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Dehydrated Stabilized Egg. Importance and Determination of pH[a,b]

HAROLD SALWIN, I. BLOCH, AND J. H. MITCHELL, JR.
Quartermaster Food & Container Institute for the Armed Forces, Chicago, Illinois

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A method for determining the pH of dehydrated stabilized egg is described. The pH measurement is made on the reconstituted sample after it has been cooked. The method is shown to be valuable as a control test since it is more sensitive to acidity and alkalinity than when uncooked eggs are used. To determine the pH range that describes the most desirable product consumer and laboratory tests were applied, respectively, to scrambled eggs and to sponge cakes (prepared from dehydrated stabilized eggs) of varying pH. A suitable range for the pH of cooked reconstituted dehydrated egg was shown to be from 7.0 to 9.0. Formations of green color under conditions of heat and high pH were noted. The reaction apparently involving iron and sulfur compounds can be inhibited by a metal-complexing agent.

A number of processes are being used for stabilizing the flavor, color, solubility and other desirable properties of dehydrated egg during storage. Among these are gas packing, drying to very low moisture content, removal of glucose by fermentation, enzymatic oxidation of glucose, and acidification. The acidification process was first reported by Stewart, Best and Lowe *(5)* who used 10% lactic acid for adjusting the pH prior to drying. They found that acidification had a marked beneficial effect on solubility, but that lowering the pH below 6.5 caused an objectionable alteration in flavor and texture. Boggs and Fevold *(2)* used dilute hydrochloric acid and found that acidification of egg emulsion to the pH of egg yolk, 5.5, improved markedly the retention of palatability during storage. These workers reconstituted the acidified egg powder with sodium carbonate equal to the acid used in acidification in order to prevent undesirable textures from developing during heating. Conrad *et al. (3)* state that when sodium bicarbonate is used for neutralizing the acid, the correct amount to add to the acidified powder is 1.5% of the weight of powder.

In order to realize the benefits of these developments for the Armed Forces, the Quartermaster Corps, in 1949, adopted the acidification process for the production of powdered egg. The product, called Egg, Stabilized, Dehydrated, is manufactured by a process designed to improve the flavor stability. After the liquid egg is pasteurized, it is acidified with hydrochloric acid to a pH of 5.5 and then spray dried. Sodium bicarbonate is added to the egg powder at the plant in order to restore the normal pH at the time of reconstitution and use.

Research at the Quartermaster Food and Container Institute has demonstrated that the flavor, color and functional properties of stabilized egg are adversely affected by either inadequate or excessive amounts of sodium bicarbonate. Furthermore, the addition of sodium bicarbonate in quantities beyond those actually needed would have the same monetary effect as an equivalent adulteration of the product. One objective of this study was to establish pH limits for dehydrated stabilized egg which would insure the presence of the optimum level of sodium bicarbonate.

During reconstitution of dehydrated stabilized egg, carbon dioxide is generated by the reaction between hydrochloric acid and sodium bicarbonate. Because of the difficulty of obtaining reliable pH measurements in the presence of carbon dioxide, a second objective of this study was to develop a dependable method for measuring the pH of this product.

Tests indicate that samples which give a certain pH value when one method of reconstitution is followed may not give the same value when the manner of mixing is changed. The variable nature of pH measurements is demonstrated by the data in Tables 1 and 2. Loss of carbon dioxide from the mixture causes the pH value to rise, and the final acidity depends upon the extent to which the carbon dioxide is liberated. The efficiency and speed of the mixer, the time of mixing, the degree of aeration, and the temperature influence the rate of liberation of carbon dioxide. The pH value of acidified powder to which no sodium bicarbonate had been added was found to be independent of the manner of mixing.

In order to obtain consistent results, it is necessary to remove carbon dioxide under uniform conditions. By defining the brand name and type of mixer and the time for mixing, uniform results can be obtained. For example, with 30 seconds of blending in 4 different Waring blenders,[c] the pH values of a commercial sample were 7.3, 7.4, 7.4 and 7.4. However, it is desirable to avoid specification tests which are restrictive with regard to equipment requirements. For that reason, the possible advantages of heating the samples to remove carbon dioxide were investigated. On the basis of data published by Conrad *et al. (3)*, it appeared that variations in acidification and neutralization were reflected best by the pH of cooked, rather than uncooked, reconstituted egg. Thus, in addition to providing the

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[b] This paper reports research undertaken by the Quartermaster Food and Container Institute for the Armed Forces and has been assigned No. 437 in a series of papers approved for publication. The views or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or indorsement of the Department of Defense.

[c] The mention of this and other commercial products does not imply that they are endorsed or recommended by the Department of Defense over other similar products not mentioned.

TABLE 1

Effect of method of reconstitution upon the pH of dehydrated stabilized egg

Method of mixing	pH									
	Time of mixing, minutes									
	⅓	1	2	3	5	6	10	20	40	50
Hand mixing in 250 ml. beakers		6.8								
Kahn Shaker, glass stoppered, Erlenmeyer flasks							6.9			
Glass paddle-stirrer and motor										
Low speed					7.0			7.5		8.0
High speed			7.1		7.3		7.7	8.1	8.3	8.3
Hand Mixing 1.5 minutes followed by Hamilton Beach Malted Milk Mixer	7.5	7.8		8.1		8.3	8.3			
Waring blender	7.3	7.5		7.7						

desired standardization of the test, cooking the samples should also give more informative results.

MATERIALS AND METHODS

Equipment.

(a) Balance and weights, for weighing to the nearest 0.1 g.

(b) Waring or similar food blender, with covered jars.
pH meter equipped with glass and calomel electrodes. (Five-inch Beckman electrodes with shielded leads for use external to the pH meter were used with a Beckman Model G meter.)

(c) Cooking apparatus (Figure 1).
  a. No. 10 tin can, 6⅛ in. diameter, 7 in. high, provided with wire-screen shelf 2 in. above bottom.
  b. Watch-glass cover, approximately 7¾ in. diameter, set in inverted position (convex side up) over can.
  c. Source of heat.

(d) Thermometer.

(e) Crucible or beaker tongs.

(f) Cold water bath or trough.

(g) Spatula.

(h) No. 7 rubber stopper.

(i) Crystallizing dishes, approximately 4 in. diameter.

(j) Graduated cylinder, 50 ml.

(k) Beakers, 50 ml.

(l) Reference buffer solution (pH 4.0 and pH 7.0 buffers were used.)

Determination of pH. Pour water into the tin can until the surface is one-fourth to one-half inch above the screen shelf. Cover the can, heat to boiling, and keep boiling. Measure 27 ml. of distilled water into food blender jar and add 10.0 g. of egg powder. Cover the jar and blend for 30 seconds. Pour the reconstituted sample into a crystallizing dish, and, with tongs, set dish on the wire screen shelf of the boiling water bath and replace the cover. After 10 minutes, remove the dish and cool it in a water trough to 25° C. With the aid of a spatula, transfer the cooked egg to a 50 ml. beaker, press it down solidly with a No. 7 rubber stopper, and, if necessary, adjust the temperature to 25° C. Insert electrodes into the egg and determine the pH. Insert electrodes in a different position and read again. Repeat, if necessary, until readings are constant. The usual precautions with regard to standardization and use of the pH meter should be observed *(1)*.

Preparation of scrambled eggs. The following formulas were used:

	With Milk	Without Milk
Acidified egg powder	70.3 g.	70.3 g.
Distilled water	198.0 ml.	236.0 ml.
Evaporated milk	50.0 ml.	......
Salt	0.9 g.	......
Soluble pepper in salt base	0.24 g.	......
Hydrogenated shortening	11.7 g.	11.7 g.

Sift egg powder, combine with water and mix for 30 seconds in Waring blender. Add milk, salt and pepper and mix well with spoon. Melt shortening in top of double boiler. The bottom of the double boiler should contain just enough water to provide

TABLE 2

Effect of method of reconstitution upon the pH of dehydrated stabilized egg, measured before and after cooking

Sample	Condition	Method of mixing	pH				
			Nominal sodium bicarbonate (percent)				
			0[a]	0.75[a]	1.5[b]	2.25[c]	3.0[c]
1	Uncooked	(A) Hand mixed 1 minute			6.8		7.2
		(B) Malted milk mixer, 20 seconds			7.2		7.7
		(C) Waring Blendor, 20 seconds			7.3		7.5
	Cooked	(A)			8.5		9.3
		(B)			8.5		9.5
		(C)			8.4		9.5
2	Uncooked	(A)	6.2	6.6	6.9	7.1	
		(B)	6.8	7.3	7.6	7.8	
		(C)	6.6	7.1	7.4	7.5	
	Cooked	(A)	7.3	8.8	9.4	9.6	
		(B)	7.4	8.6	9.3	9.7	
		(C)	7.4	8.8	9.4	9.6	

[a] Commercial powder, modified by addition of standard hydrochloric acid solution.
[b] Commercial powder, unmodified.
[c] Commercial powder, modified by addition of sodium bicarbonate.

a steam bath for the top. Pour reconstituted egg into hot shortening and cook for 4 minutes, stirring slowly as egg thickens. Cover cooked eggs, hold 20 minutes, then serve within 20 minutes.

Preparation of sponge cakes. The following formula was used for sponge cakes:

Eggs, dehydrated	58 g.
Sugar	200 g.
Water, 154° F.	172 g.
Salt	¼ teaspoon
Cake Flour	96 g.

[Dry ingredients measured at 72° F. (22.2° C.)]

Use Kitchen Aid Mixer Model K4-B with wire whip. Partly submerge the mixer and bowl in hot water bath at a temperature of 113° F. during the entire mixing process.

Sift eggs and sugar together 3 times; sift salt and flour together 3 times. Mix egg-sugar mixture 1 minute at speed control number 1. Adjust mixer to speed control number 6 and add water slowly while beating. (This process should require approximately 45 to 60 seconds.) Continue beating on speed control number 6 until a specific gravity of 0.30 is reached or for a maximum beating time of 20 minutes. Stop mixer. Record temperature of egg mix, specific gravity and beating time.

Add 2 tablespoons of the flour-salt mixture. Start mixer again, using speed control number 1. Add the remaining flour-salt mixture gradually in a 30 second period. Stop mixer, scrape sides of bowl, and mix another 30 seconds on speed control number 1. Fold batter with a rubber spatula using 3 strokes around the bowl. Record temperature and specific gravity of the batter.

Scale 300 g. of batter into a tube pan of approximately 2000 cc. capacity which has been lined on the bottom with brown paper. Bake 25 minutes at 350° F. Determine pH on remaining sample of batter. Remove from oven, invert pan for approximately 24 hours, first on rack until cool and then on table. Determine the weight of the cake. Measure the volume by the rapeseed displacement method.

RESULTS AND DISCUSSION

Determination of pH after cooking. When reconstituted egg was heated in 250 ml. beakers on a steam bath, results of pH measurements on commercial samples were not uniform. Without stirring, the pH difference between cooked and uncooked samples was approximately 0.1 unit. With stirring, the difference was approximately 1.1 units. The apparatus illustrated in Figure 1 was adopted as the source of heat for cooking. The beakers were replaced by 4-inch crystallizing dishes and the sample size was reduced without altering the sample-to-water ratio. Instead of 27 g. of egg and 73 ml. of water, as used in preliminary experiments, 10 g. of egg were reconstituted with 27 ml. of water. The sevenfold increase in surface-to-volume ratio made stirring unnecessary and permitted thorough cooking in a few minutes with complete removal of carbon dioxide. The same pH values were obtained with 5, 10 and 15 minutes of cooking. A 10-minute period was used for the determinations reported here. A 5° C. rise in the temperature of the cooked egg at the time of measuring the pH resulted in a lowering of the pH value of approximately 0.1 unit.

Whereas the mixer and mixing time influence the pH of uncooked reconstituted egg (Tables 1 and 2), these factors have little or no effect upon the pH of the cooked egg (Table 2). Uniformity of results is the first advantage derived from cooking the reconstituted sample before measuring the pH. The samples were reconstituted with a Hamilton Beach malted milk mixer, with a Waring blender, and by hand mixing. In any column of Table 2 the greatest spread of results after cooking is 0.2 of a pH unit, whereas the spread of results before cooking is 0.5 to 0.7 of a pH unit. Therefore, if the sample is cooked before the pH is measured, the method of reconstitution is not critical.

Inspection of the data in Table 2 reveals other advantages of the cooking procedure. The increments in the pH values of the cooked eggs resulting from increases in the effective sodium bicarbonate concentrations are usually double or triple the corresponding increments for the uncooked samples. Hence, a second advantage of cooking the reconstituted egg before determining the pH is the greater sensitivity of the method to variations in acidity and alkalinity.

When cooked, sample number 1 (unmodified; 1.5% column) is a normal bright yellow color, but sample number 2 (unmodified) presents an unpalatable dark

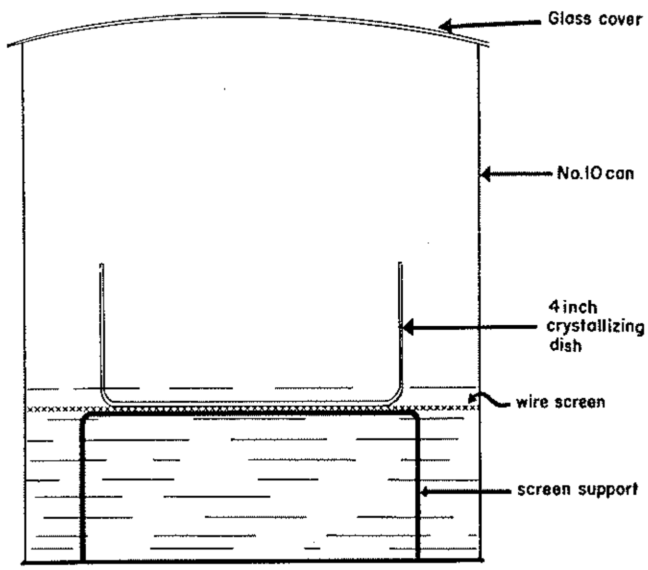

Figure 1. Apparatus for cooking reconstituted powdered egg.

green appearance. The green color is apparently the result of changes initiated by an over-alkaline condition, since it can be produced in sample number 1, also, by adding to it excessive amounts of sodium bicarbonate (modified; 3.0% column). The uncooked samples reconstituted with the Waring blender (1.5% column) have nearly the same pH, 7.3 and 7.4, whereas the pH values after cooking are very different, 8.4 and 9.4. The fact that sample number 2 is too alkaline is reflected by the pH of the cooked sample, but not by the pH of the uncooked sample. Also, the green color which develops on cooking is a simple practical test for over-alkalinity.

Additional comparisons of pH determinations made before and after cooking are presented in Table 3. Sample number 3 was bright yellow when cooked; sample number 4 when cooked was a dirty yellow. The pH values of these samples before cooking were 6.8 and 7.3, respectively, but after cooking they became more alkaline and the pH values, 7.4 and 8.7, show a much greater difference. The pH value of 7.7 determined on uncooked sample number 5 would indicate that not much excess sodium bicarbonate had been added. When cooked, however, this sample had an abnormally high pH (9.7) and a dark green color. Sponge cakes made with sample number 5 were a dark color and had texture and flavor defects.

In order to obtain the figures in the third column of Table 3, 20 ml. of an 0.088 M solution of hydrochloric acid plus 7 ml. of water were used for reconstitution of the dehydrated egg. Twenty ml. of the acid solution are equivalent to 0.15 g. of sodium bicarbonate, or 1.5% on a 10-gram sample of egg powder. If hydrochloric acid and sodium bicarbonate were used in equivalent amounts at the time of manufacture, the acid added in reconstitution should result in a pH value for the uncooked sample very near to 5.5. It is interesting to note that only sample number 3, the one which was bright yellow when cooked, gave such a value. In this instance, the pH values before and after cooking differed by only 0.3 unit. Presumably, the large excess of acid was nearly as effective as heat for removing carbon dioxide from the solution.

Much of the data in Tables 2 and 3 were obtained on commercial samples after they had been modified by the addition of either hydrochloric acid or sodium bicarbonate. The data for the curves in Figure 2 were obtained by adding increments of sodium bicarbonate to acidified egg powder which contained no sodium bicarbonate. The pronounced difference in the slopes of the 2 curves, especially in the important region near 1.5% sodium bicarbonate, explains the greater sensitivity of the method of determining pH after cooking. Similar curves were made with sample number 1 (Table 2) after adjusting the effective sodium bicarbonate concentration by the addition of various amounts of hydrochloric acid or sodium bicarbonate. That the 2 sets of curves were virtually superimposable was interpreted as establishing the validity of pH measurements made on modified commercial samples.

Effect of pH on palatability. Before the method of determining pH of cooked egg could be used as a control test, it was necessary to establish the pH range which describes the most desirable product. For flavor evaluation scrambled eggs were tested by consumer observers using the hedonic scale method *(4)*. Forty observers rated each sample on a 9-point scale ranging from *like extremely* to *dislike extremely*.

Acidified egg powder with 0, 1.5, 3.0, and 5.0% of added sodium bicarbonate was used. Inasmuch as milk

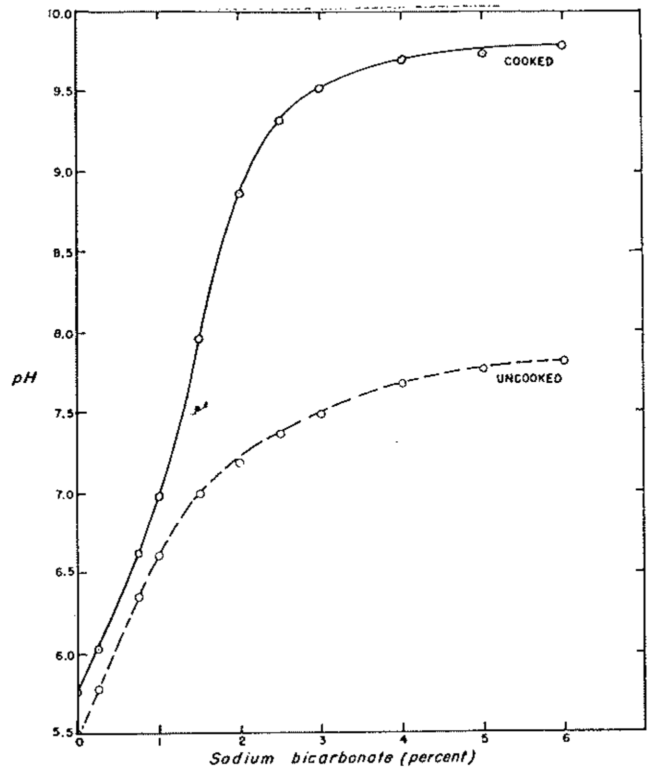

Figure 2. Effect of cooking on the pH of acidified egg powder reconstituted with sodium bicarbonate.

is listed as an optional ingredient in Armed Forces recipes for scrambled eggs, one series of samples was reconstituted with water and evaporated milk, while water alone was used for a second series. In either case, there was a distinct preference for the samples containing 1.5 and 3.0% of sodium bicarbonate, with no statistical significance between mean ratings of these 2 levels (Figure 3). Without sodium bicarbonate, the scrambled eggs had a crumbly texture resembling that of cottage cheese. Those prepared with eggs containing more than 3.0% of sodium bicarbonate had a tough, rubbery texture. Egg powder containing 5.0% of sodium bicar-

TABLE 3

pH of dehydrated stabilized egg, uncooked and cooked

Sample	Condition	pH	
		Nominal sodium bicarbonate (percent)	
		0[a]	1.5[b]
3	Uncooked	5.4	6.8
	Cooked	5.7	7.4
4	Uncooked	6.1	7.3
	Cooked	6.5	8.7
5	Uncooked	7.1	7.7
	Cooked	....	9.7

[a] Commercial powder, modified by addition of standard hydrochloric acid solution.
[b] Commercial powder, unmodified.

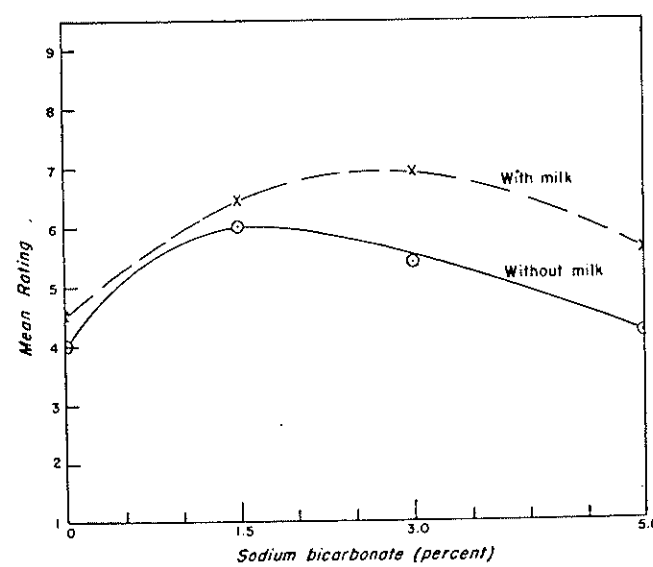

Figure 3. Effect of sodium bicarbonate concentration on consumer preference of scrambled eggs prepared with acidified egg powder.

bonate produced scrambled eggs by either recipe with a green discoloration, which had been found previously to be associated with an excess of sodium bicarbonate. The 3.0% sample containing milk had a normal color, but without milk the green color was slightly evident. The addition of milk was observed to lower the pH of cooked samples from 0.2 to as much as 0.8 of a pH unit. The inhibition of the green color by milk must be due, at least in part, to this lowering of the pH. The appearance of the green samples was described by many of the observers as unappetizing and moldy. The tasting and scoring of these green samples were done in a controlled test, but if they had been served under other circumstances it is possible that they would have been rejected entirely. In any case, it would seem advisable to avoid these off-colors by limiting the addition of sodium bicarbonate.

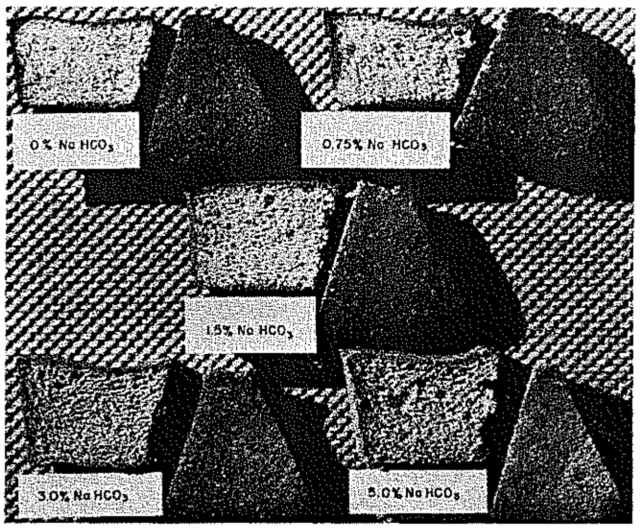

Figure 4. Effect of sodium bicarbonate concentration on volume, color, and grain of sponge cakes prepared with acidified egg powder.

Effect of pH on functional properties. Preparing sponge cakes proved to be the most convenient way to measure the functional quality of the egg powder. Acidified egg powders with 0, 0.75, 1.5, 3.0 and 5.0% of added sodium bicarbonate were used. In every test, the sample with 1.5% produced the cake of best flavor, texture and appearance (Figure 4). Egg powders with smaller amounts of sodium bicarbonate produced cakes with compact textures and with volumes reduced as much as 15%. When the egg powders contained larger amounts of sodium bicarbonate, the cakes showed coarse irregular cell structures and dark uneven colors. The color of these cakes was analyzed in the Hunter Color and Color-Difference Meter. As the amount of sodium bicarbonate in the egg powder was increased above 1.5%, the colors of the crumb changed from yellow to brown and were as much as 25% darker than normal. The crusts also acquired a definite off-color, which color-meter readings described as green. These cakes lacked the normal contrast between rich brown crust and bright yellow crumb.

The reaction between the hydrochloric acid and sodium bicarbonate of stabilized egg is similar to that of a baking powder in the sponge-cake formula. Upon inspection of Figure 4, the question arises as to whether the volume of the first cake was reduced by a damaging effect of the acid, or whether the volume of the third cake was greater than normal because of the presence of a pseudo baking powder. A control sample of unacidified powder made from the same egg pulp was not available for comparison. Therefore, sponge cakes were prepared with liquid egg as follows:

(a) Liquid egg control

(b) Liquid egg acidified with dilute hydrochloric acid to pH 5.5

(c) Liquid egg acidified with dilute hydrochloric acid to pH 5.5, then neutralized with an equivalent quantity of sodium bicarbonate.

The liquid contents of 12 shell eggs were blended together and three 216-gram portions were treated as indicated. The sodium bicarbonate was added to the third sample just prior to its use in the cake formula. The results of this experiment are illustrated in Figure 5. The volume of the cake prepared with acidified egg (number 2) was 24% below that of the control (number 1). The volume of the cake prepared with acidified and neutralized egg (number 3) was only 3% below that of the control. The results demonstrate a loss of leavening power in the presence of acid, and a restoration to the normal condition by the addition of an equivalent amount of sodium bicarbonate.

Tests with scrambled eggs and sponge cakes demonstrate the need for close control of the addition of sodium bicarbonate to acidified egg powder. The results of these tests were expressed in terms of pH by reference to the curves in Figure 2 and to similar curves prepared for other samples. It appears that a desirable range for the pH of cooked reconstituted samples is 7.0 to 9.0.

Effect of pH on color. The relationship between the pH and the color of cooked eggs has been mentioned. The formation of the green color apparently results from changes induced by heat in proteins of the yolk at high pH and involves a reaction between certain iron and sulfur compounds of the egg. It was produced in stabilized egg of normal pH by the addition of an iron

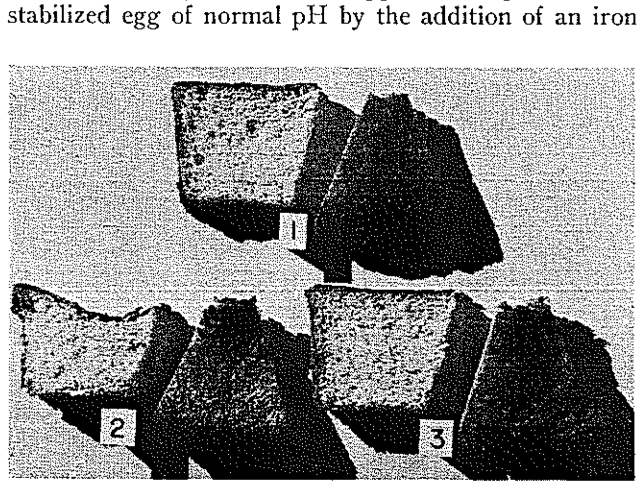

Figure 5. Sponge cakes prepared with fresh shell egg treated as follows: (1) control, (2) acidified to pH 5.5, (3) acidified to pH 5.5, then neutralized with sodium bicarbonate. pH values of batters: 7.8, 5.5 and 7.8, respectively.

salt, sulfur, sodium thiosulfate, or ferrous sulfide. Sulfhydryl sulfur added as cysteine did not produce the color. The reaction was completely inhibited by the addition of a small quantity of Versene (tetra sodium salt of ethylene diamine tetra acetic acid), a sequestrant for polyvalent metals. Tinkler and Soar *(6)* claimed that the greenish-black coloration which appears on the surface of the yolk of a hard-boiled egg is due to the interaction between iron in the yolk and sulfur from the white. It was observed in this laboratory, however, that yolk, washed free of white and made alkaline, turned green when cooked. It would appear, then, that there is enough sulfur and iron in the yolk to produce the green color, and that the only contribution of the white necessary to develop the color on the surface of the yolk of a boiled egg is the alkaline pH.

SUMMARY

A method for determining the pH of dehydrated stabilized egg is proposed in which the pH measurement is made on the reconstituted sample after it has been cooked. The advantages of this method are that it is more sensitive to changes in acidity and alkalinity than when uncooked eggs are used and that it gives results which are reproducible and independent of the method of reconstitution.

Tests with scrambled eggs and sponge cakes demonstrate the desirability of close control of the addition of sodium bicarbonate to acidified egg powder. When the pH of the powder is too low there are flavor and texture defects and loss of aerating power; when it is too high there are flavor, texture and color defects. Furthermore, the purchase of excessive quantities of sodium bicarbonate at the price of dehydrated egg constitutes a loss to the buyer. A suitable range for the pH of cooked reconstituted samples is 7.0 to 9.0.

Under conditions of heat and high pH, a reaction is induced in either whole egg or egg yolk which results in the formation of a green color. The reaction, which can be inhibited by the addition of a metal-complexing agent, apparently involves iron and sulfur compounds from the egg proteins.

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