Effect of KCl Levels on Functional and Baking Properties of Sponge Doughs and Hedonic Ratings of Their Breads[1]

ABSTRACT

Two percent mixtures of 1:1 NaCl and KCl in hard red winter wheat flour sponge bread doughs mixed 3½, 4½, or 5½ min, each at 59.5, 61, and 62.5% water absorption, and their resultant breads were compared to doughs and breads with 2% NaCl. Type of salt used did not significantly affect dough clean up times or the initial or final handling of doughs. However, absorption and mixing time interactions occurred with the final handling of the doughs. Proof times of doughs with 2% mixture of salts were significantly decreased. Specific loaf volumes and bread scores were not affected by mixing times, absorptions, or salt type. Use of the 2% salt mixture in breads relative to 2% NaCl did not significantly affect flavor ratings; however, approximately one-third of the panelists rated breads with the 2% salt mixture significantly more bitter. Panel scores of both types of bread slices were comparable when spread with margarine or used in the home.

Concern over the role of sodium chloride in the etiology of hypertension and/or high blood pressure has prompted the USDA to initiate research on the effect of salt on the functional and organoleptic properties of meats, dairy, and bakery products. As many as 20% of white Americans older than 50 years and up to 40% of black Americans 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 average salt consumption and incidence of hypertension (2).

The balance between potassium and sodium in the body is very important for proper physiological function. Some studies have supported a theory that increased intake of potassium chloride can reduce the blood pressure of hypertensive patients, even when excess sodium chloride is present (3). Potassium chloride has been reported to help protect against sodium-induced hypertension in animals and to reduce the blood pressure of diabetic children consuming excess salt in their diets (3).

Grain and cereal products contribute up to 29% of the total daily sodium intake of individuals; the total daily intake is estimated to be 6.9 g, equivalent to 17.3 g of salt (4). The sodium content of wheat flours is very low; therefore, most of this is contributed by added salt, leavening acids, and sodium bicarbonate. Three slices of bread contribute 1 g salt, which is equivalent to 12% of the recommended intake of 3.2 g sodium per day (4).

No measurable differences have been found between the normal 2% NaCl level and as high as 4% NaCl, KCl, or a 50:50 KCl/NaCl mixture on the amylograph and extensigraph properties of flour doughs (5). Farinograph dough stabilities were increased more by NaCl than KCl or the salt mixture, but dough mixing times and absorptions were the same. Using the standard AACC gassing method (6), Cooper and co-workers (5) showed that as the salt level increased to 4% NaCl had more inhibitory effect on yeast activity than did either the salt mixture or KCl. However, they showed that at the 1.5% salt level, none of the three salts significantly inhibited yeast action, compared to the control without salt. Increasing the salt mixture slightly decreases the dough mixing times and proof times. Volumes and crumb firmness were not affected.

An informal test using 20 panelists found that flavor scores of one- and four-day-old white breads with 2% salt were higher than those with 2% NaCl and KCl salt mixture (5); however, three-day-old breads scored the same. Tests using 40 experienced panelists showed that 2% NaCl and 2% salt mixture whole wheat breads were not significantly differentiated by the triangle test. Descriptive flavor analyses were also made with five expert panelists to evaluate breads containing 1.5% NaCl and 1.5% salt mixture and to compare breads with 2.2% NaCl and 2.2% salt mixture. Close similarity in many character and aroma notes between the bread pairs were found, but KCl-containing breads gave foreign or atypical mouth sensations.

Farinograph and extensigraph indices of wheat flour doughs with 2% NaCl or a replacement with up to 40% substitution of equivalent amounts of KCl were not significantly different (7). KCl had no significant effect on dough mixing times, dough pH, and bread volume. Up to 20% of NaCl may be replaced with equivalent amounts of KCl, or 30% may be replaced with a combination of 24% KCl and 6% $MgCl_2$ without significantly affecting the ability of panelists to differentiate by the triangle test (8).

Because of these results and because

[1]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.

[2]Eastern Regional Research Center, USDA Agricultural Research Service, Philadelphia, PA.

many persons daily consume large quantities of bread, I further investigated the effects of replacing NaCl with KCl on the baking and functional properties of doughs and organoleptic properties of white breads. I also investigated a factorial study comparing the effects of variable mixing times and absorptions on dough handling and bread baking when substituting half the NaCl with KCl, and determined the effect of up to 50% replacement of NaCl with KCL on their hedonic ratings and bitterness scores of the resulting breads. Studies comparing the effects of 2% NaCl, 1% NaCl, or 1% KCl on doughs and breads were also made, and the effects of physically shocking proofed doughs containing different salts on their bread volume were evaluated.

MATERIALS AND METHODS

Materials

Enriched, malted, and bleached commercial hard red winter wheat flour with 11.6% protein and 0.47% ash was used throughout the study. Vacuum-packed Saf brand instant dry yeast; ADM all-purpose vegetable shortening; Valley high-heat nonfat dry milk (NFDM) solids consisting of 1.7 mg soluble, undenatured whey protein nitrogen/g; extra fine granulated sugar; Sterling evaporated baker's-grade salt; Morton's food-grade potassium chloride and Lite Salt mixture (50% KCl/50% NaCl); and Patco Emplex brand sodium stearoyl-2-lactylate (SSL) were used. Yeast food was made by blending 40% potato starch, 25% NaCl, 25% $CaSO_4$, 9.7% NH_4Cl, and 0.3% $KBrO_3$. Except for $KBrO_3$, which was ground with a mortar and pestle, all ingredients for yeast food were sifted through a 20-mesh screen before blending. Granny Smith apples were used to cleanse the palate for evaluation of bitterness. Fleischman's margarine was used as a spread.

Methods

Baking. The bread dough formula (Table I) contained 2% salt. Instant yeast was dry blended with the preferment ingredients immediately before water was added and the dough was mixed in an A-200 Hobart mixer. Sponges were held for 3.5 hr at 30°C and 85% relative humidity. Doughs were made from the sponge and other ingredients and mixed long enough to give optimum handling as judged by the baker at speed two of the mixer. They were then given 15 or 25 min floor time at 30°C. After being divided into 520-g pieces, the doughs were rounded, and 12 min later, sheeted and molded in a model 100 Moline molder using constant settings for the sheeting rollers and pressure board. The doughs were proofed at 42°C to 1.6 cm above the top of the pan and baked for 25 min at 213°C. After cooling for 1 hr at room temperature, the bread was weighed and volumes were determined by rapeseed displacement.

Table I. Bread Dough Formula[a]

Ingredient	Sponge	Dough
Flour	65.00	35.0
Instant yeast	0.70	···
Yeast food	0.50	···
Sugar	···	7.5
Shortening	···	3.0
Nonfat dry milk	···	2.0
NaCl	···	0–2
KCl	···	0–2
Sodium stearoyl-2-lactylate	···	0.5

[a] Percent flour basis.

Scoring of Doughs. I used the following four-point scale to evaluate initial sheeting of doughs out of the mixer: 1 = excellent stretch, 2 = slight tearing, 3 = moderate tearing, and 4 = excessive tearing or short and undeveloped. For dough handling, 1 = very good handling, not sticky or stiff; 2 = good handling, slightly sticky or stiff; 3 = fair handling, fairly sticky or stiff; and 4 = poor handling, excessively sticky or stiff.

Scoring of Bread. Breads were held overnight in a closed cabinet at ambient temperature and scored the next day. I judged crust color and grain by comparing these breads to mounted standards to which I had assigned numbers. A light brown crust color rated 10 points and a fine even grain rated eight. A uniform break with even, vertical shredding along the top sides of the loaf was assigned four points; a symmetrical loaf shape, slightly rounded in the center, was assigned three. A loaf with uniform crust, sides, and bottom color also rated three points. Scores of 10 were given for soft, velvety, silky textures and for creamy white crumb colors. A loaf with lesser attributes was graded less by half points in the judgment of the scorer. The maximum score was 48 points.

Farinograph. Farinograph characteristics were determined in duplicate according to the 300-g constant flour weight AACC method 54-21 (9). When used, salt or NFDM solids were blended with the flour before water was added.

Analytical. Flour moisture, ash, and protein ($N \times 5.7$) were determined by using AACC methods 44-15A (10), 08-01 (11), and 46-12 (12), respectively. Undenatured whey protein nitrogen of NFDM solids was determined by AACC method 46-21 (13), and bread pHs were determined by AACC method 02-52 (14). Crumb compression was determined on slices from duplicate loaves by AACC method 74-10 (15) using a Baker Compressimeter. For this determination, the bread was cooled for 1 hr at room temperature, sealed in 1.5-ml polyethylene bags, and stored at room temperature. Six slices, 1.2 cm thick, were cut from the center of the loaves with an Oliver bread slicer immediately before testing. Shock tests were made by dropping fully proofed doughs three consecutive times from 6.5-cm height immediately before baking. Gas production of doughs (expressed as mm Hg) was measured by scaling 17.5 g of dough freshly mixed for baking into a pressuremeter cup, sealing, and holding at 30°C for 97 min after first mixing (equivalent to the time that allows for dough processing plus a 60-min proof).

Organoleptic Analyses. A panel of 14 to 18 judges scored 1.2-cm thick bread slices (crusts removed) on a nine-point hedonic scale for taste and texture (16). The evaluations were made in closed booths in a lighted room. The judges, employees of the USDA Eastern Regional Research Center, were not experienced in evaluating breads but had previous experience in taste panel evaluation of a variety of food products. Triangle tests were made, in which the panelists had to match two similar samples with a single different sample. Bitterness tests were made using an unmarked linear scale. The panelists were given 2% salt bread to taste and told it had no bitterness. This was marked as zero near the left end of the horizontal line. They were then given a 2% KCl bread to taste and told it had full bitterness. It was marked 13 cm from the zero point representing 2% salt bread. Two unknown KCl-containing breads and one unidentified 2% salt control bread were given to panelists, and they were asked to judge the degree of bitterness on this scale of no bitterness to full bitterness. Tart apple slices and rinse water were supplied to cleanse the palate of bitterness and astringency of the KCl-containing breads.

Statistics. Data from panels, baking quality of doughs, and compression studies were subjected to analysis of variance and Duncan's multiple range test to determine significance. A factorial design in randomized duplicated blocks of six trials with variables of three mixing times, three absorptions, and two salt levels was used in one study.

RESULTS

Rheology. Adding 1 or 2% salt or a 2% blend of 1:1 NaCl/KCl to flour lowered the farinograph absorption by 1.7% (Table II). Arrival times were the same. Peak mixing time and the stability to mixing increased as the salt level increased. All indices for 2% NaCl and for the 2% mixture of NaCl/KCl were the same. The results differed from those of Cooper and co-workers (5), who showed that a 2% salt mixture slightly lowered stability times, possibly reflecting differences in flour. The results reported are the averages of duplicate runs.

In contrast to flour alone, adding 1% or 2% NaCl or a 2% blend of 1.1 NaCl/KCl to flour with 2% NFDM raised dough absorptions by nearly equivalent amounts (Table II). Arrival times, mixing times, and stability times were increased by adding salts. The salt mixture had a slightly lower stability value, but all other indices for 2% salt and 2% salt mixture were not significantly different.

Baking Quality. The baking of the hard red winter wheat flour used in the sponge loaf was optimized by preliminary testing. The optimized formula included 2% NaCl, 15 ppm $KBrO_3$ with no malt supplementation. Floor time variations with 2% NaCl and 2% 1:1 NaCl/KCl showed that 10–18-min floor time gave the loaf the best dough handling and baking quality characteristics (Table III). A floor time of 15 min was subsequently used in the factorial study.

Varying the water absorption from 59.5 to 62.5% and mixing time from 3½ to 5½ min showed that the type of salt had

Table II. Effect of Salts on Farinograph Indices

NaCl (%)	KCl (%)	Absorption[a] (%)	Arrival Times (Min)	Peak Times	Stability Times
Flour					
0	0	58.7	1.5	7.5	15.5
1	0	57.0	1.5	11.0	24.0
2	0	57.0	1.5	15.25	30.5
1	1	57.0	1.5	15.0	30.5
Flour + 2% Nonfat Dry Milk					
0	0	59.0	1.5	8.0	16.0
1	0	59.9	3.0	11.25	19.0
2	0	60.3	5.0	14.5	23.0
1	1	60.2	5.25	14.5	20.5

[a] 14% moisture basis.

Table III. Effect of Floor Time Variation on the Baking Quality of Sponge Doughs[a] with Either 2% Salt or 2% Salt Mixture

NaCl (%)	KCl (%)	Floor Time (Min)	Final Handling[b,c]	Proof Time (Min)[b]	Grain Score[b]	Specific Volume[b] (cc/g)	Bread Score[b]
2	0	25	1.5 ab	56.5 b	6.4 a	5.54 a	41.62 a
1	1	25	1.5 ab	53.0 b	6.4 a	5.58 a	41.25 a
2	0	18	1.25 a	55.5 b	7.0 b	5.65 ab	43.38 b
1	1	18	1.25 a	53.5 a	7.0 b	5.7 ab	43.25 b
2	0	10	2.0 b	62.8 c	7.1 b	5.85 b	44.25 b
1	1	10	2.0 b	55.0 b	7.0 b	5.85 b	43.88 b
Level of significance			<0.05	<0.01	<0.01	<0.05	<0.01

[a] 61% absorption, 4½ minutes mix time, average four loaves.
[b] Different letters the same column = significantly different.
[c] Final handling: 1, very good; 2, good.

Table IV. General Linear Model for Doughs and Breads[a]

Effects	Clean Up (Sec)	Initial Handling	Final Handling	Proof Time (Min)
	Probability $>F$			
Salt (S)[b]	>0.05	>0.05	>0.05	<0.01
Absorption (A)[c]	<0.01	<0.01	0.03	>0.05
Mixing time (MT)[d]	>0.05	<0.01	>0.05	>0.05
MT × S	>0.05	>0.05	0.01	>0.05
A × S	>0.05	>0.05	0.03	>0.05

[a] Sheeting of doughs, specific loaf volume and bread scores >0.05. All MT × A, >0.05.
[b] Salt = 2% NaCl, 2% mixture of 1:1 NaCl and KCl.
[c] Percent absorption = 59.5, 61, and 61.5.
[d] Minutes mixing time = 3½, 4½, and 5½.

Table V. Effect of Equimolar Amounts of NaCl and KCl on Baking Properties of Flour Doughs

Equimolar Amt. of Salts	Salt (%)	KCl (%)	Initial Sheeting[a,b]	Dough Handling[a,b]	Pressure (mm Hg)[a]	Proof Time (Min)[a]	Specific Loaf Volume (cc/g)
E_1	2.0	0	1.0	1.5 a	133.0 a	55.5 b	5.88
	1.0	1.0	1.5	1.5 a	147.0 c	52.5 a	5.96
E_1	1.0	1.28	2.0	3.0 b	139.0 b	52.5 a	5.86
E_2	2.0	0	1.0 a	1.0 a	132.0 a	54.5 b	5.66
	0	2.0	3.0 b	2.5 b	158.5 b	50.0 a	5.86
E_2	0	2.56	2.5 b	3.0 b	147.5 b	50.0 a	5.71

[a] Different letters in the same column = significantly different at $P<0.05$. Average of two doughs (four loaves). 61% absorption, 4½ min mix time.
[b] For dough sheeting or handling, 1 = very good, 2 = good, 3 = fair, and 4 = poor.

Table VI. Effect of Shocking[a] Doughs Containing 2% Salt Mixture Versus 2% NaCl[b]

Salt	Average Specific Loaf Volume (cc/g)[c] Control	Shocked
NaCl	5.61 a	5.48 b
Salt mixture	5.76 a	5.66 a

[a] Drop three times from 6.5-cm height.
[b] Average three loaves each trial. 61% absorption, 4½ min mix time.
[c] Different letters = significantly different at P = <0.05 for rows (not significantly different for columns).

Table VII. Effect of KCl on Triangle Tests of Bread Slices

Bread	Panelists or Samples (No.)	Correct Choices (No.)	Significance
1.5% salt versus 1% salt + 0.5% KCl			
One-day-old bread	16	5	...[a]
Three-day-old bread	16	4	...[a]
2% salt versus 1% salt + 1% KCl			
One-day-old bread	15	6	...[a]
Three-day-old bread	16	6	...[a]

[a] Not significantly different.

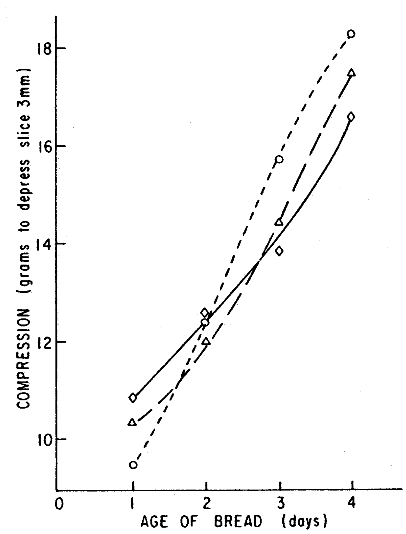

Fig. 1. The effect of variable NaCl/KCl in sponge breads on compressions of bread slices. o = 2% NaCl, Δ = 1% NaCl + 1% KCl, and ◊ = 1.5% NaCl + 0.5% KCl.

no significant main effect on seconds of mixing time to clean up doughs and on their initial or final handling (Table IV). However, as expected, absorption had a highly significant effect (Table IV) on each of these factors. As absorption or mixing time increased, a stickier, softer dough out of the mixer resulted; this effect was especially significant at 62.5% absorption. As mixing time increased, salt mixture doughs became stickier (MTXS interaction), but 2% NaCl dough final handling was unchanged. As absorption increased, final handling of 2% salt mixture doughs remained the same, but 2% NaCl doughs became softer and stickier (AXS interaction). Proof times of salt mixture breads were significantly reduced to 56 min from 60.2 min for the 2% NaCl breads. Mixing times and absorptions had no significant effects on proof times for either salt. No factor studied had any significant effect on specific bread volume or bread score.

Substituting one-half of the NaCl with an equal amount of KCl or replacing the 2% NaCl with 2% KCl significantly increased gas production and decreased proof times of doughs (Table V). Equimolar amounts of KCl relative to NaCl significantly changed these indices, indicating the more effective osmotic suppression effects of NaCl. Complete substitution of KCl for NaCl also produced a poorer handling dough out of the mixer which tore when sheeted and was sticky during handling. This was not apparent with doughs containing 1:1 KCl:NaCl. Specific loaf volumes were not significantly different. Fully proofed doughs that were shocked by dropping three times from a 6.5-cm height before baking caused a significant loss of specific volume of 2% NaCl levels but not those with 2% salt mixture (Table VI).

Replacing NaCl with up to 1% KCl did not have a significant effect on the overall staling (firming) rate of stored breads as measured by the Baker Compressimeter (Fig. 1). However, bread with 2% salt was the least firm at one day and firmest at four days.

Hedonic Rating. Using triangle tests, panelists could not significantly differentiate 1.5 and 2% NaCl bread slices with crusts removed from slices containing 1% NaCl and 0.5% KCl, respectively, or 1% NaCl and 1% KCl (Table VII). Twenty-five to 35% of the panelists appeared to be sensitive to differences between tastes of breads with NaCl or NaCl/KCl blends, but the rest could not differentiate between them. Most of the panelists could not significantly detect bitterness of the salt blends (Table VIII). Discriminating panelists who rated 2% salt breads (especially one-day-old breads identified by code only) as lacking in bitterness, rated breads containing different levels of salt blends significantly more bitter.

Replacing up to one-half of the 2% NaCl with KCl in lieu of using the 2% salt mixture or dilutions of the same did not change average hedonic flavor ratings to any statistically significant degree (Table IX). However, the hedonic flavor scores of one-day-old breads were significantly higher than those of three-day-old breads. Replacing the NaCl with up to the 1:1 blend of salts in one- or three-day-old breads did not significantly change texture ratings (Table IX). Three-day-old breads had significantly lower average texture scores than did one-day-old breads.

The flavor ratings of 1% salt, 2% salt, or 2% salt mixture breads (Table X) were not significantly different from one another, but they all rated significantly higher than that of bread with only 1% KCl.

Table VIII. Effect of KCl on Bitterness Scores of Breads

		One-Day-Old Bread			Three-Day-Old Bread		
NaCl[a] (%)	KCl[b] (%)	15 Total Panelists[c,d] (cm)	Nine Panelists (A) (cm)	Six Select Panelists (B)[d] (cm)	14 Total Panelists[c] (cm)	Nine Panelists (A) (cm)	Five Select Panelists (B)[d] (cm)
2.0	0	4.12 a	6.81	0.1 a	3.71	4.63	2.04 a
1.5	0.5	5.92 ab	7.68	3.33 b	4.09	4.38	3.60 a
1.0	1.0	6.78 b	6.58	7.12 c	4.84	3.60	7.08 b

[a]2% NaCl standard = 0 cm.
[b]2% KCl standard = 13-cm length.
[c]Total panelists were divided into two parts: nondiscriminating (A) and discriminating (B).
[d]Different letters in the same column = significantly different; one-day-old, $P<0.05$ (15 panelists); $P<0.01$ (B); three-day-old, $P<0.05$.

Table IX. Effects of Variable NaCl/KCl in Sponge Breads

Hedonic Flavor of Bread Slices			
2% NaCl	1.5% NaCl, 0.5% KCl	1.25% NaCl, 0.75% KCl	1% NaCl, 1% KCl
	For One-Day-Old Bread		
6.49	6.43	...	...
6.40	...	6.30	...
6.34	...	...	5.93
	For Three-Day-Old Bread		
5.80	5.66	...	...
5.57	...	5.46	...
5.90	...	...	5.62

Hedonic Texture of Bread Slices			
2% NaCl	1.5% NaCl, 0.5% KCl	1.25% NaCl, 0.75% KCl	1% NaCl, 1% KCl
	For One-Day-Old Bread		
6.54	6.66	...	...
6.69	...	6.75	...
6.48	...	...	6.52
	For Three-Day-Old Bread		
6.06	5.92	...	...
6.10	...	6.22	...
6.20	...	...	6.11

Table X. Comparison of KCl and NaCl on Hedonic Flavor and Texture Ratings of Breads Plain and With Margarine[a]

Plain Bread, No Margarine Spread					
		Flavor[b]		Texture	
NaCl (%)	KCl (%)	One Day	Three Days	One Day	Three Days
2	0	6.20 a,a	5.50 a,a	6.67	5.92
1	0	6.63 a,a	5.72 a,a	6.68	6.08
1	1	6.05 a,ab	5.35 a,ab	6.77	6.14
0	1	5.07 b,b	4.58 b,b	6.70	6.00

Spread with Margarine[c]					
		Flavor		Texture	
NaCl (%)	KCl (%)	One Day	Three Days	One Day	Three Days
2	0	6.86	6.33	7.06	6.64
1	1	6.59	6.59	7.07	6.83

[a]Average of duplicate panels.
[b]Different letters in each column = significantly different at $P=<0.05$ and <0.01, respectively.
[c]Not significant in columns.

The panelists rated the flavor and texture scores of bread slices containing the 1:1 mixture of NaCl and KCl and spread with salted margarine as highly as those of slices containing 2% NaCl (Table X). To study further hedonic acceptability of breads, 24 personnel informally rated 2% NaCl bread in their homes, and 24 different personnel also rated 2% salt mixture breads. The flavor of breads with 2% salt mixture scored 7.88 on the nine-point hedonic scale; breads with 2% NaCl scored 7.83. Thus, in a typical meal setting, 2% salt mixture breads are as acceptable as the 2% salt control breads.

CONCLUSION

This study shows that up to one-half of 2% NaCl may be replaced with KCl in sponge breads with only small changes in baking quality over a range of dough absorptions and mix times and no significant changes in hedonic scores.

Many of the observations reported earlier (5,7) were substantiated in this study—namely, that NaCl has a more inhibitory effect on yeast activity than do NaCl/KCl blends and that bread volumes and crumb firmness are not changed by the blend. Also, the flavor scores of white breads, with no spread used, were not significantly affected by the NaCl/KCl mixture. I have shown that the farinograph stabilities of flour doughs with either salt were the same, but including 2% NFDM with the 2% salt mixture produced a slightly shorter dough stability to mixing than with 2% NaCl. The final handling of salt mixture doughs was slightly impaired by extended mixing.

Flavor scores of bread crumb slices containing 2% salt mixture and spread with salted margarine were similar to the scores of slices containing 2% NaCl. Flavor scores of one- and three-day-old breads spread with margarine are also much the same, possibly due to masking of the less fresh flavors of three-day-old bread by margarine. Flavor scores of both breads consumed in the home averaged much the same. Thus, in a typical home setting in which spreads are used, respondents can probably not detect differences between breads.

The bulk of the sodium in bread is contributed by added NaCl, because only minor amounts of sodium are contributed by yeast food, sodium stearoyl-2-lactylate, NFDM solids, and flour. Two percent NaCl contributes an estimated 88% of the sodium content of sponge breads using the formula in Table I. Reducing the NaCl by one-half yields bread with a calculated 56% of the sodium of 2% NaCl bread. Daily consumption of three slices of bread with the NaCl/KCl blend could reduce consumption of NaCl by 0.5 g or 6% of the recommended daily intake of 3.2 g sodium per day.

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