Effect of Salt Removal on the Baking Quality and Hedonic Ratings of White, Yellow, Spice, and Devil's Food Cakes

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ABSTRACT

White, yellow, spice, and devil's food cakes with normal levels of salt had slightly but significantly greater heights or larger volumes than salt-free cakes and were slightly more compressible (less firm). However, the hedonic ratings of salt-free cakes were as good or better than those of cakes containing salt, possibly because salt-free cakes were rated as close to just right in saltiness and as sweeter than cakes with salt. Salt-free white layer cakes required reduced water content to be equivalent in baking quality to salt-containing cakes. The surface of salt-free 150% sugar/flour ratio devil's food cakes had several lightly colored sugar spots. The development of spots was controlled by salt, probably by solubilizing sugar and/or inhibiting its crystallization. The spots were thought to be crystals of sugar, because they did not occur on the surfaces of salt-free cakes when a very fine grade of sugar was used, total sugar level was reduced, or part of the added sugar was solubilized in water.

Concern over the role of sodium chloride in the etiology of hypertension and/or high blood pressure has prompted the U.S. Department of Agriculture to initiate research on the effect of salt on the functional and organoleptic properties of meats and dairy and bakery products. As many as 20% of white Americans over the age of 50 and up to 40% of black Americans are estimated to have high blood pressure (1). Excess salt in the diet may contribute to hypertension. In many studies of various ethnic populations, a positive correlation exists between the average salt consumption and the incidence of hypertension (2).

Grain and cereal products contribute up to 29% of the daily sodium (Na) intake of individuals. The total daily intake of sodium is estimated to be 6.9 g, equivalent to 17.3 g of salt (3). The sodium content of wheat flour is very low; therefore, most of the sodium in cereal products is contributed by added salt, leavening acids, and sodium bicarbonate (3). Of interest is the fact that sodium bicarbonate may not be associated with hypertension (4).

Even though persons do not normally ingest sizable amounts of sodium chloride from cakes (unless they consume two or more servings of cake per day), it was worthwhile to investigate the effects of salt removal on the functional and organoleptic properties of different cakes. No information is available on this subject. White, yellow, spice, and devil's food cakes were baked and evaluated for this study. Calculations showed that one serving of double-layer white cake (100 g) contributes approximately 0.24 g of sodium from salt or 7.5% of the recommended daily intake of 3.2 g Na per day. Sodium bicarbonate and acid pyrophosphate from baking powder each contribute approximately 0.1 g Na per 100-g cake serving. Negligible amounts of sodium are contributed by eggs, flour, and nonfat dry milk.

MATERIALS AND METHODS

Materials

Commercial bleached unenriched cake flour of pH 4.58, 12% moisture, 7.9% protein, ($N \times 5.7$), and 0.37% ash was used. Baking ingredients[2] were Domino brand extra fine-grade granulated sugar, Red Star brand special emulsified cake shortening, Hershey's brand baking cocoa, Griffith's brand spices, extra-grade low-heat spray-dried nonfat dry milk, Fleischmann's brand double-acting baking powder, International TX-10 brand evaporated salt, Baker's analyzed potassium bitartrate and sodium bicarbonate 98% pure that meets American Chemical Society specifications, distilled white vinegar, and single-strength vanilla. Commercial frozen pasteurized whole egg and egg white were thawed, placed in 12-oz metal cans, sealed, refrozen, and before use thawed and brought to 20–22° C.

Methods

Baking. The bake formula and baking conditions are shown in Table I, and calculated salt and sugar levels accounting for the weight loss of batter on baking are given in Table II.

Table I. Formulation of Control Cakes and Baking Conditions

Ingredient[a]	White[b]	Yellow	Spice[c]	Devil's Food[d]
Sugar (%)	140	115	120	150
Egg				
Whole (%)	...	57	60	75
White (%)	65	...	...	...
Shortening (%)	45	50	55	58
Nonfat dry milk (%)	11	14	20	14
Baking powder (%)	5	6	5	2
Salt (%)	2.5	2.5	3.1	4
Vanilla (%)	0.3	0.3	...	0.2
Water (%)	99	81	98	107
Baking temperature (°C)	185	188	185	190
Baking time (min)	26	26	26	29
Scaling weight (g)	430	370	400	400

[a] Ingredient expressed as percentage of flour weight.
[b] 0.6% cream of tartar.
[c] 7.5% vinegar, 5% spice blend (50% ground cinnamon, 25% nutmeg, 12.5% allspice, and 6.25% each of cloves and ginger), 1.25% $NaHCO_3$.
[d] 20% baking cocoa, 2% $NaHCO_3$.

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[2] Reference to brand or firm names does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

White cakes were prepared by using a Hobart C-10 mixer with a flat paddle in a 3-qt bowl. A proprietary emulsion method in which 23% of the sugar and all of the milk solids were placed in solution was used. The other cakes were mixed with a flat paddle in a 4-qt bowl using a Hobart N-50 mixer.

Devil's food cakes were made by creaming sugar, shortening, and cocoa, mixing that with eggs, adding the milk and flour in alternate portions, and then mixing at medium speed for 3 min.

Yellow layer cakes were made by using a two-stage process in which all of the dry ingredients were mixed with half of the eggs and water and the rest of the eggs and water were mixed at medium speed (5). Spice cakes were made by mixing vinegar-soured milk solution with 60% water with the dry ingredients, followed by adding whole eggs and the rest of the water in three portions and mixing at low speed (6).

With all of the cakes, batters were scraped at set intervals of mixing. The sides of 20.3-cm aluminum pans were greased and floured, and the bottoms were lined. Two to three cakes per batter were baked in a Dispatch electric reel-type oven on open mesh shelves. After being removed from the oven, the cakes were cooled in the pan for 15 min, turned out on a wire rack, and further cooled for 3–4 hr before being cut and evaluated.

Cake and Batter Evaluation

Specific Gravity. The specific gravity, expressed as g/cc, was determined by weighing freshly mixed batter at 22–23°C in a tared 54-g plastic cup.

Height and Volume Index. As an index of volume, the height of the cut surface of a cake half at its center plus 6 cm on each side from the center plus the height of the ends of the cake were measured in millimeters by using a special cake measuring template (7). Cake shrinkage is equal to a 203-mm pan width minus the width of the cake as measured with the template. Higher numbers indicate greater shrinkage, which reflects lower volume.

Symmetry Index. Using the template, cake symmetry was two times the center height of the cake minus the sum of heights, 6 cm from each side of the center. Higher numbers indicate desirable contour and negative numbers indicate dipping.

Cell Size. Cell size was determined visually by the author, 10 being compact; 9.5, small or fine; 9, medium; 8.5, slightly large; and 8, large.

Crust and Crumb Color. Crust and crumb color were evaluated by comparing the colors and appearances of the salt-free cakes to those of the salt control cakes. A rating of 10 indicated that they were the same; 9.5, very slightly lighter or darker; 9.0, slightly lighter or darker; and 8.5, lighter or darker. Because salt-free devil's food cakes had several light spots on the surface, they were graded down to 7.5 or 8.

Firmness. Compression was determined on cakes with the Baker Compressimeter using the second setting of the fulcrum and was expressed as the

Table III. Effect of Salt on Cake Baking Properties[a,b]

Type of Cake	Salt[c]	Batter Specific Gravity (g/cc)	Cake Height (mm)	Cake Shrinkage (mm)	Symmetry Index	Compression (g to Depress Slice/1 mm)	pH
White layer	0	0.88	155.7 a	9.2	8.3	24 b	7.44
	2.5	0.88	162.5 b	7.7	7	21 a	7.54
Yellow layer	0	0.76	158.5 a	12.5 b	1.7	20.8	7.71
	2.5	0.76	170 b	9 a	3	20	7.77
Spice	0	0.89	155.5 a	11	2	25.3 b	8.71
	3.1	0.90	163 b	10.8	−0.3	21.8 a	8.56
Devil's food	0	0.97	163 a	12.5	7.7	24.2 b	8.75
	4	0.97	174.5 b	11	5.7	20.7 a	8.66

Level of Significance

Type of Cake	Batter Specific Gravity (g/cc)[d]	Cake Height (mm)	Cake Shrinkage (mm)[d]	Symmetry Index[d]	Compression (g to Depress Slice/1 mm)[d]	pH[d]
White layer	NS	<0.05	NS	NS	<0.05	NS
Yellow layer	NS	<0.01	<0.05	NS	NS	NS
Spice	NS	<0.01	NS	NS	<0.01	NS
Devil's food	NS	<0.05	NS	NS	<0.05	NS

[a] Average two batters of three cakes each per sample. (Refer to Table I for absorptions.)
[b] Different letters given for each cake type in columns were significantly different.
[c] Percentage of flour weight.
[d] NS = significance >0.05.

Table II. Calculated Sugar and Salt Levels in Control Formula Cakes

Cake Type	Sugar (%)	Salt (%)
White	33.7	0.61
Yellow	30	0.65
Spice	29.3	0.76
Devil's food	32.2	0.86

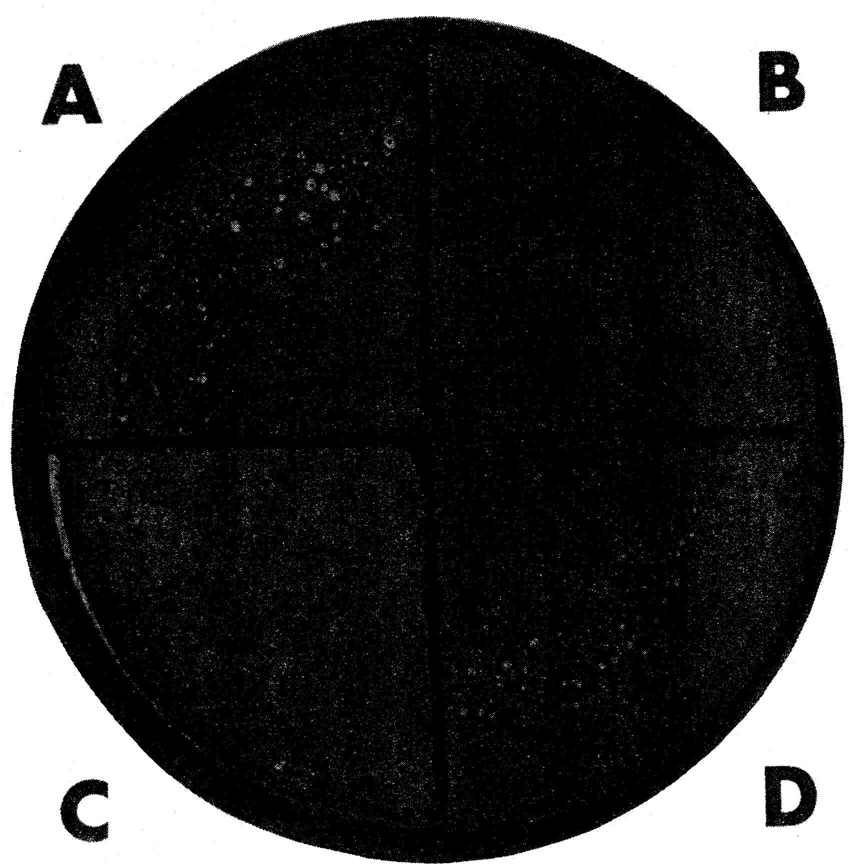

Fig. 1. Effect of sugar and salt on devil's food cake crust appearance. A, 0% salt, 150% sugar; B, 4% salt, 150% sugar; C, 0% salt, 120% sugar; D, 2% salt, 150% sugar.

grams load to depress a slice of cake 1 mm. Softer cakes have lower numbers. Three- to 4-hr old, crustless, 2.5-cm thick slices of cake, 6.25-cm square, were cut, using a mitre box to ensure uniform thickness.

Analytical Determination. Flour moisture, ash, and protein ($N \times 5.7$) determinations were made by using AACC Methods 44-15A (8), 08-01 (9), and 46-12 (10), respectively, and pHs of cake crumb were determined by AACC Method 02-52 (11).

Organoleptic Evaluation. Cake slices with crust (12 cuts per cake) were evaluated for both taste and texture on the nine-point hedonic scale (12) by 30 to 36 judges. Numerical values were equivalent to: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like or dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely. The evaluations were done in closed booths in a lighted room. Rinse water was provided. Although the judges, employees of the Eastern Regional Research Center, were not experienced in evaluating cakes, they had previous experience in taste panel evaluation of a variety of food products. Twenty-four judges matched cakes by the triangle test. Half of the panelists evaluated the salt-containing cake as the odd sample and half evaluated the salt-free cakes as the odd sample. Because the crusts of the salt-free devil's food cakes were spotty, crusts of these cakes were removed for evaluation when using triangle tests and in subsequent tests in which matching judgments were made. Saltiness and sweetness were evaluated by 23–25 unselected panelists on a seven-point scale with 1 = very lacking salt or sugar, 2 = moderately lacking, 3 = slightly lacking, 4 = just right, 5 = slightly salty or sweet, 6 = moderately, and 7 = excessively salty or sweet. A ratio scaling method in which salt-free cakes and cakes with twice the control level of salt were tasted by 11–15 salt-sensitive panelists was used to establish anchor points A and B near the ends of an unmarked 13-cm line. Panelists then determined the degree of saltiness of an unknown salt-free and salt control cake by marking points between or near points A and B which corresponded to the degree of saltiness of the cakes. The marked points were measured from A using a direct proportionality of line length to salt content. Calculated salt levels of unknowns were then computed. Control salted yellow layer cakes of 115% sugar and spice cakes of 120% sugar were also compared to yellow and spice cakes containing 145% sugar by 14 and 10 panelists, respectively, discriminating for sweetness to establish anchor points A and B on an unmarked scale. Cakes with control sugar levels with and without salt were then evaluated for sweetness by ratio scaling in the same manner as cakes were evaluated for saltiness. Because of the high level of sugar in white and devil's food cakes, additional sugar was not put in cakes to merit the use of the ratio scaling method.

Table IV. Effect of Salt and Water Absorption on the Baking Quality of White Layer Cakes[a]

Percentage of Water Absorption (Flour Weight) Basis	Specific Gravity (g/cc)	Cake Height (mm)	Cake Shrinkage (mm)	Symmetry Index	Cell Size Score
No salt					
109	0.87	150	7.2	4.5	9.5
99	0.84	159	8.5	8.5	9.8
89	0.845	166	6.2	7.5	9.4
79	0.86	163	8	6	8.5
2.5% Salt					
109	0.87	156	9	7.2	9.4
99	0.85	162	7.5	9.5	9.5
89	0.83	156	6	−3.8	8.8
79	0.84	156	5.3	−5.2	8.8

Level of Significance

	Specific Gravity (g/cc)	Cake Height (mm)[b]	Cake Shrinkage (mm)[b]	Symmetry Index	Cell Size Score[b]
Percentage of absorption (A)	<0.01	<0.01	<0.01	<0.01	<0.01
Percentage of salt (S)	<0.05	NS	NS	<0.01	NS
A × S <0.05	<0.05	<0.01	<0.01	<0.01	NS

[a] Average of four cakes each variable.
[b] NS = significance >0.05.

Table V. Effect of Salt and Water Absorption on the Baking Quality of Devil's Food Cake

Percentage of Water Absorption	Specific Gravity (g/cc)	Cake Height (mm)	Cake Shrinkage (mm)	Symmetry Index	Cell Size Score
No salt					
118	0.97	150	13	2	9.25
107	0.95	164	13	7	8.5
100	0.97	177	12.5	6.5	8.25
4% Salt					
118	0.97	158	11.5	1.5	9
107	0.94	172	11	5	9
100	0.95	185	9	10	8.25

Level of Significance

	Specific Gravity (g/cc)	Cake Height (mm)[a]	Cake Shrinkage (mm)[a]	Symmetry Index[a]	Cell Size Score[a]
Percentage of absorption (A)	NS	<0.01	<0.05	<0.01	<0.01
Percentage of salt (S)	NS	<0.01	<0.01	NS	NS
A × S	NS	NS	NS	NS	NS

[a] NS = significance >0.05.

Statistics

Data from panels and other results were subjected to analysis of variance and Duncan's multiple range test to determine significance.

RESULTS

Baking Quality

Removal of salt had no significant effect on the specific gravity of white, yellow layer, spice, and devil's food cake batters (Table III), nor on the symmetry index and cake shrinkage, with the exception of increasing the shrinkage of yellow layer cakes. Removal of salt significantly decreased all cake heights or volumes by 4.18–6.76% and generally yielded a firmer cake (by 12.5–16%), as measured by compression testing. Salt had no uniform effect on cake pH (Table III). Although not shown, salt had no significant effect on crumb color, grain, cake weight, or crust color.

Lack of salt caused spottiness to occur during cake cooling on the crust surface of devil's food cake. Salt-free cakes averaged 107 spots of different size; 2% salt cakes, 33 spots; and 4% salt cakes, no spots. No spottiness occurred on a salt-free cake whose sugar level was reduced from 150 to 120% (Fig. 1, C). Because spottiness was absent on salt-free cakes in which 30% of the sugar (flour weight basis) was put into solution and processed by the emulsion method or in which 150% very fine sugar was used, the spots were considered to be sugar crystals. Raising the sugar level to 145% by using control extra fine sugar in spice and yellow layer salt-free cakes also elicited sugar crystallization on the top surface. However, the crystals were smaller and more uniform in size than on the devil's food cake.

Variation in water level significantly affected all of the parameters of white layer cakes, and, as shown in Table IV, the significant trends of all except the cell size score depended on the presence of salt (significant A × S interaction). Cake shrinkage, symmetry index, and cell size score significantly increased with liquid level. Liquid level also significantly influenced cake height. The greatest effect of salt was observed with respect to the symmetry index. Decreasing the liquid level of cakes with salt but not the liquid level of salt-free cakes caused center dips, indicating insufficient water in these cakes (Figs. 2 and 3). Lower liquid levels (79 and 89% absorption) caused dips in 2.5% salt cakes (Fig. 2), but not in salt-free cakes (Fig.3). Both cakes at 79% absorption had a more open cell structure. The salt-free cake at 89% absorption had as good or superior baking quality as the cake with 2.5% salt and optimum liquid level.

Varying the liquid level by 18% in devil's food cakes with and without salt did not bring about the significant interaction changes in specific gravity of batters, cake height, cake shrinkage, or symmetry index observed in white layer cakes (Table V). Thus, changes in water level of both salted and unsalted cakes brought about uniform changes in these indices. Increasing water levels decreased cake heights and symmetry index and increased shrinkage and cell size score in both types of cake. Changes in water levels of yellow layer cakes (data not shown) did not bring about interaction changes, nor did changing the mixing time of the batters from 1.5 to 4.5 min. Optimum mixing for both salted and unsalted batters was 3 min.

Table VI. Effect of Salt Level on Differentiation of Cakes by 24 Panelists Using the Triangle Test

Type of Cake	Correct Choices	Level of Probability[a]
White	18	0.001
Yellow	15	0.01
Spice	17	0.001
Devil's food	18	0.001

[a] None versus control salt level in each cake.

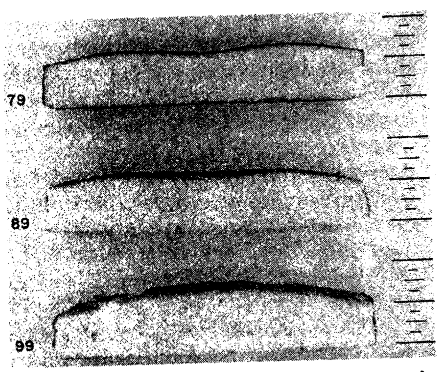

Fig. 2. Effect of water level percentage and salt on the profile of white layer cakes with 2.5% salt.

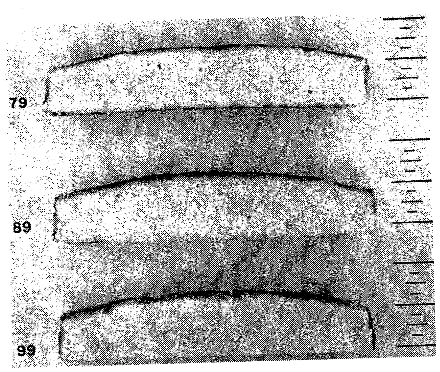

Fig. 3. Effect of water level percentage on the profile of salt-free white layer cakes.

Table VII. Effect of Salt on the Flavor and Texture Qualities of Cakes

		Hedonic Score[b]					
Type of Cake	Salt[a]	Flavor	Texture	Saltiness[c]	Sweetness[c]	Salt[d]	Sugar[d]
140% Sugar	0	6.83	7.17	3.77 a	5.7 b	0.41 a	...
White layer	2.5	6.74	7.45	5.06 b	4.98 a	2.84 b	...
115% Sugar	0	7.08 b	6.68	4 a	5.71 b	0.25 a	130 b
Yellow layer	2.5	6.39 a	6.82	5.2 b	4.58 a	2.33 b	118 a
120% Sugar	0	7.03	7.06	3.46 a	5	0.31 a	133 b
Spice	3.12	6.45	6.84	5.5 b	4.67	3.55 b	122 a
150% Sugar	0	6.65	6.65	3.43 a	4.96 b	0.26 a	...
Devil's food	4	6.58	6.52	5.26 b	4.08 a	4.2 b	...

Level of Significance

Type of Cake	Flavor[e]	Texture[e]	Saltiness[c]	Sweetness[c,e]	Percentage of Salt	Percentage of Sugar
White layer	NS	NS	<0.01	<0.05	<0.01	...
Yellow layer	<0.01	NS	<0.01	<0.01	<0.01	<0.01
Spice	NS	NS	<0.01	NS	<0.01	<0.01
Devil's food	NS	NS	<0.01	<0.01	<0.01	...

[a] Percentage of flour weight.
[b] Different letters given for each cake type in columns were significantly different.
[c] Sweetness or saltiness: 6 = moderately, 5 = slightly, 4 = just right, and 3 = slightly lacking.
[d] Percentage calculated by ratio scaling.
[e] NS = significance >0.05.

Hedonic Acceptability

Panelists could significantly differentiate each type of salt-free cake from control salted cakes when using the triangle test (Table VI). Those panelists who were able to differentiate the cakes rated the flavor of the unsalted cakes as as good as that of the control salted cakes. The unsalted yellow layer cake was given a significantly higher score (Table VII). Hedonic texture scores of cakes were not significantly different (Table VII). No differences in moistness and tenderness were noted.

The saltiness of unsalted white and yellow layer cakes was rated as close to just right, whereas spice and devil's food cakes were rated as halfway between just right and slightly lacking in saltiness (Table VII). The salted cakes were rated as slightly salty or between slightly and moderately salty in taste. Percentage of salt calculations of unsalted cakes, using ratio scaling in an independent study, showed that discriminating panelists rated the unknown salt-free cakes as having 0.25–0.41% salt, and salted cakes had calculated values within 5–15% of the actual level of salt added.

Three of the four unsalted cakes were rated as significantly sweeter than the salted cakes (Table VII). The salted cakes were rated as just right to slightly sweet, whereas the unsalted cakes were rated as slightly sweet to moderately sweet. Percentage of sugar calculations of salted cakes, using ratio scaling, showed that panelists were reasonably discriminating, in that they rated the unknown sugar cake within 2–3% of the actual level of sugar added.

DISCUSSION AND CONCLUSIONS

Different types of cakes and mixing procedures were evaluated in this study to be all-inclusive on the effects of salt in cakes.

Reducing the liquid level by 10–20% (from 99% to 79%) caused center dips in white layer cakes containing salt but not in salt-free cakes, indicating insufficient water content. Thus, salt promoted water binding in these cakes. Dough systems containing 6% nonfat dry milk solids and 2% salt increase farinograph water absorption, compared to salt-free milk solids-containing doughs (13). In this study, salt reduced water absorption in flour-only doughs. Because cakes contain relatively high levels of milk solids with respect to flour, the addition of salt may bind water.

However, water variation in other cakes with and without salt did not show the significant interaction effects on cake height and contour seen with white layer cakes. Formula and ingredients may modify the salt interaction effect in cakes. Egg white was used in white layer cakes and whole eggs were used in devil's food and yellow layer cakes, which could possibly account for the different behavior of salt and absorption.

Salt also prevented sugar crystallization in the top crust in devil's food cakes that contained more sugar. Salt either promoted solubilizing of sugar or inhibited its subsequent crystallization. Impurities inhibit sugar crystallization and sodium chloride slightly increases the solubility of sugar at 70° C (14).

Panelists rated unsalted cakes as close to just right in saltiness and sweeter than cakes with salt. The additional sweetness of the unsalted cakes and their favorable saltiness rating are thought to be factors contributing to hedonic ratings comparable to those of salted cakes. Even if salt is omitted from cakes, this lack is not considered a serious detriment to their hedonic acceptability, even though lack of salt contributes to some impairment of baking quality.

Acknowledgment

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