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BAKING ANGEL FOOD CAKE AT ANY ALTITUDE

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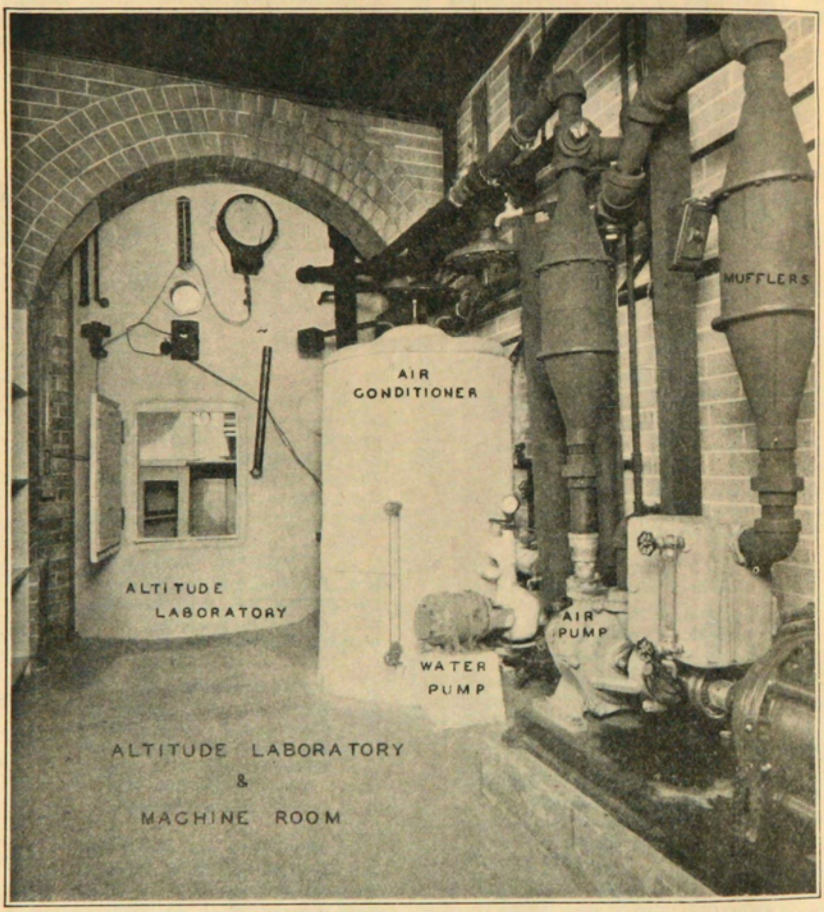
*On leave.



The equipment which makes these studies possible

BAKING ANGEL FOOD CAKE AT ANY ALTITUDE

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The main problem with which this section of the Experiment Station is at present concerned is that of the baking of quick breads at high altitudes. In 1926 the project was formulated in an attempt to meet the difficulties encountered by the housewife and the commercial baker due to the effect of reduced atmospheric pressure at elevations above 3,000 feet.

About one third of the area of the United States has been found to fall within this higher altitude range (See Figure 1). Although this area is sparsely populated it contains about 5 million people. Due to the fact that the majority of people in the United States live at low altitudes, the recipes in current use have been devised for such localities. These are unsuited to high altitudes and the greater the elevation the more impossible they become.

In 1930 a bulletin was published giving the results of some empirical studies, which constituted Part I of the project. In response to requests from the United States and foreign countries, over 11,000 copies of this first bulletin have been sent out.

Because of the wide interest and the lack of satisfactory solution and explanation of the problems arising due to the effects of altitude, Part II of the project was undertaken. This was designed to study the fundamental effects of reduced atmospheric pressure.

The first phase of Part II, a study of the behavior of egg-white foam, has been reported in Technical Bulletin 9, 1934. The second phase, a study of angel food cakes, has now been completed. This present bulletin gives the practical applications of the findings, and a later technical bulletin will give a complete report of this study.

The Finding of the Recipe

Angel food cakes, although made of the fewest ingredients, seem to give more difficulty than the more complex butter cakes. However, once one learns the important steps, success is no longer a matter of chance. It is the purpose of this publication to reveal the successful procedures.

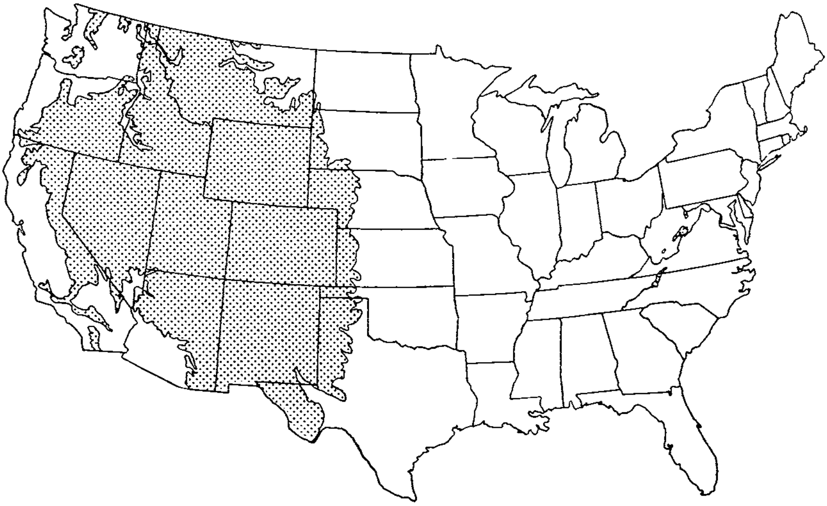


Figure 1.—The shaded area represents that portion of the United States which lies 3,000 feet or more above sea level.

Of first importance in the making of angel food cake is the recipe. The selection of a recipe that will give a good product at low altitudes is in itself not an easy matter. Attempts at changing that recipe for use at higher elevations seldom give satisfactory results. If the ingredients are not properly balanced the cake may fall or it may be tough. The most desirable cake has the most tender texture. Cakes that fall are *too* tender—in other words the structure is too weak to stand up. Therefore there is a minimum tenderness of cakes, beyond which one cannot go, but it is desirable to obtain, as near as possible, that minimum value.

The question now arises as to how the tenderness may be controlled. The work on this project has shown that it is almost entirely due to the *proportion* of ingredients. The egg white and flour make the cake tough while the sugar has the opposite effect.

The method used to estimate the tenderness was to measure the force necessary to pull apart a sample of cake of definite size. By this means it was possible to determine the tenderness value. Then by relating the effects of the ingredients to this limiting value, a mathematical equation was derived. From this, recipes were calculated for cakes that were just strong enough to stand when baked, and therefore as tender as possible.

As the altitude was increased it was found that the cakes became more delicate in texture. Then, if the altitude change was great enough to cause sufficient reduction in tenderness, the cakes fell. The remedy for this was simply to find out what the amount of change in tenderness was for each thousand feet of change in altitude, then to introduce enough flour or to take out enough sugar from the recipe to make up for the change produced by the altitude. This was done mathematically by introducing a value for the effects of altitude into the previously mentioned equation. From this final equation the recipes were calculated for altitudes varying from sea level to 15,000 feet, and are given in Tables I, II and III. These recipes were tested with three different cake flours. All were found to yield cakes of delicate texture, yet not so tender as to fall.

In using the recipe tables it is necessary to decide how much flour one wishes to use. The common recipes seem to use from 12 to 15 tablespoons per cup of egg white, but equally good cakes can be made with any one of the amounts of flour given, provided the amount of sugar is used along with it that is given in the table for the proper altitude. Follow down the column containing the number of tablespoons of flour chosen, to the line giving the altitude nearest to that at which the cake is to be baked. At the point where these two meet will be found the tablespoons of sugar to be used with the other ingredients of the recipe.

To illustrate the steps in formulating the recipe from the table, let us suppose a person located at an altitude of 5,280 feet wished to use 14 tablespoons of cake flour with a cup of egg white. If one follows down the 14-tablespoons-of-flour column to 5,000 feet, one finds that 16½ tablespoons of sugar should be used.

For an altitude of 5,280 feet the recipe will then be as follows:

Flour	14 tablespoons (1 cup less 2 tablespoons)
Sugar	16½ tablespoons (1 cup plus ½ tablespoon)
Egg white	1 cup
Salt	¼ teaspoon
Cream of tartar	1 teaspoon
Flavoring	1 teaspoon

For an altitude of 6,750 feet the recipe will be as follows:

Flour	14 tablespoons (1 cup less 2 tablespoons)
Sugar	14¾ tablespoons (1 cup less 1¼ tablespoons)
Egg white	1 cup
Salt	¼ teaspoon
Cream of tartar	1 teaspoon
Flavoring	1 teaspoon

If one wishes to make a cake of different size than can be made with 1 cup of egg white, all that is necessary is to multiply all the ingredient amounts by the amount of change desired, as might be done in any recipe. To illustrate: If one wishes to make a cake 1½ times as large as the cake made from the recipe given above for the altitude of 5,280 feet, then all that is necessary is to use 1½ cups of egg white, 21 tablespoons of flour, 24¾ tablespoons of sugar, ½ teaspoon of salt, 1½ teaspoons of cream of tartar and 1½ teaspoons of flavoring.

The same method should be used for finding or changing the recipes given in Tables II and III. These last two tables are given primarily for the use of the commercial baker, but it is hoped that some housewives will make use of them.

TABLE I.—RECIPES FOR ANGEL CAKE
Given in Tablespoons of Sugar for 8 to 15 Tablespoons of Flour

Altitude in Feet	Flour (tablespoons) 8	9	10	11	12	13	14	15
	Sugar (tablespoons)							
0	14½	15½	16½	17¾	18¾	20	21	22¼
1,000	13½	14½	15¾	16¾	18	19	20¼	21¼
2,000	12½	13¾	14¾	16	17	18¼	19¼	20½
3,000	11¾	12¾	14	15	16	17¼	18½	19½
4,000	10¾	12	13	14	15¼	16½	17½	18½
5,000	10	11	12	13¼	14¼	15½	16½	17¾
6,000	9	10	11¼	12¼	13½	14½	15¾	16¾
7,000	8	9¼	10¼	11½	12½	13¾	14¾	16
8,000	7¼	8¼	9½	10½	11¾	12¾	14	15
9,000	6¼	7½	8½	9¾	10¾	12	13	14
10,000	5¼	6½	7½	8¾	10	11	12	13¼
11.000	4½	5½	6¾	8	9	10	11¼	12¼
12,000	3½	4¾	5¾	7	8	9¼	10¼	11½
13,000	2½	3¾	5	6	7¼	8¼	9½	10½
14,000	1¾	2¾	4	5	6¼	7½	8½	9½
15,000	1	2	3	4¼	5¼	6½	7½	8¾

Egg white............................1 cup
Salt ....¼ teaspoon
Cream of tartar................1 teaspoon
Flavoring (Vanilla) ....1 teaspoon

MANIPULATION OF INGREDIENTS AND THE UTENSILS USED

The next most important point is the separation and beating of the egg white, which must come from strictly fresh or moderately fresh eggs. These must not have been kept at room temperature (approximately 70° F.) for more than 4 days since the white of the older eggs becomes "runny" and the yolk flattens out. Accompanying this liquefaction, some other change takes place which causes the cake to shrink more than that baked from fresh egg white.

TABLE II.—RECIPES FOR ANGEL CAKE

Given in Grams of Sugar for 40 to 80 Grams of Flour

Altitude in Feet	40	45	50	55	60	65	70	75	80
	Sugar (grams)								
0	150.5	162.5	174.0	186.0	197.5	209.5	221 0	232.5	244.0
1,000	141.0	153.0	164.5	176.0	187.5	199.5	211.0	222.5	234.5
2,000	131.5	143 5	155.0	166.5	178 0	189.5	201.0	213 0	224.5
3,000	122.0	133.5	145.5	157 0	168 5	180.5	192 0	203 5	215.0
4,000	112.5	124.0	135.5	147.5	159.0	170.5	182.5	194 0	205.5
5,000	103.0	114.5	126.0	138.0	149.5	161.0	172 5	184.5	196.0
6,000	93.0	105 0	116.5	128.0	139.5	151.5	163.0	174 5	186.5
7,000	84.0	95.0	107.0	118.5	130.0	142.0	153.5	165 0	177.0
8,000	74.0	85.5	97.5	109.0	120.5	132.5	144 0	155.5	167.0
9,000	64.5	76 0	87.5	99.5	111 0	122.5	134.5	146 0	157.5
10,000	55.0	66.5	78.0	90.0	101.5	113.0	124.5	136.5	148.0
11,000	45.0	56.5	68.5	80.0	91 5	103.5	115.0	126.5	138 5
12,000	35.5	47.0	59.0	70.5	82.0	94 0	105.5	117.0	129.0
13,000	26.0	37.5	49.5	61.0	72.5	84.0	96.0	106.5	119.0
14,000	16.5	28.0	39.5	51.5	63.0	74.5	86.5	98.0	109.5
15,000	7.0	18.5	30.0	41.5	53.5	65.0	76.5	88.5	100.0

Egg white .... 210 grams
Cream of tartar............... 4 grams
Salt .... 1 gram
Flavoring (Vanilla) .... 5 grams

TABLE III.—RECIPES FOR ANGEL CAKE

Given in Ounces of Sugar for 3 to 6 Ounces of Flour

Altitude in Feet	3.0	3.5	4.0	4.5	5.0	5.5	6.0
	Sugar (ounces)						
0	11.4	12.5	13.7	14.9	16.1	17.3	18.5
1,000	10.6	11.8	13.0	14.1	15.3	16.5	17.7
2,000	9.9	11.0	12.2	13.4	14.5	15.7	16.9
3,000	9.2	10.3	11.5	12.7	13.8	15.0	16.2
4,000	8.4	9.6	10.8	11.9	13.1	14 3	15.5
5,000	7.7	8.9	10.0	11.2	12.4	13.5	14.7
6,000	7.0	8.2	9.3	10.5	11.7	12.8	14.0
7,000	6.3	7.4	8.6	9.8	10.9	12.1	13.2
8,000	5.5	6.7	7.8	9.0	10.2	11.3	12.5
9,000	4.8	6.0	7.1	8.3	9.5	10.6	11.8
10,000	4.0	5.2	6.4	7.5	8.7	9.9	11.0
11,000	3.3	4.5	5.7	6.8	8.0	9.2	10.3
12,000	2.6	3.8	4.9	6.1	7.3	8.4	9.6
13,000	1.9	3.0	4.2	5.4	6.5	7.7	8.9
14,000	1.1	2.3	3.5	4.6	5.8	7.0	8.1
15,000	.4	1.6	2.7	3.9	5.1	6.2	7.4

Egg white............................ 16.0 ounces
Cream of tartar............... 0.3 ounce
Salt .... 0.07 ounce
Flavoring (Vanilla) .... 0.4 ounce

Eggs kept in an ice box or similarly cold place over a period of as much as 2 weeks may be used successfully.

In separating the white from the yolk, care must be exercised, because a satisfactory angel cake cannot be made from egg white that contains egg yolk. Yolk contains fat, and even a very small amount of fat prevents the formation of the proper egg-white foam. Fat from other sources must also be guarded against.

The egg white should be at room temperature for easy beating. If cold it will not beat up as easily, nor to quite so large a volume. A double rotary beater is probably the most satisfactory hand utensil. In this connection it might be mentioned that it is more difficult to beat strictly fresh egg white than that from eggs about 4 days old. However, if one has a power beater, just as good angel food cake can be made from the strictly fresh egg white as from that slightly older.

The cream of tartar and salt should be added during the first part of the beating period. The beating should be done as rapidly as possible, and should be continued until the foam will just "peak," which is illustrated in Figure 2. The effects of beating too much are much more serious than of not beating enough. Over beating causes holes to develop in the cake during baking. Under beating will produce a slightly smaller cake, but the texture will be as good or better than a cake of maximum size. The volume of the foam should be just about seven times the volume of the original egg white.

The procedure in the addition of sugar, flavoring and flour is as follows:—A part of the sugar, about ⅔, is added rapidly and the beating continued for about ½ minute; next, the flavoring which is stirred in with but a few strokes. Then the mixture of flour, with any remaining sugar, should be added rapidly enough so that all of the mixture has been incorporated within 3 minutes, and the *stirring* continued for about a minute. (Note that the term *stirring* has been used rather than beating.) It is understood that the sugar-flour mixture has been sifted together about three times.

For those recipes that call for less than 9 tablespoons of sugar per cup of egg white, it is recommended that all of the sugar be added at once. This corresponds to the 7 ounces of sugar per pound of egg white given in Table III, or to 90 grams of sugar per 210 grams of egg white, in Table II.

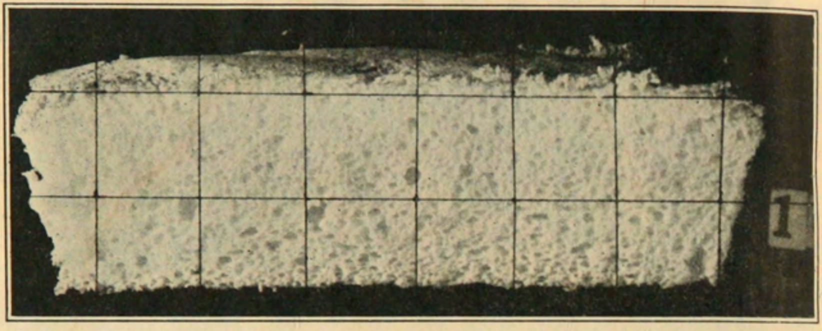
Figure 2.—The "peaking" of properly beaten egg white.

A tube pan large enough so that the batter will not occupy more than 2/3 of the total volume should be used. Then when the cake is inverted, after baking, the weight will be supported by the pan rather than by the top of the cake. This would require a pan of about 12-cup capacity for a cake made from 1 cup of egg white.

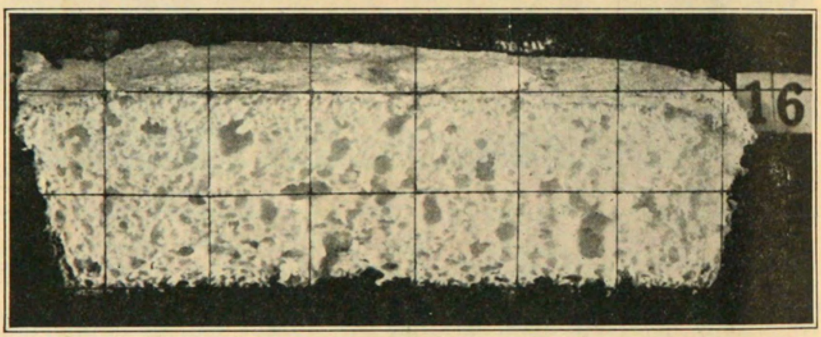
THE BAKING

The cake should be baked at a temperature of not less than 300 degrees nor greater than 350 degrees F. The time required will depend on the temperature, and will vary from 1½ hours at the lower temperature to approximately ½ an hour at the higher temperature. The best method of timing is probably that of baking long enough to get a desirable crust brownness.

Those preferring a dry-tasting angel cake should bake their cakes at some temperature between 300 and 325 degrees F. and those preferring the moist cake at a temperature between 325 and 350 degrees F. The higher temperature is more satisfactory at high altitudes because it requires a hotter oven to produce the same crust color, in a given time, than at sea level. The high temperature produces a larger, lighter cake and *does not increase the toughness.*



Result of proper beating.



Result of over beating.

Figure 3.—The cake texture resulting from proper and improper beating.

After removing from the oven, the cake and pan should be inverted, preferably over a cake-cooling rack, and allowed to cool in that position.

DIFFERENCES DUE TO TWO SPECIFIC INGREDIENTS

In the work of this laboratory two widely distributed brands and one local brand of cake flour were used. These shall be called A, B and C. Neither A nor C was found to be as satisfactory as B, because both of the former caused considerable shrinking of the volume when added to the meringue.* Flour B was found to cause practically no shrinking, and so could be stirred into the meringue long enough to insure its even distribution throughout the mixture. Therefore the use of flours A and C resulted in smaller, heavier cakes than the use of flour B.

*Meringue is the name generally used for a mixture of egg white and sugar and is so used in this publication.

The explanation of the difference in these three flours seems to be due to their fineness. Flours A and C give indications of being finer than B. This difference was thought to cause A and C to take up the moisture of the egg white so rapidly that it caused the tiny bubbles of the foam to burst.

Cream of tartar seems to be the best form of acid for use in angel food cakes. Lemon juice and vinegar vary in acid content, introduce unnecessary liquid and neither produces as desirable a bubble size or color as does cream of tartar.

The amount of cream of tartar recommended is that which appeared to give the most satisfactory color and bubble size. This amount may be increased or decreased. If increased it will produce a whiter cake but the taste of the cream of tartar will be noticeable, and perhaps objectionable to some people. If the amount is reduced, the color of the cake will be slightly yellow but the taste of the cream of tartar will be entirely absent. The amount should not be reduced to less than ½ of the recommended amount.

The size of the sugar particles has been claimed by some to affect the size of the air bubbles in the finished cake. Ordinary granulated sugar and powdered sugar have both been used, with identical results, so there is apparently nothing to be gained by using any sugar other than ordinary granulated table sugar.

MEASURING INGREDIENTS

One of the troubles encountered by the housewife, that causes considerable difficulty, is that of the measuring of ingredients of recipes. Very few measuring cups are accurate.* Probably the easiest way to test their accuracy is to place four cupfuls of water in an accurate quart measure. It should just fill it.

Even with accurate measuring utensils, only liquids can be measured accurately unless considerable care is exercised. Flour is the most difficult to measure. It should be sifted *once*, and then placed lightly into the cup with a spoon. There should be no packing manipulations, that is, no jolting or pressing into place. The cup should be filled heaping full and then *scraped* off level, with a straight-edged instrument such as the back edge of a knife. For measuring spoonfuls, the spoon should be dipped into the once-sifted flour and then leveled off. Sugar should be measured the same way except that there is no need to sift it unless it is lumpy.

*Halliday and Nobel (Hows and Whys of Cooking, Chicago University Press, 1933. First Edition, p. 34.)

In measuring out the large number of tablespoons of flour or sugar given in the recipe, it should be remembered that 16 tablespoons are equal to 1 cup. In many cases it will be easier to measure out fractions of a cup of the ingredients, then to add, or to remove, sufficient numbers of tablespoons to give the correct amount.

The solution to all the difficulties in measuring can be easily overcome by weighing the ingredients, but it is realized that that method is by no means always possible.

The following weights and corresponding measuring units have been used to set up the three tables given.

1 cup	=	236.6 cc., or ½ pint, or 16 tablespoons
1 tablespoon	=	3 teaspoons
1 cup egg white	=	246 grams or 8.7 ounces
1 cup cake flour	=	96 grams or 3.4 ounces
1 cup sugar	=	200 grams or 7.1 ounces
1 tablespoon flour	=	6 grams or 0.21 ounce
1 tablespoon sugar	=	12.5 grams or 0.44 ounce
1 teaspoon cream of tartar	=	4 grams or 0.14 ounce
1 teaspoon flavoring	=	5 grams or 0.18 ounce

SUMMARY OF PROCEDURE

The recommended procedure, then, is as follows:

1. Use the amounts of ingredients that best suit the supplies and utensils at hand and for the altitude nearest to that at which the cake is to be baked.
2. Beat the egg whites until they peak, adding the salt and cream of tartar during the first part of the beating period.
3. Beat in ⅔ or all of the sugar.
4. Add the flavoring.
5. Stir in the sifted cake flour and any remaining sugar.
6. Bake for about 30 minutes at 340 to 350 degrees F. Remove from the oven, invert at once and allow to cool in the pan.
7. Ice if desired,* following the directions of a good cookbook.

At very high altitudes, above 10,000 feet, the cakes contain so little sugar in proportion to their flour content that they can scarcely be called cakes. A thick icing may then be desirable.

*The texture and color of a fine angel cake is so pleasing that it is generally undesirable to mask this with an icing. However, that is a matter of personal opinion.

CAUSES AND PREVENTION OF FAILURES

A tough cake is most likely due to too much flour, or too little sugar, or to over stirring during the addition of the flour.

A fallen cake will be the result if the cream of tartar is omitted. In this case the inside of the cake will be distinctly yellow. Just as in other situations, a cake falls because of the lack of supporting material. In other words it is not strong enough. This can be due to insufficient flour or to too much sugar.

Even with the most detailed directions it takes some practice to produce prize-winning cakes, although it is believed that if these directions are followed carefully and thoughtfully no real failures can result, even for the beginner.