A STUDY OF SOME FACTORS WHICH AFFECT THE COLOR AND QUALITY OF CHOCOLATE CAKES

by

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INTRODUCTION

The purpose of this investigation was to study under controlled conditions the effect of certain factors upon the color and quality of chocolate cake. The color had reference primarily to the hue, while the quality dealt with the appearance, size, grain, texture, and flavor. It is needless to say that the person of good taste demands the best quality, and it seems that the majority are partial to a chocolate cake of red color. For this discussion the emphasis has been placed upon color rather than upon the quality. The housewife and the commercial baker have both attempted to produce a cake of the desired color but little scientific study has been done. Because of the great variety of ingredients used and their possible effect upon the color and quality of the cake, it seemed that a study of this problem might reveal information of practical value.

REVIEW OF LITERATURE

The red color of chocolate cakes has long been associated with the use of soda. However, a search of literature reveals only one scientific study of this particular problem.

The effect of ingredients upon the color of chocolate cakes was studied by Grewe (1). She found the quantity of soda used was an important factor in determining the color.

This she attributed to a change in hydrogen-ion concentration. She also found a variation in color resulted from the use of sweet and sour milk. This, too, was probably related to a change in hydrogen-ion concentration. As a result of this study, Grewe concluded that there was a close relationship between the color and the hydrogen-ion concentration of chocolate cakes.

Although this is the only study found which was made directly on chocolate cakes, other investigations reveal information relating to this problem. Grewe and Child (2) found that the hydrogen-ion concentration as determined by the use of acid potassium tartrate, affected the color as well as the grain of angel cakes. Apparently the color of molasses cookies is also affected by the hydrogen-ion concentration. Stephens, Child and Bailey (3) report that molasses cookies browned or took on a darker value as the proportion of soda was increased within the limits ordinarily used. Although the authors did not determine the hydrogen-ion concentration, it seems reasonable to assume that this was the determining factor.

Before a study of color relationships can be made a satisfactory method of measuring the color must be selected. The system worked out by A. H. Munsell (4) has been quite generally and successfully used in scientific work. The method consists of matching the color of a sample against a standard and the consequent expression of the results in terms of hue, brilliance, and chroma, the three psychological color attributes. These three attributes are defined, according to the report of the colorimetry committee of the Optical Society of America for 1920-'21 (5) as follows:

> Hue is that attribute of certain colors in respect of which they differ characteristically from the gray of the same brilliance and which permits them to be classed as reddish, yellowish, greenish, or blueish.
>
> Brilliance is that attribute of any color in respect of which it may be classed as equivalent to some member of a series of grays ranging between black and white.
>
> Chroma (termed saturation by the report) is that attribute of all colors possessing a hue, which determines their degree of difference from a gray of the same brilliance.

The application of this system to color problems has been perfected by Miss Dorothy Nickerson, Color Technologist in the Bureau of Agricultural Economics, Washington, D. C. With special emphasis given to agricultural products (6) she found that in order to obtain consistent results a constant source of light was important. She found also that when this system was used under controlled conditions for determining color that there was close agreement between observers. But not only has this method been used for determining the color of agricultural products but also it has been applied to measuring the color of food products. Sweetman (7) employed it in a study of the color of potato chips, MacGillivray (8) to determine the quality of tomato juice, and Grewe, Marshall and Harrel (9) measured the color of bread in this manner.

And Miss Emily Grewe (1) used this method in her study of the color of chocolate cake.

In any experimental work, it is needless to say, that the ingredients must be uniform except when this is the point under investigation, for all conditions must be carefully controlled. Eggs show a variation in composition when they are fresh and develop marked changes when stored. Sharp and Powell (10) report that as soon as an egg is laid the pH of the white begins to increase, due to loss of carbon dioxide. This increase in pH, then, might be a limiting factor in determining color.

The method of combining the ingredients must likewise receive consideration. This subject has had considerable attention but those having studied the question differ widely. Allen (11) states that the quick method of mixing produces a cake of as good texture as the one made by the conventional method. Milan (12) and Wellman (13) both report that melting the fat does not affect the quality of the cake and saves much time in mixing. The latter emphasizes the importance of getting the ingredients thoroughly mixed. Miller and Allen (14), and Halliday and Noble (15) suggest that there is an optimum time for beating cakes, and that it is governed by the method of mixing. Either more or less beating than the optimum has a definite effect upon the quality of the cake. In addition Halliday and Noble (15) state that the muffin method produces a fair cake, that is, one which is light and of good flavor; but the ideal cake, one having the much desired velvety quality, is obtained by using the conventional method of mixing. These workers attribute this superior quality to the stable emulsion which exists when the conventional method is successfully used.

The limited information on the subject may be summed up as follows:

1. To produce a cake of high quality, the thoroughness of mixing the ingredients is more important than the method of combining.

2. There is a close relationship between the color and the hydrogen-ion concentration of certain baked products.

3. The Munsell color system is successfully used in the measurement of color of food products.

PROCEDURE

In this investigation the problem was first of all to secure a good chocolate cake. Using it as a standard, other cakes were made in which the ingredients or the method of mixing varied. In order to compare their effect upon the finished cake the following determinations were made: the hydrogen-ion concentration of both the batter and the baked product, the breaking point, the weight of uniform sizes of cubes from upper and lower parts of the cake, the height of the cake, and the color. Criticism was obtained from three judges who determined the quality of the cake by means of an accepted score card. Throughout the experiment an effort was made to use ingredients, apparatus, and methods of work practical for use in the home.

Ingredients

The selection of ingredients for cakes is of primary importance. Good cakes cannot be made from inferior materials hence only those ingredients which are strictly fresh and of fine quality should be used. In this investigation Crisco, a hydrogenated fat of good quality (16), and a finely granulated sugar were selected. The eggs were collected daily from the same group of hens at the college poultry farm and were approximately twenty hours old when used. As there is a decided variation in the proportion of white to yolk the whites and yolks were weighed separately. Determinations made from time to time during the experiment showed little variation in the pH of the eggs. The whites varied from a pH 8.18 to 8.75 and the yolks from a pH 5.88 to 6.17. Baker's bitter chocolate, Swansdown cake flour, and Royal baking powder were used. Whole, sweet, pasteurized milk was obtained daily from the college dairy and used in the first series of cakes. Cultured buttermilk was used in the second series of experiments. This was selected in preference to ordinary sour milk for it was believed that the buttermilk would have greater constancy from day to day. It was made under controlled conditions at the college dairy and kept in the ice compartment of a refrigerator until its immediate use. The chemists advised neither to use dry nor evaporated sour milk as there was a possibility that the collodial condition of the milk might affect the quality of the product. When practicable, the ingredients were purchased in quantities sufficient for the entire investigation.

Apparatus

Another consideration of importance is the choice of utensils for they affect manipulation. A KitchenAid electric mixer, having a six-quart capacity and provided with three speeds, was used for the first part of the mixing process. The flat beater attachment for beating heavy mixtures, ordinarily mixed with a spoon, was used. The temperature was controlled by use of a pan which was attached under the mixing bowl. Water of the desired temperature was placed in this pan. A Dover egg beater was used for beating the eggs, and the stirring was done with a wooden spoon.

All cakes were baked in heavy tin pans seven and one-fourth inches square and two inches high in a gas oven with a Lorain regulator. The temperature control was set for 350°F., as suggested by Halliday and Noble (15), and this temperature was checked by a Taylor oven thermometer. The time determinations were made by use of a stop watch. All materials, except salt and flavoring, were weighed on a Trip scale.

A piece of apparatus (plate 1) was used for measuring the angle at which a slice of cake broke when the two ends were pulled together. The two ends of a slice of cake were held between metal uprights and rested on supports, in such a manner as to leave the cake free from support in the center. By means of a gear attached to a crank the cake was moved slowly and at a uniform speed to an angle which caused it to break. The angle through which the cake rotated was measured by means of a protractor and expressed in degrees.

To obtain comparable results it was necessary that slices of uniform width be broken. An apparatus (plate 2) similar to a miter box was made as a means of securing such slices. One end of the apparatus was enclosed, against which the cake was placed. The kerf was made one inch from this end, making it possible to cut through these grooves with a long knife and thus obtain a uniform slice of cake one inch in thickness.

The color problem in this investigation concerned the specification of colors already produced, expressing them in terms of hue, brilliance, and chroma. In order to make these measurements it was necessary to work out a method

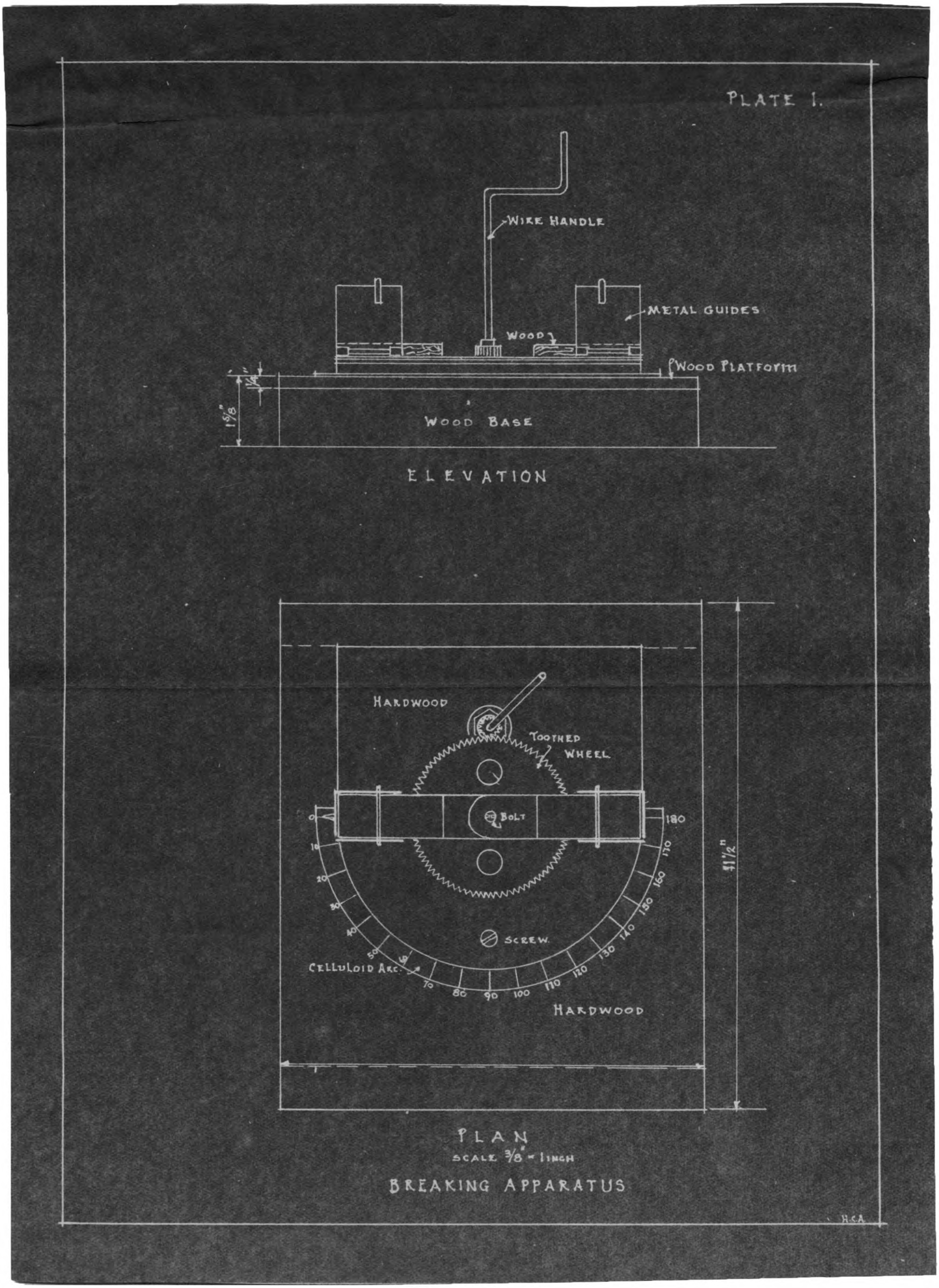
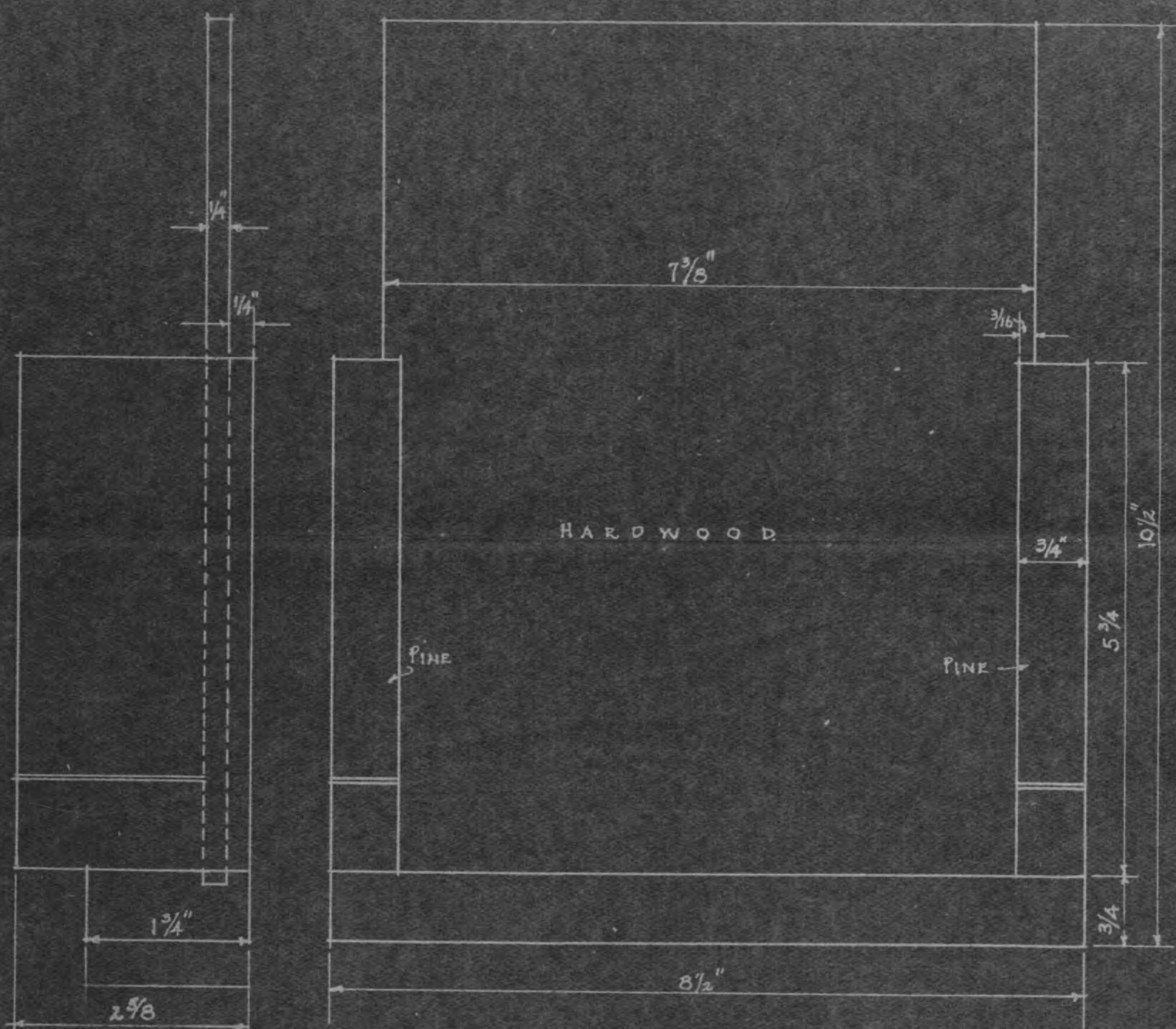


PLATE I.
WIRE HANDLE
METAL GUIDES
WOOD
WOOD PLATFORM
1/4"
1 5/8"
WOOD BASE
ELEVATION
HARDWOOD
TOOTHED WHEEL
BOLT
0
180
SCREW
CELLULOID ARC
HARDWOOD
11 1/2"
PLAN
SCALE 3/8" = 1 INCH
BREAKING APPARATUS
H.C.A.

PLATE 2



PLAN
SCALE 1/2" = 1 INCH

CUTTING DEVICE

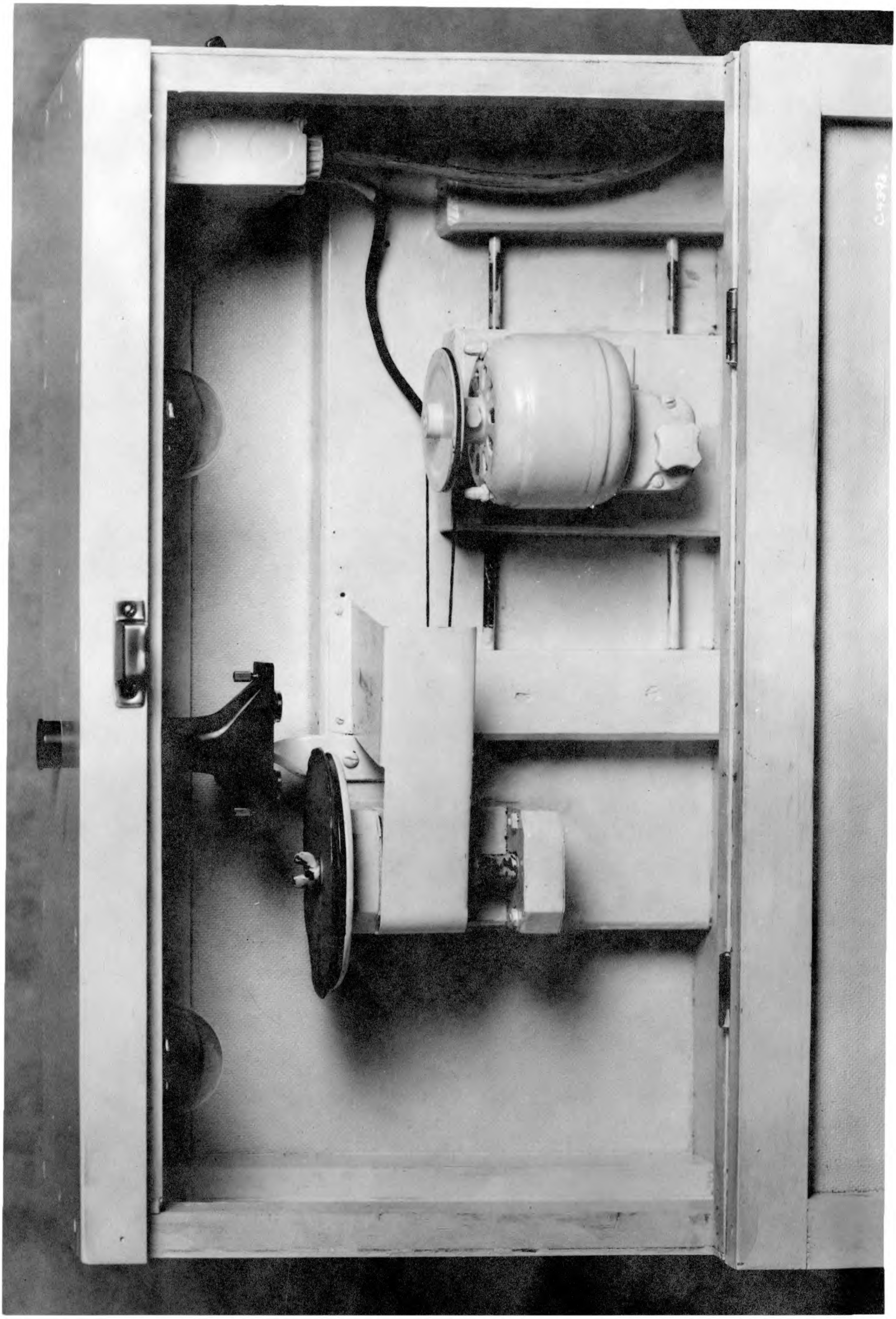
of controlling the light, of obtaining two similar fields for comparison, and of making the observations always from a single point.

A box was constructed (plate 3) which controlled these factors quite satisfactorily. The box, which was eight and three-fourths inches wide, fifteen and one-half inches high, and two feet long, was opened by a hinged door and constructed so securely that no light rays could enter during the observation at which time the door was closed. The interior of the box was painted with a matte finish white paint which has a high reflection factor. As a result, the distribution of light in the box was quite uniform.

The light came from two, 40-watt, clear, daylight blue Mazda lamps which were placed in the upper part of the box, one at either end. The light intensity, measured by means of a Macbeth Illuminometer, averaged 100 foot candles.

A Bausch-Lomb comparator eyepiece was used to view the two fields simultaneously. This extended through an one-inch opening in the top of the box. Directly beneath the comparator were the attachment for holding the color disks and the support for the piece of cake which was being matched. It was necessary that the surface of the cake and the disks be on the same level. The disks were supported by a shaft attached to a motor which turned the color disks about 3200 revolutions per minute.

Plate III. Apparatus for Measuring Color



Any color which lies in the color solid within the region bounded by the colors may be matched by using Maxwell disks (disks which are cut with a radial slit so that several may be slipped together with portions of each visible) and spinning them at a speed great enough so there is no flicker (17). For this work R 4/14, Y 8/12, N 1/ and N 9/ were used as standards. In these cases R refers to red, sometimes spoken of as 5R, or simply 5, since this number is the numerical notation given to red in the Munsell system. Y refers to yellow, often designated as 5Y, or 25 which is its numerical notation. N refers to the absence of hue. The numbers above the line refer to the brilliance, which ranges from absolute black at 0 to absolute white at 10. The numbers below the line refer to chroma. They vary from neutral gray, which is 0, and progress to as strong a color as is required. Hence, R 4/14 means red with a brilliance of 4 and a chroma of 14.

The color measurement is made by changing the area of the disks until, when viewed through the comparator, the resulting color matches exactly that of the product. A calibrated disk is used to note the readings in percentage of the exposed area of each color. These readings are then converted by means of formulas into terms of hue, brilliance, and chroma based on the Munsell system of notation.

The method of working the formulas is that as given by Nickerson (17):

"The hue notation is simply the proportion of one hue to the total. Instead, however, of using only the area proportion, the area is multiplied by its brilliance and its chroma, to give what may be called the 'power' number of the color. The following formula is quite simple:

$$H = z - \frac{A_x P_x}{A_x P_x + A_z P_z} (z - x)$$

in which

x = number of first hue
z = number of second hue
A = area
P = power number
H = hue resultant

"In working out the brilliance of any match, the area of each color is multiplied by the square of the brilliance. The square of brilliance is used since reflection under certain illuminations bears a relation to brilliance according to a square law. The formula that is used is as follows:

$$B = \sqrt{\frac{A_1 B_1^2 + A_2 B_2^2 + A_3 B_3^2 + \ldots}{100}}$$

when B = brilliance and the area is expressed in percentage.

"The chroma of any color match is the proportion of the chromas used to the total, or 100 per cent of the area.

$$C = \frac{A_1 C_1 + A_2 C_2 + A_3 C_3 + \ldots}{100}$$

when C = chroma."

The hydrogen-ion concentration was determined by means of a quinhydrone electrode set which is the property of the chemistry department. A heavy platinum wire was used as the electrode. The potentiometric outfit used balances current resistance drop taken from an Edison cell against the e.m.f. of the electrode system, the e.m.f. being measured by a voltmeter in conjunction with a galvonometer. From this measured potential difference the pH is calculated by means of a working formula.

Manipulation

Previous work has placed special emphasis upon the importance of the method of mixing the ingredients as a factor determining the quality of the product. In this investigation the conventional method was used, unless the method of mixing was the point under consideration.

The mechanical mixer was used only for the creaming process, for it was found that a better product resulted when the remaining ingredients were mixed with a spoon. Time and labor were saved by using the machine during the first part of the process and with equally satisfactory results. These directions were followed in mixing:

Machine Mixing. Hold temperature at 73°F.

1. Cream shortening 1 minute at high speed. Scrape bowl.
2. Add sugar gradually during next 4 minutes, medium speed. Scrape.
3. Add egg yolk, mix one-half minute, medium speed. Scrape, continue mixing for another one-half minute. Scrape.

4. Add melted chocolate, mix one-half minute, medium speed. Scrape, continue another one-half minute.

Hand Mixing.

1. Add one-fifth of flour, which has been sifted with baking powder and salt, stir until dampened (about 10 seconds). Beat for 30 seconds.

2. Add one-fourth of milk, to which vanilla has been added, mix in lightly.

3. Repeat additions of flour and milk, beating 10 seconds after each addition of flour. After last portion of flour is added, beat for 15 seconds.

4. Add beaten egg whites, stir gently but quickly for about 5 seconds, then beat for 25 seconds.

The mixture was then poured into a pan which was oiled on the sides and lined in the bottom with oiled paper. To eliminate air spaces the batter was cut through with a spatula. Care was taken to place the cakes in the center of the oven. They were baked until done according to accepted tests. Generally they required 42 minutes but in some cases, particularly when buttermilk was used, a longer time was necessary.

The cakes were removed from the oven and left in the pan for five minutes, after which they were turned out onto a cake rack and cooled in a place free from drafts. When cold, they were placed in a cake box and kept for fifteen hours at the end of which time the tests were made.

Two cakes were made to check each variation. If the results were practically the same, it was assumed that any individual characteristics were the result of the point being investigated.

Determinations

The methods of determinations were as follows:

1. The hydrogen-ion concentration was made on three grams of batter reserved for that purpose. Ten cubic centimeters of distilled water were added to the mixture and the determination made at once. Likewise, three grams of the baked product were used and fifteen cubic centimeters of water added.

2. For the breaking test, four slices of cake were cut. The first was discarded and the next three, from which the crusts had been removed, were used.

3. As a means of comparing the lightness of cakes, one-inch cubes, cut from the top and from the bottom were weighed. By use of the apparatus available for cutting the slices, the cubes were easily made. Three cubes were weighed from each part and an average taken.

4. The size of the cakes was compared by measuring the height of a slice of each cake. In doing this, the fourth slice was used and three measurements taken; one at either end and one at the center. The two end measurements were averaged together and this figure averaged with the

center measurement and used as a means of comparing the different cakes.

5. For making the colorimetric measurements, a piece from approximately the same area of each cake was used for the observation.

6. As a means of estimating the quality, the cakes were scored by three persons working individually. The following score card was used:

Name:
Date:
Cake No.:

SCORE CARD FOR CHOCOLATE 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		
Texture		
Tender		
Not sticky		
Not sugary		
II. General Appearance - Internal	35	
1. Texture - 15		
Tender		
Moist		
Velvety		
2. Grain - 10		
Small uniform cells		
Thin cell walls		
Free from large air space		

	Perfect Score	Actual Score
3. Color - 5		
4. Crust - 5		
Thin		
III. Flavor	50	
1. Taste - 35		
2. Odor - 15		

RESULTS AND DISCUSSION

Before attempting a study of cakes, it is necessary that the characteristic qualities of a good product be recognized. The ideal cake is symmetrical in shape, has a slightly rounded top, and is attractive in appearance. The crust is thin and tender, free from cracks, and presents a dull surface. The cake is light, has a fine, even grain and a moist, tender crumb. The quality of an excellent cake is spoken of as "velvety", meaning that to the fingers or tongue it has the feeling of soft velvet.

In the beginning of this study an attempt to improve a recipe used in the laboratory was made. After some modifications one was obtained which resulted in a cake that fulfilled the above requirements. From this basic recipe, then, variations were made and the following standard was evolved:

	Weight in grams	Approximate measure
Crisco	70	1/3 cup
Sugar	200	1 cup
Eggs		
Yolks	36)	2 medium sized
Whites	60)	
Chocolate	29	1 square
Cake flour	148	1 1/2 cup

	Weight in grams	Approximate measure
Baking powder	7.7	2 1/2 teaspoons
Milk	162	2/3 cup
Vanilla		1/2 teaspoon
Salt		1/4 teaspoon

Specific

Effect of Adding to and Substituting for Ingredients in the Standard. The results of the effects of adding to and substituting for ingredients in the standard appear in Table 1.

1. Addition of varying amounts of chocolate. The addition of chocolate had more effect upon the brilliance and chroma of the cake than upon any other factor. As the amount of chocolate was increased the color became darker in value and less intense. And it was noted that the increased chocolate also increased the acidity. Additional chocolate likewise made a small difference in breaking, which indicates a slightly more tender cake. The chocolate flavor, too, was developed with the increased amounts of chocolate.

2. Addition of water. By increasing the amount of water in the cake, the volume of the baked product was decreased. It was shown by the difference in height and in weight. The latter manifested itself in a soggy layer at the bottom, but the remainder of the cake had a fine grain. The crust appeared "bubbly." The hue and brilliance of the cake were not affected but the chroma appeared less intense when the water was added.

Table 1. The Effect on Cake Quality of Adding to and Substituting for Ingredients in the Standard

Cake No.	Ingredient varied	pH: Batter	pH: Product	Breaking (degrees)	Height (inches)	Weight: Top cubes (grams)	Weight: Bottom cubes (grams)	Hue	Brilliance	Chroma
13*	None	6.06	6.52	62.6	2	6.23	7.45	Data not available (1)		
87		6.35	6.34	61.2	2	6.47	6.50	14.8	4.325	5.55
Av.		6.20	6.43	61.9	2	6.35	6.97			
15*	Chocolate	6.07	6.25	55.7	2	6.31	6.90	Data not available (1)		
85		6.07	6.17	56.2	1 7/8	6.80	6.95	14.3	3.86	4.91
Av.		6.07	6.21	55.9	1 15/16	6.55	6.92			
16*	Chocolate	6.07	6.08	56.0	2 1/8	6.52	7.18	Data not available (1)		
86		6.10	6.10	58.8	2 1/8	6.57	6.89	14.2	3.15	3.87
Av.		6.08	6.09	57.4	2 1/8	6.54	7.03			
37*	Liquid	6.13	6.51	60.3	1 7/8	6.26	7.57	14.9	4.09	4.75
39		6.14	6.50	63.8	1 5/8	7.44	9.56	15.3	4.49	4.99
Av.		6.13	6.50	62.0	1 3/4	6.85	8.56	15.1	4.29	4.87
77*	Leavening	7.32	8.14	56.6	2 1/16	6.84	7.63	6.4	1.76	1.73
80		7.12	7.91	59.3	2 3/16	6.43	7.40	5.6	1.70	1.68
Av.		7.22	8.02	58.4	2 1/8	6.63	7.51	6.0	1.73	1.70
1*	Leavening	5.93	7.39	74.3	2 1/4	4.81	5.52	Data not available (1)		
5		6.39	7.78	75.2	2 1/4	5.83	6.64	10.9	2.64	3.35
Av.		6.16	7.58	74.7	2 1/4	5.32	6.08			
3*	Leavening	6.96	8.54	74.7	2 1/4	3.93	5.54	Data not available (1)		
81		7.10	8.09	75.3	2 1/8	5.20	6.35	9.4	2.30	2.75
Av.		7.03	8.31	75.0	2 3/16	4.56	5.94			
12*		6.20	6.25	61.2	1 15/16	6.47	7.17	Data not available (1)		
84	Sugar	6.09	6.08	62.2	1 15/16	6.69	7.20	15.5	4.01	4.92
Av.		6.14	6.17	61.7	1 15/16	6.58	7.18			

(1) Because of difficulty in interpreting the readings only one set of results was available.

Standard cake with:

13* -- Standard ingredients
15* -- Addition of 1/2 square chocolate
16* -- Addition of 1 square chocolate
37* -- Addition of 4 T. cold water
77* -- Substitution of 1 t. soda for baking powder
1* -- Addition of 1/2 t. soda
3* -- Addition of 3/4 t. soda
12* -- Substitution of 200 grams brown sugar for granulated

3. Substitution of soda for baking powder. When soda was substituted for baking powder the hydrogen-ion concentration was decreased and a very decided effect upon the color was noted. It was less yellow, darker, and less intense. The cake with soda content broke at a slightly smaller angle than that of the standard. With the exception of a crack a good smooth crust was noted.

4. Addition of soda. As the amount of soda increased the hydrogen-ion concentration decreased and the color was affected in proportion to the amount of soda added. The color of the cake containing soda was less yellow, darker, and less intense. The addition of soda produced a cake larger in volume as shown by the increase in height of the slices and the decrease in weight of the cubes. There was a wide difference in the angle at which the cakes broke, indicating a less tender cake when soda was added. The crust was wrinkled and the color of the cake was uneven.

5. Substitution of brown sugar for white. A slight increase in hydrogen-ion concentration occurred when brown sugar was used. This was accompanied by a change in color, that of the cake containing brown sugar was slightly more yellow and less intense. In this particular case, the brown sugar had a decided effect upon the crust making it smoother but less tender. The grain of the cake was also affected; it was uneven and had large holes and tunnels.

substitution of all brown sugar had such a marked effect upon the flavor that the chocolate taste was almost entirely covered up. However, considering a number of other cakes (not shown in the table) in which brown sugar was the variation it was observed that on the whole brown sugar did not have a great effect on the cake other than upon the crust and flavor. Half brown sugar gave a pleasing taste and helped to cover up the soda flavor.

Effect of Substituting Cocoa and Using Different Brands of Cocoa and Chocolate. The results of the effect of substituting cocoa and using different brands of cocoa and chocolate are shown in Table 2.

Six tablespoons of cocoa were used as a possible equivalent of two squares of chocolate in making this substitution. Only two brands were available. A difference in the breaking was noted, those made with chocolate breaking at a smaller angle. Possibly the larger fat content of the chocolate may account for this. A very small difference occurred in the color, that of the cakes with cocoa content was slightly more yellow, possibly a little darker, and less intense. This difference in color is probably due to the amount of cocoa substituted for the chocolate. According to the judges, the cakes made of cocoa had a little better texture and grain and a tender, moist crumb. This was contrary to the results of the breaking apparatus but it is possible that the judges failed to distinguish between tenderness and

Table 2. The Effect on Cake Quality of Substituting Cocoa and Using Different Brands of Cocoa and Chocolate

Cake No.	Variation	pH Batter	pH Product	Breaking (degrees)	Height (inches)	Weight Top cubes (grams)	Weight Bottom cubes (grams)	Hue	Brilliance	Chroma
32*	Baker's cocoa	7.00	8.08	67.7	2 1/16	6.86	7.80	10.3	2.03	1.83
34		6.96	8.08	57.8	1 15/16	7.03	8.03	10.0	2.02	1.86
Av.		6.98	8.08	62.7	2	6.94	7.91	10.1	2.02	1.84
41*	Hershey's cocoa	7.30	8.51	67.7	2 1/16	6.10	7.29	5.0	1.42	.97
42		6.93	8.10	60.0	1 15/16	6.75	7.75	9.3	1.95	1.78
Av.		7.11	8.30	63.8	2	6.42	7.52	7.1	1.67	1.37
19*	Baker's chocolate	7.24	7.94	59.1	2 1/8	6.08	7.12	11.7	2.48	2.71
20		7.05	8.09	56.5	2 1/8	6.11	7.51	11.6	1.84	2.11
Av.		7.14	8.01	57.8	2 1/8	6.09	7.31	11.6	2.16	2.41
44*	Hershey's chocolate	6.98	7.99	54.7	2 1/16	6.25	7.55	11.0	2.30	2.37
46		6.93	7.71	61.0	2 1/16	6.37	7.80	12.8	2.42	2.34
Av.		6.95	7.85	57.8	2 1/16	6.31	7.67	11.9	2.36	2.35

Three-fourths t. soda was added to the standard in each case.

32*--6 T. Baker's cocoa cooked with 6 T. water in double boiler, and soda added.
41*--6 T. Hershey's cocoa cooked with 6 T. water in double boiler, and soda added.
19*--2 squares Baker's chocolate cooked with 4 T. water in double boiler, and soda added.
44*--2 squares Hershey's chocolate cooked with 4 T. water in double boiler, and soda added.

the "velvety" quality.

The effect of the brands of both chocolate and cocoa was negligible so far as could be determined.

Effect of Varying the Methods of Adding and the Amounts of Soda. The results of the effect of varying the methods of adding and the amounts of soda appear in Table 3.

Three methods of adding the soda were used: sifting it with the flour, dissolving it in two tablespoons of hot water, and adding it to the cooked, hot chocolate. These varying methods did not greatly affect the product. It is probable that dissolving the soda in hot water slightly affected the color. Although the difference is small, it appeared more yellow and perhaps more intense. It was observed by the judges that, when the soda was sieved with the flour or when it was dissolved in the hot water, the color was uneven or had rather a mottled appearance. This was overcome when the soda was added to the cooked chocolate. When the soda was sieved with the flour the cake was a little higher and was a little lighter in weight than when the soda was added to the cooked chocolate.

The relation between the amount of soda and its relative effect upon the hydrogen-ion concentration and the color was noted as before.

Table 3. The Effect on Cake Quality of Varying the Methods of Adding and the Amounts of Soda

Cake No.	Amount of soda and method of adding	pH: Batter	pH: Product	Breaking (degrees)	Height (inches)	Weight: Top cubes (grams)	Weight: Bottom cubes (grams)	Hue	Brilliance	Chroma
1*	1/2 t. soda in flour	5.93	7.39	74.3	2 1/4	4.81	5.52	Data not available(1)		
5		6.39	7.78	75.2	2 1/4	5.83	6.64	10.9	2.64	3.35
Av.		6.16	7.58	74.7	2 1/4	5.32	6.08			
2*	1/2 t. soda in hot water	6.08	7.61	74.3	2 3/16	4.89	5.57	Data not available(1)		
78		6.49	7.67	72.6	2 3/16	5.66	6.50	12.4	3.03	4.07
Av.		6.28	7.64	73.4	2 3/16	5.27	6.03			
3*	3/4 t. soda in flour	6.96	8.54	74.7	2 1/4	3.93	5.54	Data not available(1)		
81		7.10	8.09	75.3	2 1/8	5.20	6.35	9.4	2.30	2.75
Av.		7.03	8.31	75.0	2 3/16	4.56	5.94			
4*	3/4 t. soda in hot water	6.78	8.08	74.1	2 1/4	5.13	6.37	Data not available(1)		
9		6.59	8.67	75.7	2 1/4	5.66	6.65	10.5	2.49	3.00
Av.		6.68	8.37	74.9	2 1/4	5.79	6.51			
10*	3/4 t. soda in cooked chocolate	6.86	8.74	69.5	2 1/16	6.41	7.85	Data not available(1)		
11		6.82	8.49	71.0	2 1/16	6.68	8.37	9.3	2.19	2.44
Av.		6.84	8.61	70.2	2 1/16	6.54	8.11			

(1) Because of difficulty in interpreting readings only one set of results was available.

<u>Series 1</u> -- Standard cake with addition of:

1* -- 1/2 t. soda sieved with flour
2* -- 1/2 t. soda dissolved in 2 T. hot water
3* -- 3/4 t. soda sieved with flour
4* -- 3/4 t. soda dissolved in 2 T. hot water
10* -- 3/4 t. soda to cooked chocolate

Table 3 continued

Cake No.	Amount of soda and method of adding	pH: Batter	pH: Product	Breaking (degrees)	Height (inches)	Weight: Top cubes (grams)	Weight: Bottom cubes (grams)	Hue	Brilliance	Chroma
58*	1 t. soda in flour	6.81	8.04	57.5	2 1/4	6.35	7.75	7.8	1.79	1.59
60		6.77	8.06	52.7	2	5.83	6.90	10.0	1.96	1.71
Av.		6.79	8.05	55.1	2 1/8	6.09	7.32	8.9	1.87	1.65
64*	1 t. soda in cooked	6.71	7.91	57.5	1 7/8	7.19	7.50	8.2	1.84	1.68
66	chocolate	6.82	7.91	55.5	1 7/8	7.30	7.32	7.3	1.90	1.98
Av.		6.76	7.91	56.5	1 7/8	7.24	7.41	7.7	1.87	1.83
67*	1 1/2 t. soda in flour	7.32	8.24	60.2	1 15/16	6.65	6.96	5.0	1.57	1.37
68		7.34	8.42	58.2	1 15/16	6.80	8.06	5.0	1.38	.84
Av.		7.33	8.33	59.2	1 15/16	6.72	7.51	5.0	1.47	1.10
63*	1 1/2 t. soda in cooked	7.79	7.90	59.3	1 3/4	7.20	7.90	7.2	1.70	1.46
65	chocolate	8.02	8.46	54.7	1 3/4	7.93	8.10	7.4	1.66	1.30
Av.		7.90	8.18	57.0	1 3/4	7.56	8.50	7.3	1.68	1.38

<u>Series 2</u> -- Cakes containing buttermilk and 2 squares chocolate with:

58* -- Addition of 1 t. soda sieved with flour
64* -- Addition of 1 t. soda to cooked chocolate
67* -- 1 1/2 t. soda, sieved with flour, substituted for baking powder
63* -- 1 1/2 t. soda added to cooked chocolate, substituted for baking powder

Effect of Various Liquids on Cake Quality. The result of using various liquids is shown in Table 4.

1. The effect of using sweet milk and buttermilk. The cake containing buttermilk had a slightly higher hydrogen-ion concentration than the cake made of sweet milk. The color was more yellow and a little lighter in value. This cake had a nice grain and seemed to be more moist. Taking into consideration all the cakes containing milk, it was found that those made with buttermilk broke at a smaller angle. This agrees with popular opinion that a more tender cake results when sour milk is used.

2. Substitution of water for sweet milk. When cold water was substituted for sweet milk an increase in hydrogen-ion concentration was observed. The color was affected, but contrary to previous results, for the cake was less yellow, darker, and less intense. The height of the cake and the weight of the cubes show that the cake was lighter. Water had a decided effect upon the crust, too, making it dull and smooth. On the whole the cake had a good texture and received a high score.

3. The effect of using one-half cold water and one-half boiling water with buttermilk. Results show that using cold or boiling water with buttermilk had little effect upon the product. The color was slightly less yellow than when all buttermilk was used. The judges noted that the cake containing cold water had a nice velvety texture

Table 4. The Effect on Cake Quality of Using Various Liquids

Cake No.	Liquid used	pH: Batter	pH: Product	Breaking (degrees)	Height (inches)	Weight: Top cubes (grams)	Weight: Bottom cubes (grams)	Hue	Brilliance	Chroma
19	Sweet milk(1)	7.24	7.94	59.1	2 1/8	6.08	7.12	11.7	2.46	2.71
20		7.05	8.09	56.5	2 1/8	6.11	7.51	11.6	1.84	2.11
Av.		7.14	8.01	57.8	2 1/8	6.09	7.31	11.6	2.16	2.41
25	Cold water(1)	6.76	6.30	54.8	1 15/16	6.70	7.70	8.2	1.94	1.90
28		6.83	7.96	57.0	1 13/16	7.02	8.10	10.0	1.95	1.71
Av.		6.78	7.13	55.9	1 7/8	6.86	7.90	9.1	1.94	1.90
51	Half cold water and	6.94	7.76	60.8	1 15/16	6.62	7.48	10.7	2.64	2.53
53	half buttermilk(1)	6.76	7.79	56.7	1 7/8	7.09	8.00	9.9	2.13	3.43
Av.		6.85	7.77	58.7	1 7/8	6.85	7.74	10.3	2.38	2.98
57	Half boiling water and	6.74	7.84	59.5	2 1/16	7.09	7.57	10.6	2.29	2.41
59	half buttermilk(1)	6.51	7.64	57.5	1 15/16	7.19	7.27	11.7	2.41	2.52
Av.		6.62	7.74	58.5	2	7.14	7.42	11.1	2.35	2.46
47	All buttermilk(1)	6.49	7.51	54.7	2	5.94	7.37	12.4	2.52	2.66
48		6.68	7.49	58.2	2	6.49	7.73	12.8	2.68	2.99
Av.		6.58	7.50	56.6	2	6.21	7.55	12.6	2.60	2.82
70	Half cold water and	7.16	8.27	55.3	2 1/16	6.80	7.54	5.0	1.52	1.23
72	half buttermilk(2)	7.15	8.37	57.3	1 15/16	7.20	7.61	5.0	1.48	1.12
Av.		7.15	8.32	56.5	2	7.00	7.57	5.0	1.50	1.17
73	Half boiling water and	7.12	8.25	57.7	2	7.03	7.83	5.0	1.58	1.40
74	half buttermilk(2)	7.34	8.42	60.0	2 1/16	6.43	7.20	5.0	1.44	1.01
Av.		7.23	8.33	58.8	2 1/32	6.72	7.51	5.0	1.51	1.20

These cakes each contain 2 squares chocolate.

(1) In each cake 1 square chocolate and 3/4 t. soda were added to standard. Variation in liquid was made as indicated.

(2) Same as above except 1 1/2 t. soda was used.

and a good crust. Half water and half buttermilk were used in preference to all buttermilk in the cakes in this series because the judges preferred the flavor and quality of the former.

Effect of Varying the Amounts of Soda, with and without Baking Powder. The effects of varying the amounts of soda, with and without baking powder, are shown in Table 5.

As the amount of soda increased, the hydrogen-ion concentration decreased. The presence of baking powder lowered it only slightly. As noted elsewhere, a very definite relationship was shown between the increase in the amount of soda and its effect upon the color. It became less yellow, darker, and less intense in proportion to the amount of soda used. This was especially true when the amount of soda was the only factor varied.

The increased amount of leavening, when baking powder and soda were both used, made a lighter cake as shown by the height of the slices and the weight of the cubes. These cakes had a nice even grain and were soft. The soda flavor was not distasteful.

In the cakes without baking powder, a very fine grain, perhaps too fine to be desirable, resulted and the soda taste was more evident. The cake with two teaspoonfuls of soda was too dark and the soda taste was objectionable.

Table 5. The Effect on Cake Quality of Varying Amounts of Soda, With and Without Baking Powder

Cake No.	Leavening used	pH: Batter	pH: Product	Breaking (degrees)	Height (inches)	Weight: Top cubes (grams)	Weight: Bottom cubes (grams)	Hue	Brilliance	Chroma
51*	With baking powder	6.94	7.76	60.8	1 7/8	6.62	7.48	10.7	2.64	2.53
53	$\frac{3}{4}$ t. soda	6.76	7.79	56.7	1 7/8	7.09	8.00	9.9	2.13	3.43
Av.		6.85	7.77	58.7	1 7/8	6.85	7.74	10.3	2.38	2.98
64*	With baking powder	6.71	7.91	57.5	1 7/8	7.19	7.50	8.2	1.84	1.68
66	1 t. soda	6.82	7.91	55.5	1 7/8	7.30	7.32	7.3	1.90	1.98
Av.		6.76	7.91	56.5	1 7/8	7.24	7.41	7.7	1.87	1.83
70*	With baking powder	7.16	8.27	55.3	2 1/16	6.80	7.54	5.0	1.52	1.23
72	$1\frac{1}{2}$ t. soda	7.15	8.37	57.3	1 15/16	7.20	7.61	5.0	1.48	1.12
Av.		7.15	8.32	56.5	2	7.00	7.57	5.0	1.50	1.17
61*	No baking powder	7.40	8.06	60.0	1 7/8	7.38	8.13	10.7	2.33	2.52
62	1 t. soda	7.50	8.14	58.2	1 5/8	8.64	9.06	9.7	2.10	2.26
Av.		7.45	8.10	59.1	1 3/4	8.01	8.59	10.4	2.21	2.39
63*	No baking powder	7.79	7.90	59.3	1 3/4	7.20	7.90	7.2	1.70	1.46
65	$1\frac{1}{2}$ t. soda	8.02	8.46	54.7	1 3/4	7.93	8.10	7.4	1.66	1.30
Av.		7.90	8.18	57.0	1 3/4	7.56	8.50	7.3	1.68	1.38
69*	No baking powder	7.21	8.59	59.0	2	6.77	8.20	5.0	1.43	.97
71	2 t. soda	7.44	8.59	60.3	2 1/16	6.57	7.70	5.0	1.37	.83
Av.		7.32	8.59	59.6	2 1/32	6.67	7.95	5.0	1.40	.90

*These are all buttermilk cakes with 2 squares chocolate; soda added to cooked chocolate.

Effect of the Methods of Mixing. The effect of the methods of mixing upon the quality of the cakes is shown in Table 6.

With the proportions used in this investigation results show that the conventional method of mixing gave a cake of higher quality. It was found that when the chocolate was cooked with the fat and water or with half the milk and sugar, an inferior cake was produced. A harsh, bready texture and a coarse grain with a soggy layer resulted. Both of the cakes in which the fat was melted had an unattractive shiny surface. The muffin method, likewise, yielded an inferior product. It was smaller in size and had a poor texture. A soggy layer near the crust was noted.

General

As a result of these experiments, certain general observations were made.

Although various workers have determined the pH of certain baked products, apparently no comparison of the pH of the product before and after baking has been made. It was thought that such a comparison might be interesting. Therefore, in each of these cakes the pH was determined on both the batter and the baked product. This comparison showed that in some cases there was a marked difference before and after baking. The cakes in which baking powder

Table 6. The Effect on Cake Quality of Varying Methods of Mixing

Cake No.	Method	pH: Batter	pH: Product	Breaking (degrees)	Height (inches)	Weight: Top cubes (grams)	Weight: Bottom cubes (grams)	Hue	Brilliance	Chroma
19*	Conventional	7.24	7.94	59.1	2 1/8	6.08	7.12	11.7	2.48	2.71
20		7.05	8.09	56.5	2 1/8	6.11	7.51	11.6	1.84	2.11
Av.		7.14	8.01	57.8	2 1/8	6.09	7.31	11.6	2.16	2.41
26*	Cooked chocolate with	6.81	7.83	61.1	1 7/8	8.10	7.75	10.9	2.17	2.08
29	fat and water	6.90	7.89	57.8	1 7/8	8.70	8.70	10.5	2.16	2.10
Av.		6.85	7.86	59.4	1 7/8	8.40	8.22	10.7	2.16	2.09
27*	Cooked chocolate with	6.62	7.71	63.3	2 1/8	5.17	6.30	11.3	2.24	2.17
30	1/2 sugar and 1/2	6.70	7.78	62.5	2 1/8	5.68	6.63	11.6	2.37	2.44
Av.	milk	6.66	7.74	62.9	2 1/8	5.42	6.46	11.4	2.30	2.30
38*	Muffin	6.80	7.79	69.3	1 3/4	6.80	7.37	11.8	2.09	1.76
40		6.90	7.79	63.5	1 3/4	6.45	7.37	11.1	1.97	1.59
Av.		6.85	7.79	66.4	1 3/4	6.62	7.37	11.4	2.03	1.67
35*	Conventional	6.45	7.94	68.0	2 1/8	5.90	6.55	10.9	2.12	1.95
36		6.77	7.78	66.5	2 1/8	6.17	6.53	11.3	2.06	1.75
Av.		6.61	7.86	67.2	2 1/8	6.03	6.54	11.1	2.09	1.85

These cakes contained sweet milk with 3/4 t. soda added. Two squares of chocolate were used in first three variations and 6 T. cocoa in last two.

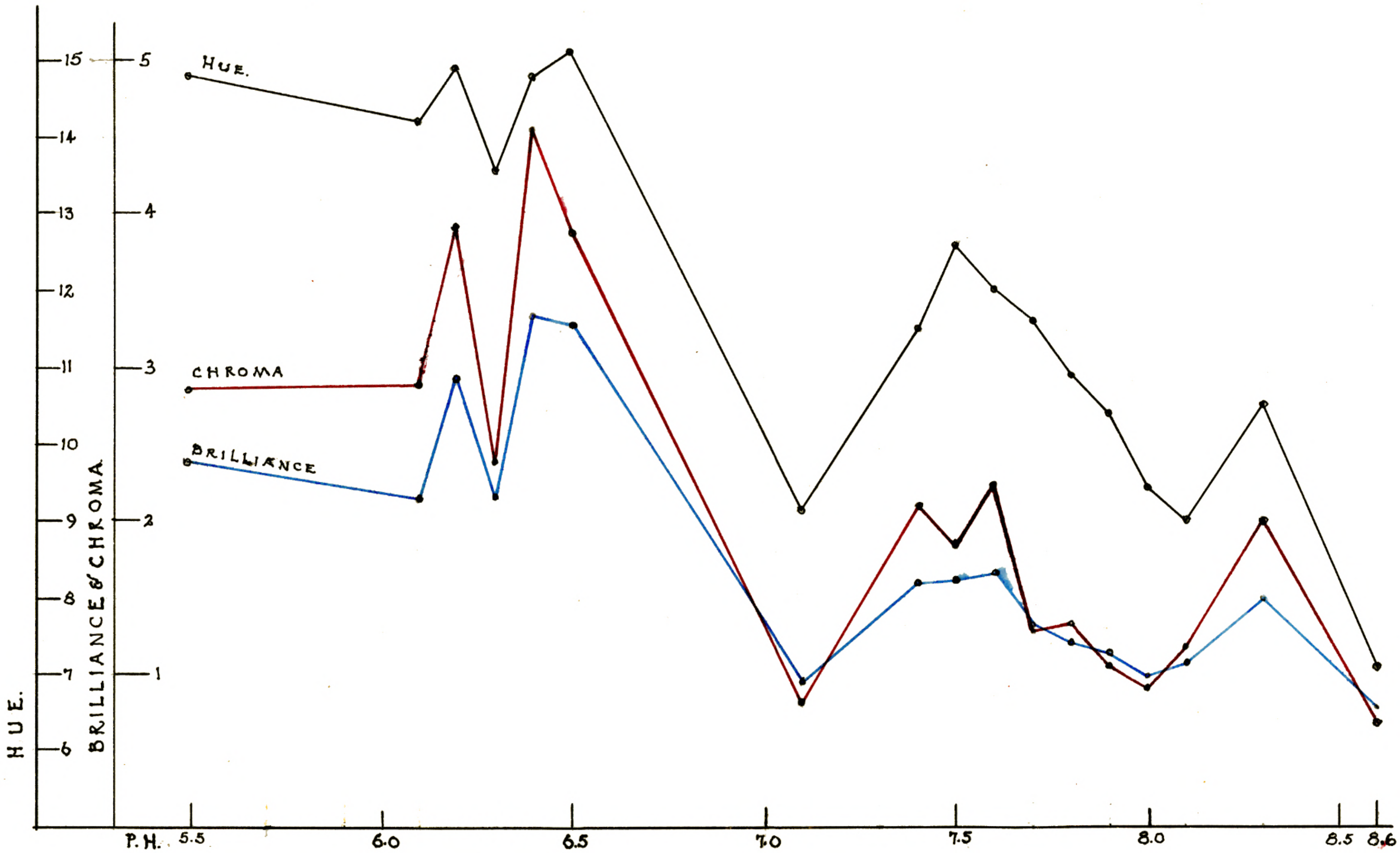
19* -- Creamed fat and sugar, added egg yolk, and cooked chocolate. Alternated addition of flour and milk. Added beaten egg whites.
26* -- Chocolate, 1/2 c. boiling water and fat heated in double boiler till chocolate melted, beaten till glossy. Soda added in flour. Sugar, flour, 1/2 c. milk and unbeaten egg added to chocolate mixture and beaten vigorously 2 minutes.
27* -- Chocolate cooked with half of sugar and half of milk, added just before egg whites.
38* -- Melted fat and egg yolk added to milk, mixed with dry ingredients, beaten 15 seconds, egg whites added, beaten for 25 seconds.
35* -- Creamed fat and sugar, added egg yolk and cooked cocoa. Alternated addition of flour and milk. Added beaten egg whites.

alone was used showed little or no change in pH as a result of baking. Any differences noted were so small that they might easily have been due to an error in determination. Cakes containing sweet milk and soda showed the greatest change in hydrogen-ion concentration after baking. A difference of a pH of 1.88 was shown in one of these while others showed a variation of 1.69 or 1.58. Though less noticeable in cakes containing buttermilk, in every case when soda was used there was a decided upward trend in pH after baking.

These comparisons indicate that the pH of the cake after baking is more indicative of the true alkalinity of the product than is that of the batter.

The relationship between the hydrogen-ion concentration and color is shown graphically (figure 1). It is interesting to observe that as the pH increases there is a downward trend numerically in color--the hue becomes less yellow, the brilliance becomes darker, and the chroma less intense. The curves, though definitely downward, do not follow the change in pH absolutely. This is probably accounted for by the fact that certain ingredients might affect the color without affecting the pH to the same extent. This relationship of the hydrogen-ion concentration to the color seems to be in disagreement with part of Grewe's findings. She has stated that the attribute "chroma" was not significant in judging the color of chocolate cakes, while

FIG. 1.



HUE.
CHROMA
BRILLIANCE
HUE.
BRILLIANCE & CHROMA
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
P.H. 5.5
6.0
6.5
7.0
7.5
8.0
8.5
8.6

in this investigation it is shown that there is a close relationship.

The weight of the cubes and the height bear a close relationship in estimating the lightness of the cakes, as shown in figure 2. As the cake increases in height there is a corresponding decrease in weight of cubes. The lines, representing cubes from the top and the bottom of the cake, have a distinct upward trend and are almost parallel. This means of comparing the lightness of the cakes was satisfactory and much simpler than certain other methods which have been used, such as volume displacement.

There is no accounting for taste and because of the differences in personal preferences, it seemed impossible to make a product which would be considered ideal by all. Many persons preferred the grayish yellow color of the standard cake, while others preferred the glossy dark red of certain cakes. Again, some found the flavor obtained by the use of buttermilk with the chocolate more desirable while others preferred that resulting from the use of sweet milk. Likewise, the use of brown sugar gave a characteristic taste which was delightful to some and displeasing to others.

SUMMARY

The results of this investigation may be summed up as follows:

1. That a close relationship existed between the hydro-

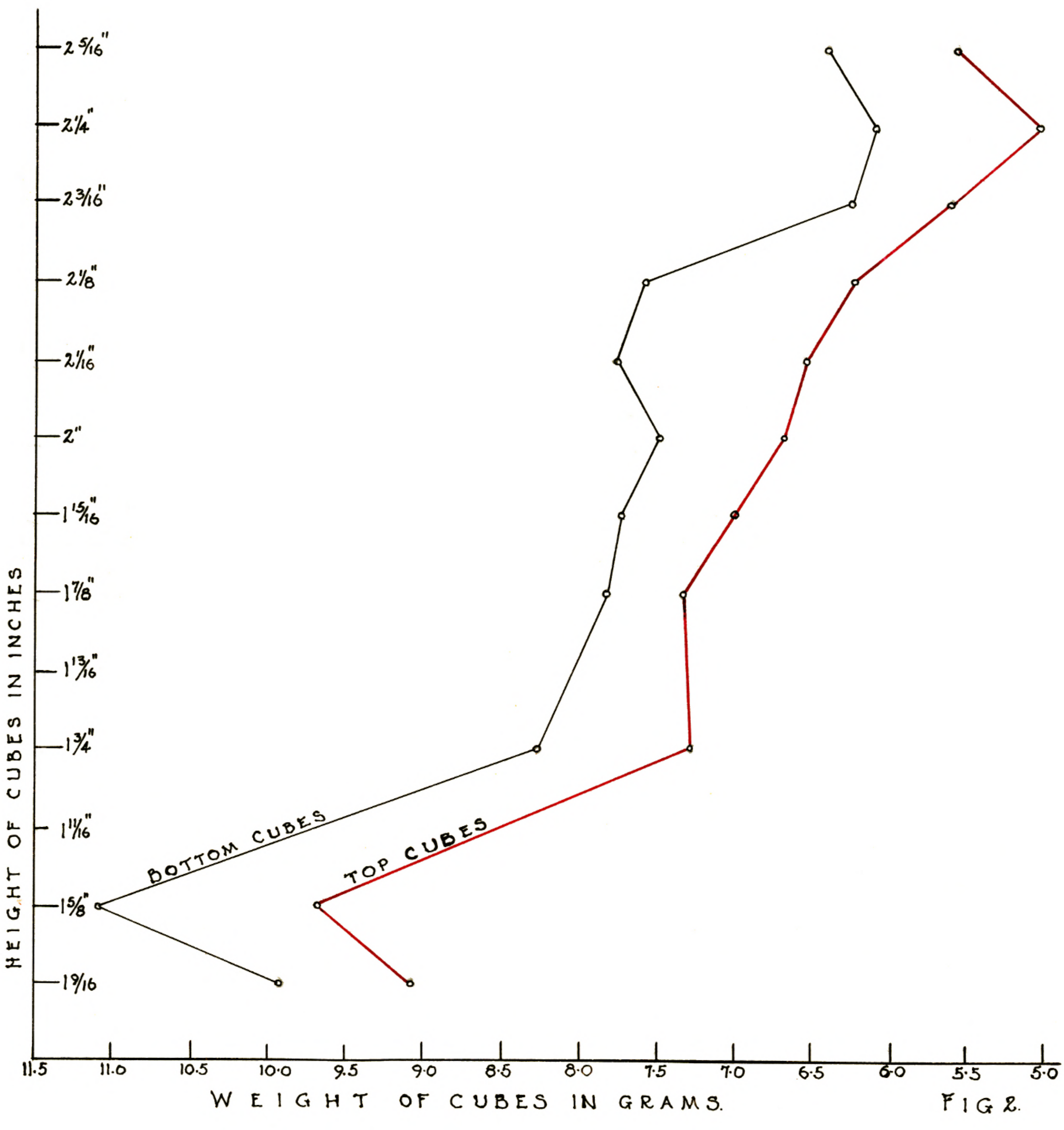

HEIGHT OF CUBES IN INCHES
2 5/16"
2 1/4"
2 3/16"
2 1/8"
2 1/16"
2"
1 15/16"
1 7/8"
1 13/16"
1 3/4"
1 11/16"
1 5/8"
1 9/16
BOTTOM CUBES
TOP CUBES
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
WEIGHT OF CUBES IN GRAMS.

FIG 2.

gen-ion concentration and the color; as the pH increased the cake became less yellow, darker, and less intense.

2. That the substitution of brown sugar for white had a decided effect upon the flavor and crust of the cake.

3. That increased amounts of chocolate affected the color and developed the flavor.

4. That there were no differences found when two different brands of cocoa and chocolate were used.

5. That cakes containing cocoa had a more velvety texture than those containing chocolate.

6. That a more uniform color was obtained when soda was added with the cooked chocolate rather than with the flour or hot water.

7. That soda was more effective as leavening when it was added with the flour.

8. That buttermilk tended to make a cake more moist and tender than sweet milk did, although some individual exceptions to this rule were observed.

9. That when water was substituted for sweet milk a cake with better texture and the desirable dull surface resulted.

10. That the conventional method of mixing gave a cake of higher quality than those made by other methods of mixing.

11. That when soda was added in an amount sufficient to raise the pH above 8, the taste of soda became quite

evident.

12. That the pH of the baked product indicated more truly the alkalinity of the cake than did the pH of the batter.

CONCLUSION

It may be concluded that although the hydrogen-ion concentration is of greatest importance in determining the color, other factors influence the color and also condition the quality of chocolate cake.

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