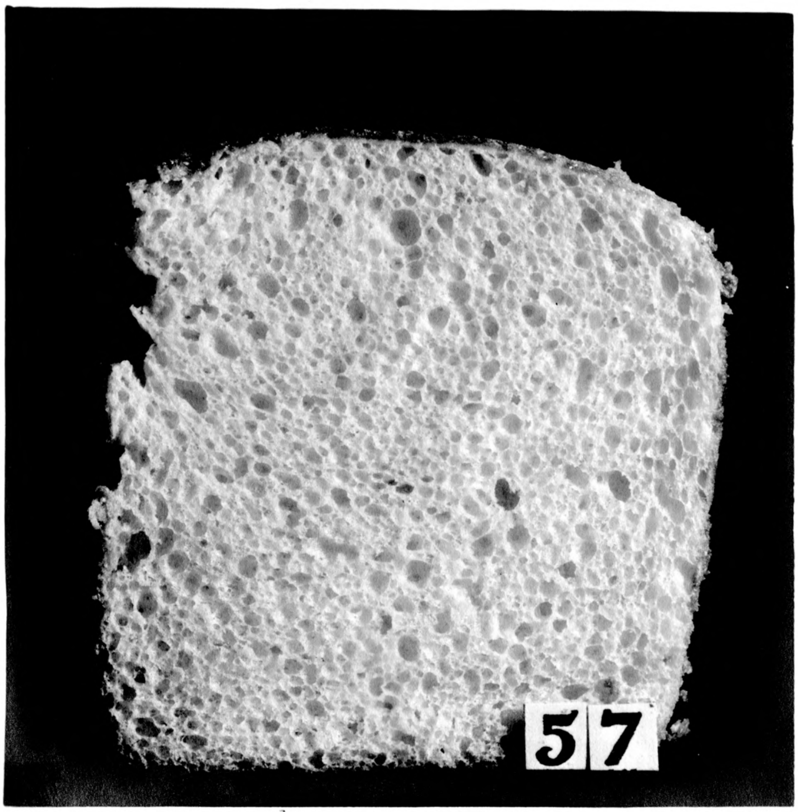
Cake No.	Variation Egg Whites gm.	Variation Egg Whites cups	Oven Temperature Initial degrees F.	Oven Temperature Baking Average degrees F.	Oven Temperature Final degrees F.	Cake Temperature Rise degrees F.	Cake Temperature Final degrees F.	Breaking Force gm./sq.in.	Volume Increase[2] cc.	Relative Viscosity Batter (water = 1)	Relative Viscosity Egg Whites (water = 1)	Results
55	303	1¼	319.2	307.0	308.4	66.0	211.2	37.05	1150	2.63	1.31	Light brown crust
56	"	"	321.8	306.0	308.1	97.0	210.9	43.8	1150	2.63	0.78	Tender
Average			320.5	306.5	308.2	81.5	211.0	40.42	1150	2.63	1.04	Large volume
57	364	1½	317.3	271.0	303.2	78.4	206.9	38.5	1550	2.63	1.05	Light brown crust
58	"	"	316.4	298.0	300.9	55.8	206.6	38.0	1550	2.89	1.31	More tender
Average			316.8	284.0	302.0	67.1	206.7	38.3	1550	2.76	1.18	Much larger volume
59	425	1¾	311.3	296.0	298.0	60.7	206.4	36.4	1600	2.36	0.78	Light brown crust
60	"	"	317.6	304.0	307.4	77.2	208.9	37.4	1600	2.36	1.05	Most tender
Average			314.4	300.0	302.7	68.9	207.6	36.8	1600	2.36	0.91	Largest volume
39	243	1	328.4	308.0	311.6	91.9	210.9	61.7	1050	1.47	No data	Light brown crust
40	"	"	320.9	307.0	310.8	54.0	210.5	63.2	1050	2.89	" "	Somewhat tough
Average[3]			324.6	307.5	311.2	72.9	210.7	62.4	1050	2.18		Smaller volume

1. All cakes baked 45 minutes in an aluminum tube pan with oven regulator set at 325° F.
2. 66 gm. of batter were taken out for viscosity determinations.
3. Control.

Plate 7. Effect of Increasing the Amount of Egg Whites



1 cup egg whites



$1\frac{1}{2}$ cup egg whites

Table VIII. The Effect on Cake Quality of Varying Amount of Cream of Tartar.[1]

Cake No.	Variation: Cream of Tartar		Oven Temperature			Cake Temperature		Breaking Force	Volume Increase[2]	Relative Viscosity		pH		Results
	gm.	t.[3]	Initial	Baking: Average	Final	Rise	Final			Batter	Egg Whites	Batter	Egg Whites	
			degrees F.	degrees F.	degrees F.	degrees F.	degrees F.	gm./sq.in.	cc.	(water=1)	(water=1)			
61	4.7	$1\frac{1}{2}$	319.2	302.0	304.8	60.1	208.5	37.0	1700	2.36	1.05	4.98	8.44	Light brown crust
62	"	"	318.2	302.0	304.8	69.3	208.9	38.0	1700	2.63	1.31	5.32	8.43	Creamy interior
														Poor shape
Average			318.7	302.0	304.8	64.7	208.7	37.5	1700	2.49	1.18	5.15	8.44	Larger volume
63	6.2	2	324.5	303.0	307.7	66.0	210.0	37.0	1700	2.36	1.05	5.86	8.37	Light brown crust
64	"	"	318.2	304.0	307.4	79.0	209.0	38.0	1700	3.10	1.05	5.66	6.75	White interior
														Good shape
Average			321.3	303.5	307.5	72.5	209.5	37.5	1700	2.73	1.05	5.76	7.56	Larger volume
59	2.3	$\frac{3}{4}$	311.3	296.0	296.0	60.7	206.4	36.4	1600	2.36	.78	6.78	8.03	Light brown crust
60	"	"	317.6	304.0	307.4	77.2	208.9	37.4	1600	2.36	1.05	6.06	7.35	Creamy interior
														Very poor shape
Average[4]			314.4	300.0	301.7	68.9	207.6	36.7	1600	2.36	.92	6.42	7.69	Smaller volume

1. All cakes baked 45 minutes in an aluminum tube pan with oven regulator set at 325° F.
2. 66 gm. were taken out for viscosity and pH determinations.
3. t. equals teaspoon.
4. Control.

very close for all of the cakes in this series so it does not appear probable that much of the difference was due to variation in the pH of the egg whites.

The interior of the cake appeared whiter in color as suggested in the literature (4, 7), though no data are available to show that this is a direct result of increased hydrogen-ion concentration.

The volume of these cakes was also somewhat greater. This perhaps may have been due to the fact that the larger quantity of acid acted on the protein in such a way that it enabled it to retain more air.

F. Varying the amounts of water.

From the data in Table IX it appears that addition of water definitely increased the tenderness of the cake, the breaking force decreasing from an average of 61.5 to 43.4 grams per square inch when 2 tablespoons of water were added. Increasing the water to 4 tablespoons made the cake but little more tender and gave a decidedly small-volume as seen in Plate 8. In no case was the volume improved by addition of water.

Moisture was determined on all cakes in this series. It was found to increase as the table indicates.

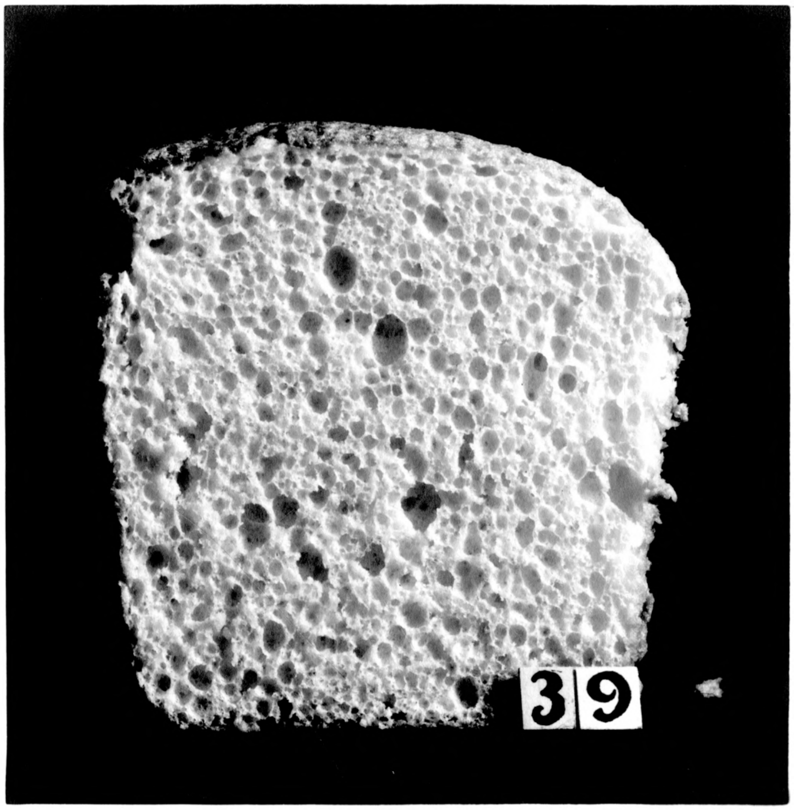
Substitution of water in varying amounts for egg white showed practically no difference for breaking force,

Table IX. The Effect on Cake Quality of Addition of Water and of Substitution of Water for Eggs.[1]

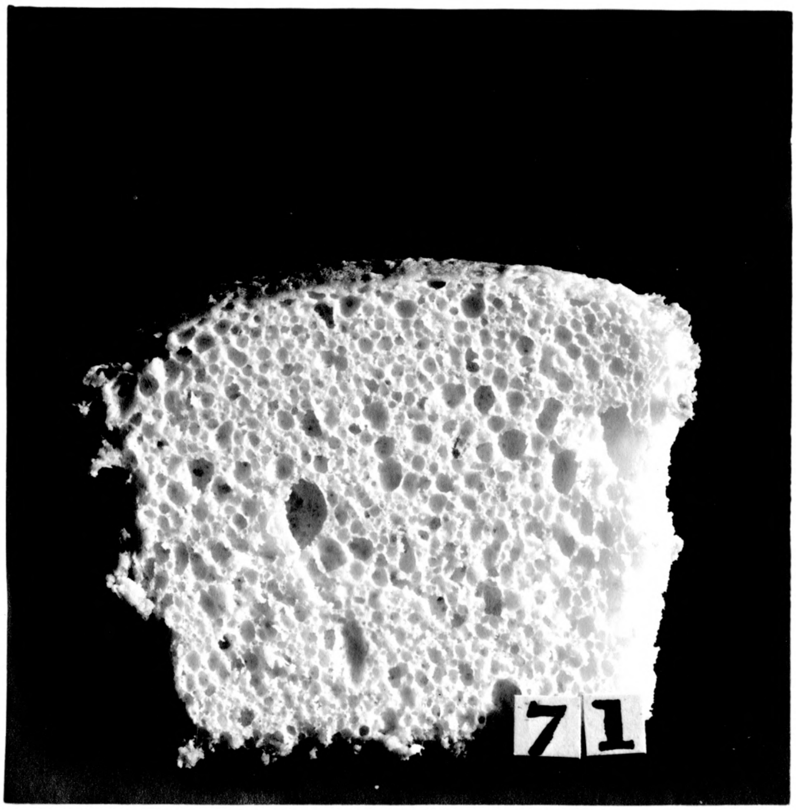
Cake No.	Variation: Eggs cups	Variation: Water T.[3]	Oven Temperature: Initial degrees F.	Oven Temperature: Baking Average degrees F.	Oven Temperature: Final degrees F.	Cake Temperature: Rise degrees F.	Cake Temperature: Final degrees F.	Breaking Force gm./sq.in.	Volume Increase[2] cc.	Relative Viscosity: Batter (water=1)	Relative Viscosity: Egg Whites (water=1)	Moisture per cent	Results
39 (a)	1		310.8	295	301.6	77.1	194.0	61.0	1025	No data	No data	37.4	Light brown crust
40 (b)	"		301.6	290	301.6	80.0	201.2	62.0	1025	" "	" "	37.4	Tender
Average[4]			306.2	292	301.6	78.5	197.6	61.5	1025			37.4	Large volume
67	1	2	311.0	299	301.2	60.8	208.2	42.4	1000	2.63	1.31	42.4	Light brown crust
68	"	"	308.1	268	300.0	70.0	205.3	44.4	1050	2.63	1.05	41.1	More tender
Average			309.5	283	300.6	65.4	206.7	43.4	1025	2.63	1.18	41.7	Large volume
69	1	4	305.6	292	292.4	81.4	202.2	40.4	800	2.63	1.31	44.1	Light brown crust
70	"	"	307.7	294	296.4	82.8	206.4	42.4	900	2.36	1.05	44.1	More tender
Average			306.6	293	294.4	82.1	204.3	41.4	850	2.49	1.18	44.1	Small volume
71	3/4	2	313.7	301	301.6	66.6	219.2	41.4	700	3.15	1.05	36.4	Pale crust
72	"	"	313.7	303	304.2	58.8	219.3	42.4	700	3.15	1.31	35.4	More tender
Average			313.7	302	302.9	62.7	219.2	41.9	700	3.15	1.18	35.9	Smaller volume
73	1/2	4	313.3	300	301.6	63.9	223.5	39.4	500	3.42	1.05	37.7	Pale crust
74	"	"	309.7	289	301.2	87.6	219.3	44.4	500	3.15	1.05	32.8	Tender Heavy
Average			311.5	294	301.4	75.7	221.4	41.9	500	3.28	1.05	35.2	Very small volume

1. All cakes baked 45 minutes in an aluminum tube pan with oven regulator set 325° F.
2. 66 gm. of batter were taken out for viscosity determinations.
3. T. equals tablespoon.
4. Control.

Plate 8. Effect of Substituting Water for Egg Whites



1 cup egg whites, no water



$\frac{3}{4}$ cup egg whites, 2 tablespoons water all the cakes being equally tender. The volume was markedly reduced and in proportion to the amount of water added. The results indicate that it is scarcely desirable to substitute water for egg whites, at least beyond the point of 2 tablespoons of water for 2 eggs (2). Even then the volume will be correspondingly smaller.

Part IV. Variation of the methods of mixing.

The results of the effects of varying the method of mixing appear in Table X.

Variations (A), (B), (C), (D), and (F) gave good products which may be regarded as equal as to quality except for grain which was closer, more even, and generally desirable in (D). In this cake the folding was continued for 2 minutes at the end of the mixing process. The texture is contrasted with (C) in Plate 9.

In (E) the grain was fine in general, but contained a great many large holes as Plate 10 indicates. In (G) the cake did not stand up well, apparently lacking body. This may be due to the fact that the acid cream of tartar has greater strengthening effect on the eggs when added directly to them.

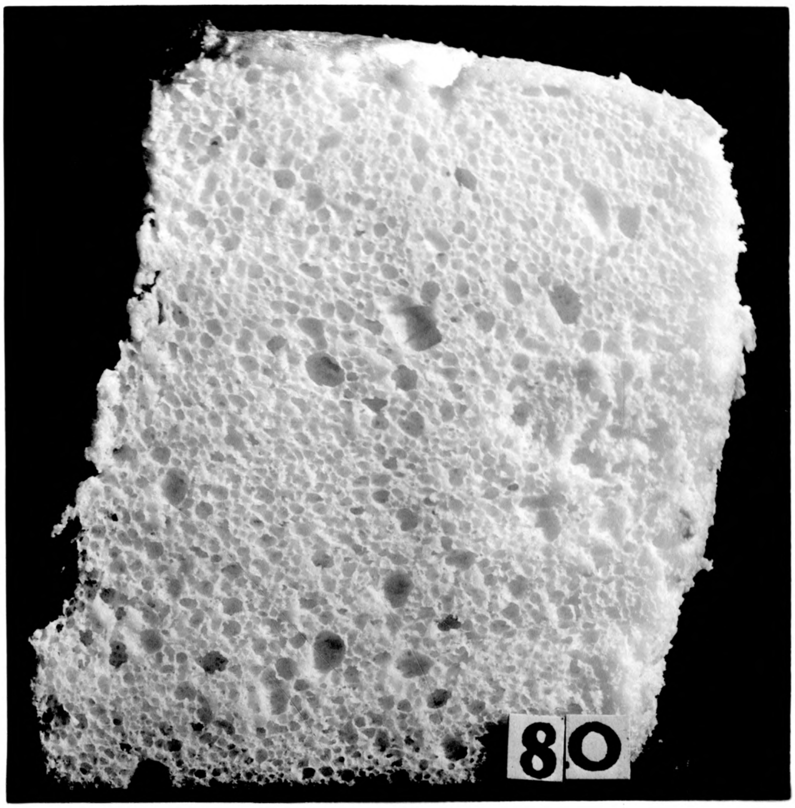
Variation (D) may be considered to give the most desirable product. It is shown in Plate 11. Because the crust was paler then the general public likes it was decided to extend the baking period 10 minutes. The result

Table X. The Effect on Cake Quality of Varying the Methods of Mixing.[1]

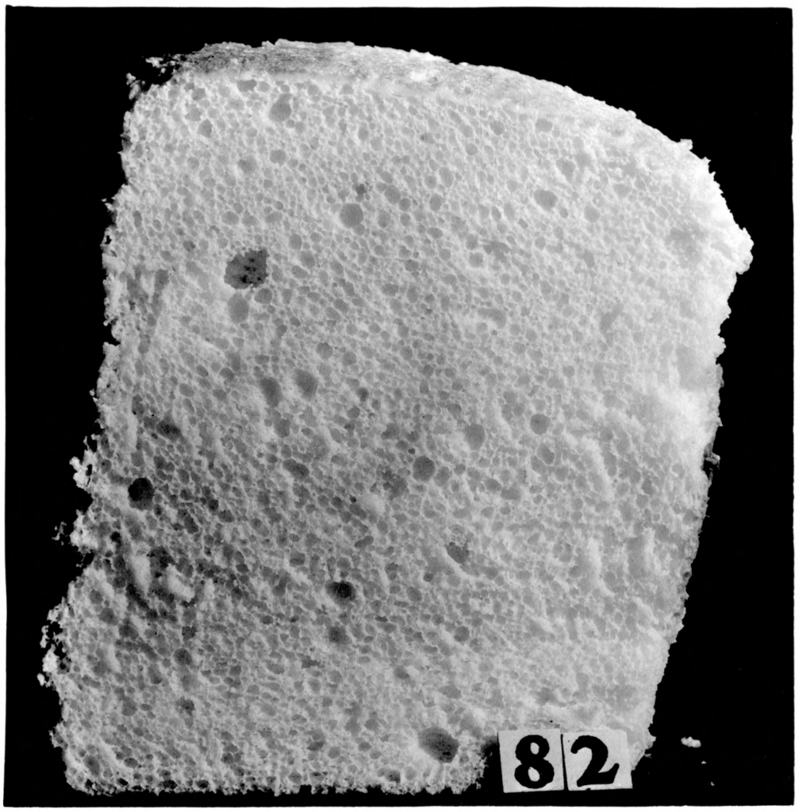
Cake No.	Variation	Oven Temperature: Initial degrees F.	Oven Temperature: Baking Average degrees F.	Oven Temperature: Final degrees F.	Cake Temperature: Rise degrees F.	Cake Temperature: Final degrees F.	Breaking Force gm./sq.in.	Increase in Volume[2] cc.	Relative Viscosity: Batter (water=1)	Relative Viscosity: Egg Whites (Water=1)	pH: Batter	pH: Egg Whites	Results
75	(A). Sugar and flour sif-	310.1	298.0	303.2	66.8	205.3	32.8	1400	2.63	1.05	5.86	7.35	Light brown crust
76	ted together 3 times,	312.8	299.0	302.1	57.2	206.0	32.4	1800	2.63	1.31	5.52	7.21	Tender
Average	folded in at the last.	311.5	298.5	302.7	62.0	205.7	32.6	1600	2.63	1.18	5.69	7.28	Moderately fine grain
77	(B). 1 cup sugar, sifted	315.3	270.0	303.8	38.7	204.8	33.4	1800	2.36	1.05	5.62	7.35	Same as (A)
78	once, beaten into eggs	313.7	298.0	301.2	40.6	207.6	30.4	1800	3.42	1.31	5.66	8.03	
Average	with spoon; remaining ½	314.5	284.0	302.5	39.7	206.2	31.9	1800	2.89	1.18	5.64	7.69	
	cup combined with flour,												
	sifted 3 times, folded in												
	at the last.												
79	(C). Same as (B) except	310.1	296.0	301.2	60.0	208.0	31.4	1800	2.63	1.31	5.32	8.19	Same as (A)
80	sugar was beaten into	314.6	300.0	304.5	74.0	206.0	31.4	1800	3.42	1.05	5.93	8.36	
Average	eggs with a Dover egg	312.4	298.0	302.9	67.0	207.0	31.4	1800	3.03	1.18	5.63	8.27	
	beater and beating con-												
	tinued 2 minutes.												
81	(D). Same as (C) except	314.9	302.0	306.1	47.0	208.0	31.6	1800	3.42	0.78	5.96	7.69	Light brown crust
82	folding continued 2	314.0	299.0	304.5	86.0	208.5	32.4	1800	3.10	1.05	5.32	7.01	Tender
Average	minutes.	314.5	300.5	305.3	66.5	208.3	32.0	1800	3.26	0.92	5.64	7.35	Fine and even grain
83	(E). Sugar made into syrup	316.0	300.0	301.6	51.0	206.0	37.4	1800	2.63	1.05	5.15	7.01	Very light brown crust
84	with 119 cc. water (½ c)	306.0	294.0	298.5	84.0	203.3	36.4	1800	2.63	1.05	5.49	7.84	Somewhat tough
Average	cooked to 119°C. (firm	311.0	297.0	300.1	67.5	204.7	36.9	1800	2.63	1.05	5.32	7.43	Fine grain marred by
	ball) poured slowly while												many large holes
	beating over stiffly												
	beaten egg whites beaten												
	with a spoon until cold.												
85	(F). Whip substituted for	311.0	298.0	300.0	52.0	206.0	32.4	1800	3.10	1.05	5.32	8.36	Same as (A)
86	Dover egg beater; other-	306.1	296.0	296.4	86.0	202.8	33.4	1800	3.10	0.78	5.66	8.36	
Average	wise same as (C).	308.6	297.0	298.2	69.0	204.4	32.9	1800	3.10	0.92	5.49	8.36	
87	(G). Cream of tartar add-	321.8	307.0	313.5	38.0	206.4	33.4	1800	3.81	1.31	5.59	7.69	Light brown crust
88	ed to flour-sugar mixture,	321.8	306.0	309.3	45.0	206.6	33.4	1800	3.15	1.05	5.86	7.35	Tender; creamy interior
Average	otherwise same as (C).	321.8	306.5	311.9	41.5	206.5	33.4	1800	3.48	1.18	5.73	7.52	Lacked body
65	(H). Sugar sifted once,	316.9	301.0	304.5	81.0	208.0	34.4	1800	2.36	1.05	5.86	8.36	Same as (A)
66	flour 3 times, sugar beaten	315.3	302.0	304.8	67.0	208.0	30.4	1800	2.07	1.05	5.52	6.03	
Average[3]	gradually into egg whites	316.1	301.5	304.7	74.0	208.0	32.4	1800	2.22	1.05	5.69	7.20	
	with a spoon, flour folded												
	in at the last.												

1. All cakes baked 45 minutes in an aluminum tube pan with oven regulator set at 325° F.
2. 66 gm. of batter were taken out for viscosity and pH determinations.
3. Control.

Plate 9. Effect of Folding at End of Mixing Process

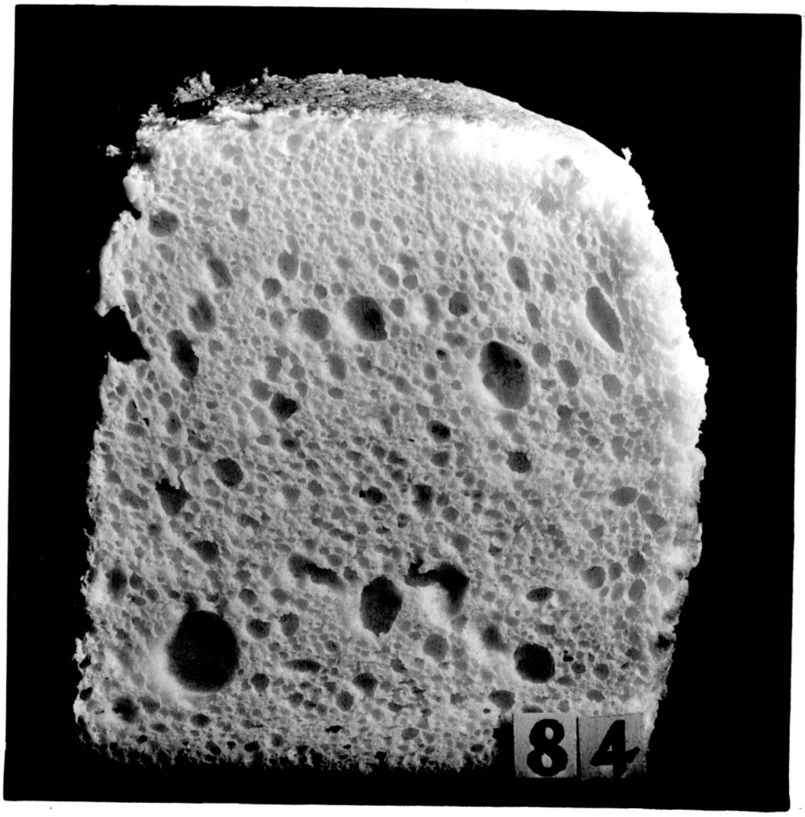


Without folding



Folding 2 minutes at end of mixing process

Plate 10. Effect of Making Sugar into a Syrup



Sugar made into a syrup, beaten into egg whites, and beating continued until cold

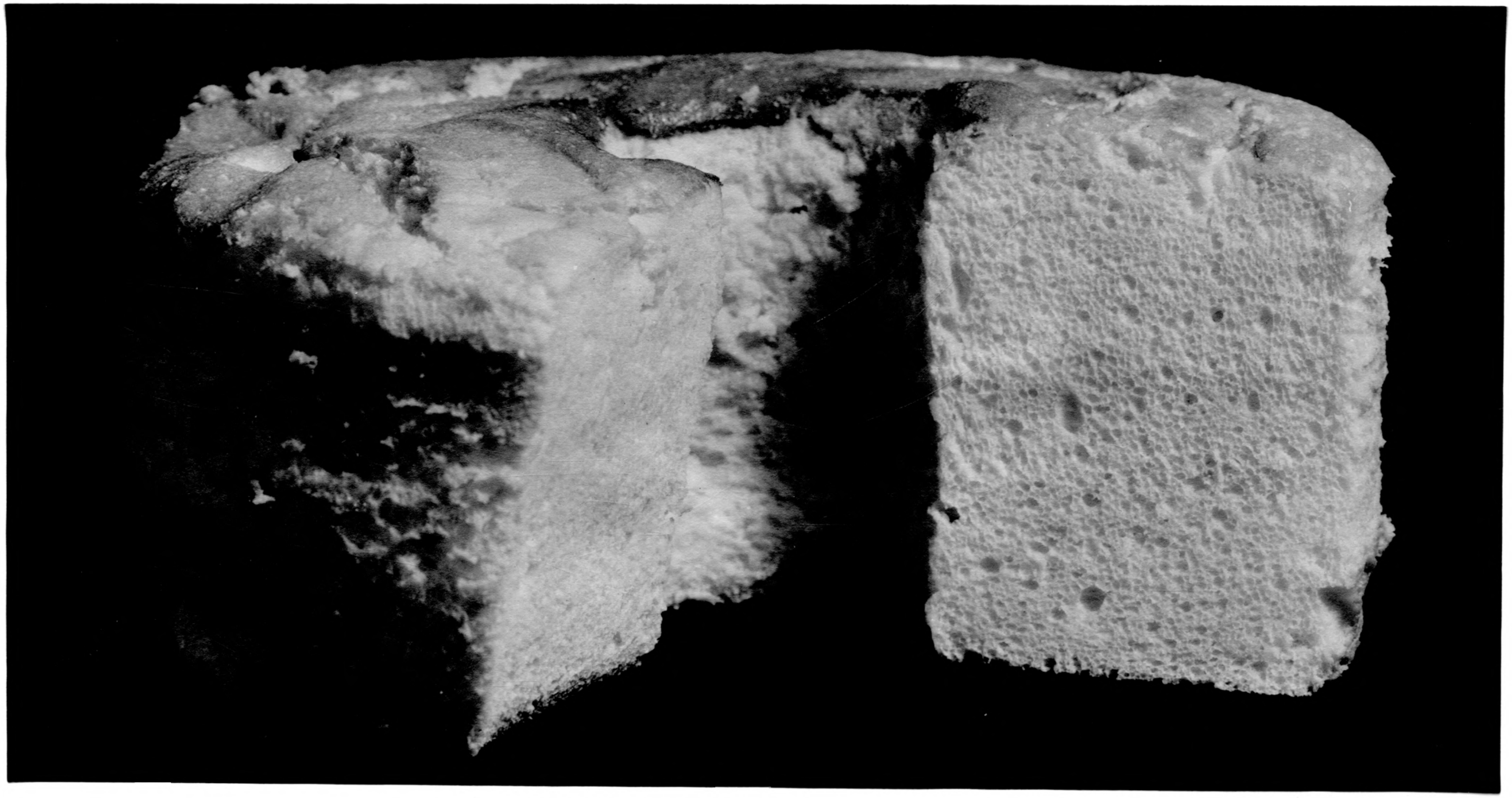


Plate 11. Effect of a Shorter Baking Period
Cake baked 45 minutes

is shown in Plate 12. The shrinkage was slightly greater resulting in a decreased size, but the crust and contour of the cake were improved with little sacrifice of tenderness.

As a result of this series of experiments the following recipe was evolved:

Ingredients	Weight gm.	Approximate measure
Flour (Swansdown)	100.0	1 cup
Sugar	300.0	$1\frac{1}{2}$ cups
Egg Whites	425.0	$1\frac{3}{4}$ cups
Salt	1.0	$\frac{3}{4}$ teaspoon
Cream of tartar	8.2	2 teaspoons
Vanilla	5.6	1 teaspoon

Sift sugar once; add $\frac{1}{2}$ cup of it to the flour and sift 3 times. Beat egg whites with a Dover egg beater until frothy, add salt and cream of tartar and continue beating until eggs are just stiff enough to hold their shape.

Add 1 cup of sugar, beating in gradually with the egg beater. After sugar is thoroughly mixed, add vanilla and continue beating for 2 minutes with the egg beater. Then with a large spoon or whip beater, fold in the flour-sugar mixture. Continue folding for 2 minutes. Pour batter into an ungreased angel food pan, turning the pan as the mixture is put in. Then give it several taps on the table

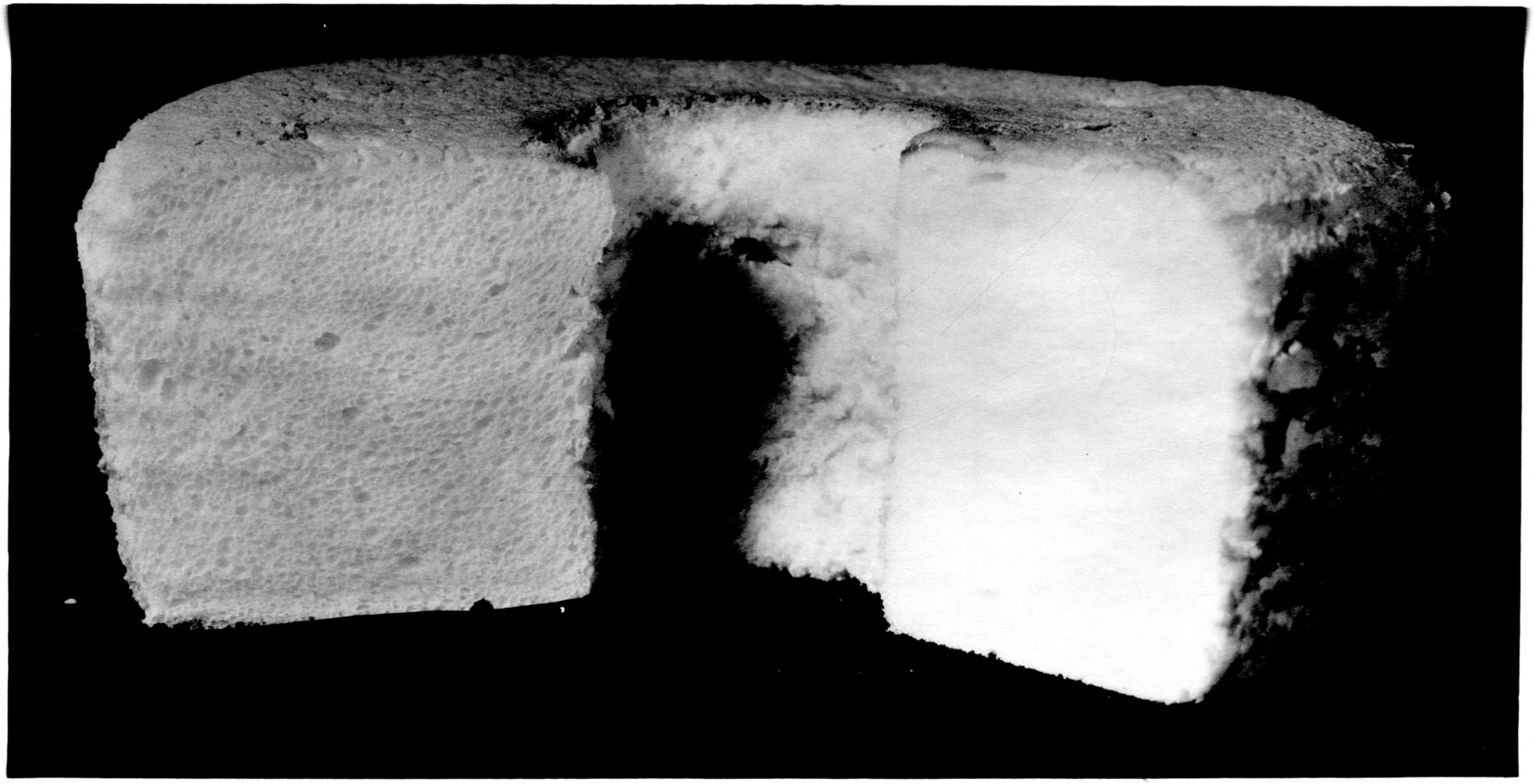


Plate 12. Effect of a Longer Baking Period

Cake baked 55 minutes

to free it of air bubbles. Bake in a moderate oven (325° F.) from 45 to 55 minutes according to the degree of brownness desired. Remove from oven and invert pan until cake is cold.

The general findings for the entire series of experiments may be summed up as follows:

1. Differences were observed when pans of different materials were used. Aluminum and tin gave similar results as did enamel and glass, the latter showing a greater rise and a higher final temperature in the cake. Stove pipe iron gave irregular results.

2. No uniform differences were detected when pans with and without tubes were used. The temperature in the cake tended to rise more evenly in pans with a tube.

3. A low inside temperature tended to make a more tender cake as measured by its breaking force. Some exceptions to this rule were observed.

4. An equally good product was secured with different temperatures and times for baking. It appeared to be related to a low inside cake temperature and was obtained in these experiments with a relatively low baking temperature.

5. Bread flour gave a less desirable product than pastry flour. Substitution of a small amount of cornstarch for part of the bread flour improved the quality to

some extent.

6. Increased amounts of sugar and egg whites, within limits, improved the flavor and increased the tenderness and volume of the cake.

7. Increased amounts of cream of tartar, within limits, improved the shape of the cake and the color of the interior without sacrifice of tenderness.

8. Addition of water definitely increased the tenderness without corresponding increase of volume.

9. Substitution of water for egg whites also increased the tenderness but decreased the volume.

10. A fine grain without sacrifice of volume and tenderness was secured when part of the sugar was added with the flour and the folding at the end of the process was continued for 2 minutes.

CONCLUSIONS

1. This work should be regarded as exploratory rather than final.

2. The methods used for determining temperature and testing tenderness appear to be satisfactory.

3. Until differences in composition of eggs and

methods of mixing can be better controlled, the measurements of viscosity and pH, as made in this investigation, are difficult of interpretation and of doubtful value.

ACKNOWLEDGMENT

The writer is indebted to Dr. Martha S. Pittman, Head of the Department of Food Economics and Nutrition, for directing this study, and to Professor E. V. Floyd of the Department of Physics for the construction of the machine with which the breaking tests were made. From both of these she received valuable suggestions and encouragement throughout the experiment. Further gratitude is due Dr. E. L. Tague of the Department of Chemistry for supervision of the chemical part of the work and to Miss Gladys E. Vail of the Department of Food Economics and Nutrition for her services in scoring the cakes.

LITERATURE CITED

1. Cornehl, Bernice and Swartz, VeNona W. Speed and Efficiency of Oven Utensils. J. Home Econ., 23, 464-467, 1931.

2. Dept. of Food Economics and Nutrition. Practical Cookery. 11th Ed., K. S. C., Manhattan, Kans., 1930.

3. Food, F. F. The Thermal Efficiencies of Cooking Utensils. J. Home Econ., 15, 435-438, 1923.

4. Grewe, Emily and Child, Alice M. The Effect of Acid Potassium Tartrate as an Ingredient in Angel Cake. Cereal Chem., 7, 245-250, 1930.

5. Halliday, E. and Noble, I. Hows and Whys of Cooking. University of Chicago Press, Chicago, Ill., 1928.

6. Loeb, Jacques. Proteins and The Theory of Colloidal Behavior. 2nd Ed., McGraw-Hill Book Co., Inc., N.Y., 1924.

7. MacLeod, Annie Louise and Nason, Edith H. Chemistry and Cookery. McGraw-Hill Book Co., Inc., N. Y., 1930.

8. Romanoff, Alexis L. The Dry Matter in Different Layers of Egg Albumin. Science, 70, 314, 1929.

9. Sharp, P.F. and Powell, Chas. K. Increases in the pH of the White and Yolk of Hens' Eggs. J. Ind. and Eng. Chem., 23, 196-199, 1931.

10. Sullivan, Dr. E.C. Glass Characteristics. Corning Glass Works, Corning, N. Y., 1931.

11. Swans Down Cake Manual. 2nd Ed., Gen. Foods Corporation, N. Y., 1931.

12. Woodruff, Sybil. Weights of One Cupful of Food Materials. J. Home Econ., 14, 270-271, 1922.