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A Salt Reduction of 50% in Bread Does Not Decrease Bread Consumption or Increase Sodium Intake by the Choice of Sandwich Fillings[1–3]

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Abstract

Bread is a major contributor to sodium intake in many countries. Reducing the salt (NaCl) content in bread might be an effective way to reduce overall sodium intake. The objectives of this study were to examine the effects of gradually lowering the salt content in brown bread, with and without flavor compensation (KCl and yeast extract), on bread consumption and sodium intake compensation by choice of sandwich fillings. A total of 116 participants (age: 21 ± 3 y; BMI: 22 ± 2 kg/m^2) consumed a buffet-style breakfast on weekdays for 4 wk. Participants received either regular bread (control group: n = 39), bread whose salt content was gradually lowered each week by 0, 31, 52, and 67% (reduced group: n = 38), or bread whose salt content was also gradually lowered each week but which was also flavor compensated (compensated group: n = 39). A reduction of up to 52% of salt in bread did not lead to lower consumption of bread compared to the control (P = 0.57), whereas less bread was consumed when salt was reduced by 67% (P = 0.006). When bread was flavor compensated, however, a reduction of 67% did not lead to lower consumption (P = 0.69). Salt reduction in bread (with and without flavor compensation) did not induce sodium intake compensation (P = 0.31). In conclusion, a salt reduction of up to 52% in bread or even up to 67% in flavor-compensated bread neither affected bread consumption nor choice of sandwich fillings. J. Nutr. 141: 2249–2255, 2011.

Introduction

Sodium intake around the world largely exceeds physiological need (1,2). High levels of dietary sodium intake are directly related to raised blood pressure (3), a main risk factor for cardiovascular disease (4,5). Cardiovascular disease is a leading cause of mortality globally (6). Increasing evidence suggests that a high sodium intake is also related to renal disease and it has been implicated as a major cause of stomach cancer (2).

Sodium intake in industrialized countries is determined by processed foods for 75–80% (1,7,8). Therefore, reducing the sodium content in processed foods might be an effective strategy to reduce the sodium intake of a population (1,9). Bread is a major contributor to dietary sodium intake in many countries due to its relative high sodium content and its important role in the daily menu (1,10).

NaCl is more commonly known as salt and so this term is used in this paper. Salt is added to a wide range of foods to increase palatability and improve preservation and processing (9). It is appreciated for its saltiness but also enhances the overall flavor and suppresses bitterness (11,12). Reduced salt content in bread is indeed associated with a less pleasant taste (13–15). However, reductions of 10–20% (16) and a gradual salt reduction of 25% in bread (17) have been shown not to affect perceived pleasantness. Moreover, one study showed that salt reductions of up to 31% did not lower consumption of a restaurant lunch (18). It is not known to what extent salt reductions in bread will remain acceptable by means of perceived pleasantness or consumption. Because sudden large reductions of salt can make foods unacceptable to consumers (19), a gradual reduction of the salt content in small steps might be a better approach (9,17). By reducing the salt content in steps, people may gradually adjust to the changed taste (20,21), whereby the change may even remain unnoticed (16,17).

Bread is typically consumed with spreads and fillings. Choosing more salty spreads and fillings may compensate for

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the flavor loss of salt-reduced bread. For example, salted butter has been shown to increase the perceived overall saltiness and pleasantness of salt-reduced breads (14,18). To our knowledge, it has not previously been studied whether people will choose more salty-tasting fillings when consuming salt-reduced bread.

A way to prevent flavor loss of salt-reduced breads is to substitute part of the sodium with potassium or add other additives to enhance saltiness, such as proteins or yeast extracts (9,22,23). It has been shown that replacing part of the sodium with potassium maintains the acceptability as measured by the sensory properties of salt-reduced bread (24,25). When salt-reduced bread is compensated in flavor, therefore, fewer changes in bread consumption are expected compared to salt-reduced bread without flavor compensation.

The objectives of this study were to examine the effects of gradually reducing the salt content in bread on bread consumption and sodium intake compensation. This was executed by reducing the salt content in brown bread for 4 wk by 31, 52, and 67%, with and without flavor compensation (KCl and yeast extract). Sodium intake compensation was measured by the choice of sandwich fillings used with the bread during breakfast. It is common to consume bread for breakfast in The Netherlands and brown bread is the most consumed type of bread (26).

Methods

Experimental design. The study followed a parallel study design with 3 treatments (**Table 1**). The participants were unaware of the treatment groups and were randomly divided into 3 groups. The groups were balanced for gender, usual bread consumption, and the habitual consumption of savory or sweet fillings. During the first week (run-in), all participants received regular bread. After the first week, participants in the control group were offered regular salted bread, and the participants in the reduced group were offered bread that was gradually reduced in salt content each week. Participants in the compensated group were offered bread that was gradually reduced in salt content each week but that was flavor compensated. Groups were indicated by color coding. On the last 2 d of the study, the breads were evaluated for sensory aspects.

Before the start of the study, participants tasted all the available fillings on brown bread. During the study, participants came to the study location (Restaurant of the Future at the Wageningen University campus) on weekdays between 0730 and 1000 h to have breakfast on an empty stomach. Participants were allowed to skip attending the breakfast twice during the study. During breakfast, participants were free to choose foods from the color-coded shelves. The only difference between the foods on the shelves was the bread (except for the first week). No table salt was provided at the buffet or on the tables.

In this paper, the term sodium is used in relation to intake and the term salt is used in relation to food products.

Participants. The study population consisted of 120 students and employees of Wageningen University in The Netherlands. Four participants dropped out during the study, 1 in the control group, 2 in the reduced group, and 1 in the compensated group. The data analyses are therefore based on 116 participants. The participants were recruited via flyers and posters in the university buildings. Applicants completed an online questionnaire and were eligible for participation if they were aged between 18 and 35 y, had a BMI between 18.5 and 25 kg/m^2, and consumed breakfast with bread and savory fillings (e.g. cold meat products, cheese) at least 4 times/wk. Vegetarians were excluded from participation.

The control group consisted of 39 participants (54% female; age: 21 ± 3 y; BMI: 21 ± 2 kg/m^2). The reduced group consisted of 38 participants (51% female; age: 21 ± 4 y; BMI: 22 ± 2 kg/m^2). The compensated group consisted of 39 participants (57% female; age: 21 ± 3 y; BMI: 22 ± 2 kg/m^2).

All participants were informed about the procedures of the study and signed an informed consent form. The study proposal was presented to the Medical Ethical Committee of Wageningen University, which decided that no formal approval was required. Participants received a reimbursement after completion of the study.

The participants were informed that the aim of the study was to examine breakfast habits. At the end of the study, the participants were asked about the aim of the study. Twelve multiple choice options were given on a questionnaire including the answers "salt reduction in bread," "no idea," and an option to add an aim that was not listed.

Foods. The different types of brown bread (**Supplemental Table 1**) were produced by a local bakery. The highest salt concentration was that of regular bread, 1.80% [1.8 g NaCl/100 g of flour (21.7 mmol or 498 mg Na/100 g bread)], followed by 3 logarithmic reductions in salt, resulting in 1.25, 0.87, and 0.60% salt [i.e. reductions of 31, 52, and 67%, respectively, corresponding to 15.1 mmol or 346 mg Na, 10.5 mmol or 241 mg Na and 7.3 mmol or 167 mg Na/100 g bread]. The flavor-compensated breads were prepared by adding Maxarite Delite and KCl. Maxarite Delite (DSM) consists of nonsodium material extracted from yeast. It contains 20% 5′GMP + 5′IMP nucleotides (DSM, product data sheet) and was added in equal amounts (0.3% on flour, recommended by the manufacturer) to all salt-reduced breads. The compensated bread with 1.25% salt (NaCl) contained 0.55% KCl, resulting in 1.80% total salt, the compensated bread with 0.87% salt (NaCl) contained 0.87% KCl, resulting in 1.74% total salt, and the compensated bread with 0.60% salt (NaCl) contained 0.60% KCl, resulting in 1.20% total salt. These concentrations were chosen as larger ratios of KCl:NaCl in prepared breads resulted in an excessive off-flavor. The types of bread (regular, salt-reduced, with or without flavor compensation) did not differ in appearance.

Cornflakes and Dutch rusks (i.e. a hard, dry, twice-baked bread), both with regular salt content, were offered as bread replacers (Supplemental Table 1).

Nine types of savory fillings (cold meat products and cheese) with varying sodium contents were available (Supplemental Table 1). In addition, 2 types of sweet fillings with low sodium contents were offered: jam and chocolate sprinkles. Other foods available during breakfast were: apples, bananas, oranges, kiwis, pears, coffee, tea, orange juice (Chiquita), milk (semi-skimmed, Groene Koe), and margarine (Becel, Unilever).

The salt contents of the different breads were calculated from the bread recipes. The salt contents of the other foods were obtained from the manufacturer or from the Dutch Food Composition Database (NEVO, version 2009) (Supplemental Table 1).

TABLE 1 Experimental design of the 4-wk study

Week	Control group (n = 39)	Reduced group (n = 38)	Compensated group (n = 39)
wk 1 (run-in)	Regular[1]	Regular	Regular
wk 2	Regular	−31% Salt[2]	−31% Salt flavor-compensated[2,3]
wk 3	Regular	−52% Salt[2]	−52% Salt flavor-compensated[2,3]
wk 4	Regular	−67% Salt[2]	−67% Salt flavor-compensated[2,3]
wk 4 (two last days)	Sensory evaluation	Sensory evaluation	Sensory evaluation

[1] Regular means bread with regular salt content (containing 1.8% salt/100 g of flour).
[2] Percent of salt reduction as compared to the regular bread.
[3] The flavor was compensated by KCl and yeast extract.

Food consumption and sodium intake. All foods chosen were registered per participant at the checkout. To be able to distinguish between fillings consumed with bread or Dutch rusks, participants were asked to place fillings for bread next to the bread and fillings for Dutch rusks next to the Dutch rusks on their trays. Each participant's tray was then photographed. In addition, the tray was photographed after breakfast to correct for leftovers. Food was left on 24% of the trays. The amount of leftovers was quantified per food item per participant and the consumed amount was accordingly adjusted. To assess the quality of the leftover quantification, we assessed the between-observer variability and 61% of the estimates were the same for both observers. When estimates differed, it was by 9 ± 5% (mean ± SD) over all food items. All foods, with the exception of bread, coffee, tea, and fruit, were already packed in portion packages, so the exact quantity was known. Products without packaging, e.g. slices of bread, were weighed and the average of one slice of bread was used for further calculations. Sodium intakes from breakfast food items were calculated by multiplying the consumed amount by the sodium content of the food per food item per participant. Fat and sugar intakes were not examined.

Sensory evaluations. At the end of the study, the different types of bread were evaluated for sensory aspects. After breakfast, 37 participants of each group tasted the 7 types of bread (regular, 3 reduced in salt, and 3 reduced in salt but flavor compensated), once without filling and once with ham. Ham was chosen because it contains a moderate amount of salt compared to other savory fillings. The samples (discs 4 cm in diameter) were presented in random order with at least a 2-min interval between samples. Participants were instructed to rinse their mouths with water between samples. Foods were rated on pleasantness, saltiness, off-flavor, and tenderness on a 100-mm visual analogue scale with labeled ends. Left anchors (0 mm) and right anchors (100 mm) were, respectively, "not pleasant at all" and "very pleasant," "not salty at all" and "very salty," and "not tender at all" and "very tender." The question about off-flavor was first separated as a choice of "yes, this bread has an off-flavor" or "no, this bread has no off-flavor." Second, if the answer was yes, participants rated how strong the off-flavor was on a 5-points scale ["very weak off-flavor" (1) till "very strong off-flavor" (5)].

Statistical analyses. Statistical analyses were performed using SAS version 9.1.4 (SAS Institute). Data in the tables are presented as means ± SD and $P < 0.05$ was considered significant. Fisher's least significant differences tests were used for all post hoc comparisons.

Consumption (g) and intake variables [sodium in mmol (and mg) and energy in kJ] during breakfast were calculated as weekly means per participant. Effects of salt reduction in bread on consumption and intake were assessed by first calculating the changes in consumption (wk 2, 3, 4 minus wk 1) per participant. Then the changes were compared between the different groups by a linear model (proc GLM), which included gender. Least-squares means were generalized computed for between-group comparisons as well as confidence limits for differences between group means. Effects of salt-reduction in bread on consumption within groups, were, in addition, assessed by a linear model that included gender. Differences between groups in their awareness of the aim of the study (assessed in the questionnaire) were evaluated by a chi-square test.

In the sensory evaluation tests, the ratings of bread with and without ham of the control group were evaluated separately, because this group was not exposed to the salt-reduced breads. The effect of ham on (salt-reduced) bread on pleasantness and saltiness ratings of the control group was assessed with a linear model that included the effect of ham (with or without), the salt contents of the breads and their interactions. In addition, to investigate whether participants in the reduced and compensated groups had adjusted to the salt-reduced bread and whether they perceived salt-reduced breads (without ham) differently, the differences in pleasantness and saltiness between the reduced, compensated, and control groups were evaluated with a linear model that included the group, the salt contents of bread, and their interactions.

Results

Consumption of bread and bread replacers. Bread consumption in the reduced group did not change from wk 1 to wk 3 (up to 52% salt-reduced bread) but decreased in wk 4 (67% salt-reduced bread) (**Table 2**). Bread consumption in the compensated group did not change from wk 1 to wk 4, but it tended to increase in the control group (P = 0.08). Consequently, bread consumption in the reduced group decreased from wk 1 to wk 4 compared to both the control [15 g (95% CI = 4, 25); P = 0.006] and compensated [13 g (95% CI = 2, 23 g); P = 0.012] groups. This difference in bread consumption between groups was not observed from wk 1 to wk 3 (P = 0.57). The compensated group did not differ in bread consumption from wk 1 to wk 4 compared to the control group (P = 0.69).

Consumption of Dutch rusks increased over time in the reduced group (P = 0.002) and the compensated group (P = 0.007) compared with wk 1 but did not change in the control group (P = 0.53) (Table 2). The changes in rusk consumption over time in both groups did not differ from that in the control group (P = 0.30). Consumption of cornflakes did not change over time in any of the groups ($P > 0.09$) and did not differ between groups (P = 0.32).

Consumption of fillings and sodium intake from fillings. Consumption of savory fillings did not change over time within groups ($P > 0.14$) and did not differ between groups (P = 0.18) (Table 2). The total consumption of all savory fillings was calculated, because consumption of separate fillings did not change over time within groups or differ between groups, except for pâté. Consumption of pâté did not change in the reduced and compensated groups but increased in the control group compared to both other groups (P = 0.008).

In the reduced group, sweet fillings (chocolate sprinkles and jam) decreased in consumption from wk 1 to wk 4 (P = 0.015); however, this decrease in the reduced group did not differ from the other 2 groups (P = 0.17) (Table 2). The decrease in sweet filling intake in the reduced group was due to a decrease in the amount of chocolate sprinkles (P = 0.006), whereas there was no change in consumption of jam (P = 0.60). The reduction in the amount of chocolate sprinkles in the reduced group differed from the consumption during the 4 wk in the other groups (P = 0.008). Changes over the 4 wk in the consumption of jam did not differ between groups (P = 0.30).

Sodium intake compensation from fillings was calculated as the change in sodium from fillings per 100 g bread consumed (Table 2). Sodium from fillings per 100 g bread tended to increase in the reduced group (P = 0.07). However, this change did not differ from the change in either the control or compensated group (P = 0.31). The sodium intake from all other foods except bread was also calculated (Table 2). The sodium intake from other foods changed over time in the reduced group (P = 0.020) but not in the compensated and control groups ($P > 0.62$). However, the changes from wk 1 to wk 4 did not differ between groups (P = 0.32).

Sodium and energy intake from breakfast. Total sodium intake during breakfast increased over the 4 wk in the control group due to an increase in total consumption (P = 0.017) and decreased in both the reduced and compensated groups ($P < 0.001$) (Table 2). In the reduced group, the total sodium intake was 13% lower in wk 2 ($P < 0.001$), 21% lower in wk 3 ($P < 0.001$), and 25% lower in wk 4 ($P < 0.001$) compared to wk 1. Consequently, the sodium intake in the reduced group was less than in the control group during wk 3 [10.0 mmol (95% CI = 6.4, 13.7);

TABLE 2 Consumption and intake during breakfast for each group during 4 wk[1]

Group	wk (% salt reduction)[2]	Bread and bread replacers: Bread	Rusk	Cornflakes	Fillings: Sweet	Savory	Sodium: Fillings[4]	Other[5]	Total	Energy
			g/d		*g/d*		*mmol/100 g*		*mmol/d*	*kJ/d*
Control	1 (0)	76 ± 31	2 ± 4	4 ± 8	7 ± 8	34 ± 19	13.2 ± 7.1	3.6 ± 1.2	34.9 ± 12.1[a]	2260 ± 600[a]
	2 (0)	78 ± 33	3 ± 4	4 ± 8	8 ± 9	36 ± 21	13.1 ± 7.1	3.6 ± 1.2	37.1 ± 13.1[ab]	2450 ± 776[b]
	3 (0)	80 ± 37	3 ± 5	4 ± 8	8 ± 8	38 ± 24	12.5 ± 7.5	3.6 ± 1.3	37.1 ± 15.9[ab]	2440 ± 831[b]
	4 (0)	83 ± 39	3 ± 5	4 ± 9	7 ± 8	39 ± 25	13.5 ± 7.3	3.7 ± 1.3	39.0 ± 17.4[b]	2500 ± 926[b]
Change (wk 3−wk 1)		4 ± 17	1 ± 4	0 ± 4	0 ± 6	3 ± 15	−0.7 ± 5.4	0.0 ± 1.1	2.2 ± 8.9	181 ± 477
Change (wk 4−wk 1)		7 ± 21	1 ± 4	0 ± 4	1 ± 6	5 ± 19	0.4 ± 5.2	0.1 ± 0.9	4.0 ± 10.9	242 ± 599
Reduced	1 (0)	80 ± 49[a]	2 ± 3[a]	3 ± 8	9 ± 11[a]	35 ± 20	14.0 ± 8.1	3.6 ± 1.1[ab]	36.3 ± 16.1[a]	2370 ± 878
	2 (31)	81 ± 52[a]	2 ± 4[ab]	4 ± 9	9 ± 12[a]	34 ± 23	12.4 ± 6.8	3.4 ± 1.2[a]	31.6 ± 13.5[b]	2480 ± 924
	3 (52)	80 ± 50[a]	3 ± 4[bc]	4 ± 10	8 ± 11[ab]	35 ± 22	13.1 ± 6.1	3.5 ± 1.3[a]	28.7 ± 12.6[c]	2480 ± 940
	4 (67)	72 ± 43[b]	4 ± 5[c]	5 ± 11	6 ± 10[b]	36 ± 24	15.0 ± 7.2	3.8 ± 1.5[b]	27.1 ± 27.1[c]	2450 ± 896
Change (wk 3−wk 1)		0 ± 20	1 ± 3	1 ± 5	1 ± 5	0 ± 13	−0.9 ± 7.0	−0.1 ± 0.8	−7.7 ± 6.8*†	109 ± 318
Change (wk 4−wk 1)		−8 ± 27*†	2 ± 4	2 ± 7	−2 ± 6	1 ± 13	0.6 ± 7.5	0.2 ± 1.0	−9.2 ± 9.3*†	71 ± 477
Compensated	1 (0)	70 ± 22	2 ± 3[a]	3 ± 7	8 ± 9	30 ± 16	14.5 ± 7.5	3.7 ± 1.2	33.1 ± 10.1[a]	2090 ± 563[a]
	2 (31)[3]	74 ± 25	3 ± 4[ab]	4 ± 8	8 ± 10	30 ± 17	13.2 ± 6.7	3.6 ± 1.4	31.5 ± 11.0[a]	2270 ± 679[b]
	3 (52)[3]	74 ± 28	3 ± 4[b]	4 ± 8	7 ± 10	30 ± 21	13.1 ± 7.4	3.6 ± 1.5	27.3 ± 11.6[b]	2310 ± 699[b]
	4 (67)[3]	75 ± 28	3 ± 5[b]	4 ± 8	8 ± 10	28 ± 17	13.0 ± 7.7	3.5 ± 1.5	25.1 ± 11.0[c]	2360 ± 801[b]
Change (wk 3−wk 1)		4 ± 19	1 ± 3	1 ± 3	0 ± 5	1 ± 15	−1.3 ± 5.8	−0.0 ± 1.0	−5.8 ± 8.1*	214 ± 402
Change (wk 4−wk 1)		5 ± 20	1 ± 3	1 ± 3	0 ± 5	−2 ± 12	−1.5 ± 6.6	−0.1 ± 1.0	−8.0 ± 6.7*	264 ± 352

[1] Values are mean ± SD, n = 38 or 39. Means for a group in a column with superscripts without a common letter differ, $P < 0.05$. *Different from control, $P < 0.05$. †Different from compensated, $P < 0.05$.
[2] Percent reduction relative to the regular bread (containing 1.8% salt/100 g of flour).
[3] The flavor was compensated by KCl and yeast extract.
[4] Sodium from fillings per 100 g of bread.
[5] Sodium from other foods consumed except for bread (per 100 g of consumed food, except bread).

231 mg (95% CI = 148, 314); $P < 0.001$] and wk 4 [13.2 mmol (95% CI = 9.0, 17.3); 302 mg (95% CI = 207, 397 mg); $P < 0.001$]. In the compensated group, the total sodium intake was 5% lower in wk 2 ($P = 0.16$), 17% lower in wk 3 ($P < 0.001$), and 24% lower wk 4 ($P < 0.001$) compared to wk 1. Consequently, the sodium intake in the compensated group was less than in the control group during wk 3 [8.0 mmol (95% CI = 4.4, 11.7); 185 mg (95% CI = 102, 268); $P < 0.001$] and wk 4 [11.9 mmol (95% CI = 7.7, 16.0); 273 mg (95% CI = 178, 367); $P < 0.001$].

Energy intake during breakfast increased during the 4 wk in both the control group ($P = 0.004$) and the compensated group ($P < 0.001$) but not in the reduced group ($P = 0.20$). However, the change in energy intake did not differ between groups ($P = 0.20$).

Sensory evaluation of the salt-reduced breads. The saltiness of the 31% salt-reduced bread as rated by the control group at the end of the study was lower compared to regular bread; however, the perceived pleasantness did not differ (**Table 3**). A reduction of 52 and 67% led to a further decrease in saltiness and pleasantness, both, in bread with and without flavor compensation. Overall, both saltiness ($P < 0.001$) and pleasantness ($P = 0.015$) were rated lower for bread without flavor compensation compared to bread with flavor compensation. Off-flavor was not significantly affected by salt content or flavor compensation. Tenderness was rated lower in the 52% salt-reduced breads without flavor compensation and in both 67% salt-reduced breads with and without flavor compensation.

Perceived saltiness of bread with sandwich filling. Participants rated higher saltiness for 52 and 67% salt-reduced breads with ham compared to plain breads (**Fig. 1***A*). Also pleasantness tended to be rated higher when bread was tasted with ham (difference in slopes: $P = 0.06$) (Fig. 1*B*).

Sensory evaluation of salt-reduced breads at the end of the study. The reduced group rated saltiness higher than the

TABLE 3 Sensory characteristics of all bread types tasted without filling as assessed by the control group[1]

Characteristic	Regular 0%	Salt reduced: −31%	−52%	−67%	Salt reduced, flavor compensated: −31%	−52%	−67%
Pleasantness[2]	58 ± 24[a]	54 ± 19[a]	40 ± 18[bc]	33 ± 16[c]	61 ± 18[a]	43 ± 20[b]	42 ± 24[b]
Saltiness[2]	52 ± 23 [a]	40 ± 19[b]	30 ± 17[cd]	22 ± 15[d]	48 ± 20[ab]	42 ± 24[b]	32 ± 20[c]
Off-flavor[3]	1.1 ± 1.5	1.0 ± 1.4	1.2 ± 1.6	1.1 ± 1.3	1.1 ± 1.3	1.5 ± 1.8	1.7 ± 17
Tenderness[2]	55 ± 22[ab]	61 ± 19[a]	50 ± 22[b]	51 ± 21[b]	62 ± 18[a]	59 ± 21[ab]	53 ± 21[b]

[1] Values are means ± SD, n = 39. Means in a row with superscripts without a common letter differ, $P < 0.05$.
[2] Ratings on 100-mm visual analogue scale.
[3] Off-flavor was rated on a 5-point scale (1 very weak off-flavor, 5: very strong off-flavor).

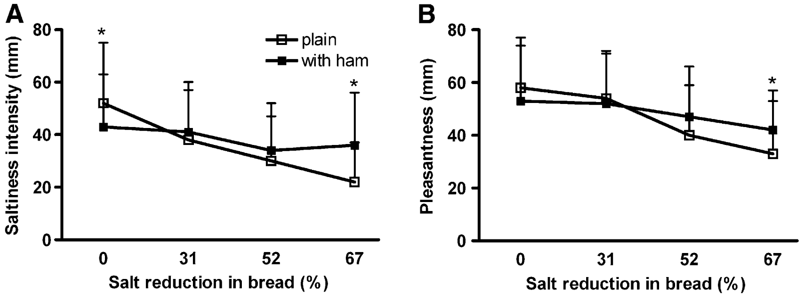

FIGURE 1 Saltiness intensity (*A*) and pleasantness (*B*) of breads, with and without ham, rated by the control group. The breads tested were regular and salt-reduced (without flavor compensation). Values are mean ratings + SD, *n* = 39. *Plain bread and bread with ham differ, $P < 0.05$.

compensated group (P = 0.003), whereas the ratings of these groups were in between (**Fig. 2***A*). This also applied to the ratings of pleasantness, the reduced group rated pleasantness higher than the compensated group (P = 0.005), whereas the ratings of the reduced and compensated group were in between (Fig. 2*B*).

Awareness of the aim of the study. Twelve of the 111 participants (11%) indicated that they thought the study was about salt reduction in bread. One of these 12 participants was in the control group (3% of the control group), 5 in the reduced group (13% of the reduced group), and 6 in the compensated group (15% of the compensated group) (P = 0.14). Their awareness of the aim did not influence the results for bread consumption (exclusion of participants who were aware of the aim still led to a lower consumption of 67% salt-reduced breads, the mean value would then be 71 ± 41 g instead of 72 ± 43 g) (Table 2). The most frequently chosen answer was that the study aimed to examine the choice of cold cuts (29%) and 24% of the participants claimed to have no idea what the aim of the study was.

Discussion

The present study shows that reducing salt in bread by up to 52% did not lead to lower consumption of bread compared to the control and did not induce compensation of sodium intake from fillings. Further reduction of the salt content of up to 67% resulted in lower bread consumption. However, when salt-reduced bread was compensated for flavor, a reduction of 67% neither led to lower bread consumption nor induced sodium intake compensation from fillings. In the group that consumed salt-reduced bread (based on a 52% reduction) the total sodium intake during breakfast was 21% lower, i.e., a difference of ~10 mmol (0.23 g) sodium compared to breakfast with regular salted bread in this group. In the group that consumed flavor-compensated bread (based on a 67% reduction), total sodium intake was 24% lower, i.e., a difference of ~12 mmol (0.27 g) sodium compared to breakfast with regular salted bread in this group.

In the literature, few studies were found that measured the effect of salt reduction in bread on consumer acceptance. In our study, the acceptance of salt-reduced bread was measured both in terms of consumption of bread during the study as well as by sensory evaluations of salt-reduced breads at the end of the study. Tuorila-Ollikainen et al. (18) investigated the effect of salt reduction on bread consumption over 12 wk at a lunch restaurant. Regular salted wheat bread was available at the start and end of the experiment (3-wk periods both) and 31% salt-reduced bread was offered in the 6 wk between. This study showed unchanged bread consumption when the salt-reduced bread was offered, which is in line with our results. The present study shows that an even larger reduction of ~52%, established stepwise within 2 wk, did not affect bread consumption.

Two studies (16,17) reported on the sensory characteristics of salt-reduced bread. Rodgers et al. (16) showed that a salt reduction of 10–20% in whole meal bread did not lead to lower pleasantness and participants could not taste any differences in salt content. Another study found that reducing the salt content in white bread in small steps of 5% each week over 6 wk, thus a 25% reduction in total, did not affect ratings of pleasantness and flavor strength during the study (17). In the present study, participants of the reduced group, who consumed 67% salt-reduced bread at the end of the study, rated the saltiness and pleasantness of the salt-reduced breads higher compared to the control and compensated groups. This may suggest that participants in the reduced group had adjusted to the salt-reduced breads. In accordance, Zandstra et al. (13) also showed, within a short period of 5 d, an increase in both ratings of desire to eat the bread and consumption of the unsalted bread. The adjustment observed in the present study may partly explain why salt could be reduced to a large extent in the bread whereas its consumption did not decrease. Some studies suggested that the preferred level of salt in foods depends on the level of salt consumed and that this preferred level possibly can be lowered by decreasing customary salt intake (20,21,27–29). It is not exactly clear when the preference will shift to lower levels of salt; it has been suggested that this might take a number of weeks (20,30,31). In addition, the participants in the compensated group, who were exposed to the salt-reduced bread that was flavor compensated (KCl and yeast extract), showed the lowest pleasantness ratings for the regular and salt-reduced breads. These participants may

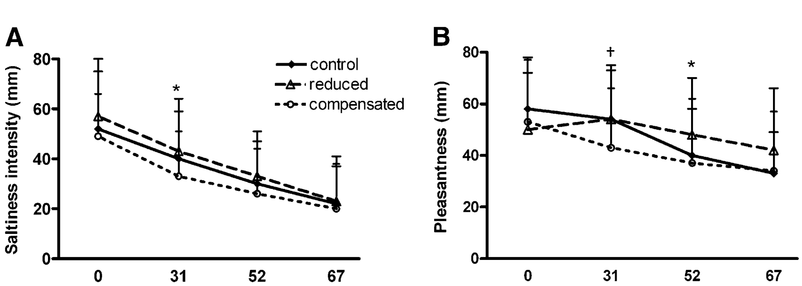

FIGURE 2 Saltiness intensity (*A*) and pleasantness (*B*) of plain regular and salt-reduced bread (without flavor compensation) as rated by all groups at the end of the study. Values are mean ratings + SD, *n* = 38 or 39. *Reduced and compensated group differ, $P < 0.05$. †Control and reduced groups differ from the compensated group, $P < 0.05$.

have adjusted to the KCl/yeast extract salty flavor and therefore rated the regular salt-reduced bread as less pleasant. Further studies are needed to investigate adjustments in taste after long-term consumption of salt-reduced foods.

Breads that were reduced in salt by up to 52% and to 67% when flavor compensated did not trigger sodium intake compensation by changing the choice of fillings by the participants. When the 67% salt-reduced bread (without flavor compensation) was served, the choice of fillings tended to be different, because fewer chocolate sprinkles were consumed. Savory fillings were, however, not used to compensate for the salt reduction in bread. Another study showed that when consuming a soup with a low salt content, no compensation of sodium intake in the second course was found (32). To the best of our knowledge, no other study has examined the effects of a salt-reduced meal on sodium intake compensation by other foods. Compensation with the use of table salt was previously investigated (33,34). When participants consumed a low-salt diet for several weeks, differing by 3.8 g (64.6 mmol) in salt compared with habitual diet, only 0.8 g (13.6 mmol, i.e., 20%) salt was added with salt shakers (33). When participants consumed 2 types of hot meals differing by 4.6 g (78.2 mmol) in salt content, a compensation of ~1 g (17 mmol, i.e., 22%) of table salt was found after the low-salt meal (34). Consumers might respond to reductions of salt levels in processed foods by choosing other salty foods during the day. This can be studied by measuring changes in 24-h urinary sodium excretion as an objective indicator of daily dietary sodium intake (35).

An explanation as to why salt in bread could be reduced to a large extent while remaining acceptable in terms of consumption is that the fillings may have compensated for the flavor loss of the salt-reduced bread. Salt-reduced bread with ham was perceived as more pleasant and salty compared to bread without ham. Other savory fillings had similar effects on the ratings of saltiness and pleasantness (A.M. Janssen and S. Kremer, unpublished data from pilot experiments). Whereas a higher saltiness and pleasantness was perceived after adding savory fillings to salt-reduced breads (as measured in the control group) (Fig. 1), the choice of fillings during the 4 wk of the study did not change in the reduced group, as discussed above. Because savory fillings such as meat products and cheese are also major contributors to sodium intake (36), it is desirable to limit consumption and reduce the salt contents in these products as well. Further research is needed to investigate acceptability when both bread and fillings are reduced in salt content.

A strength of this study is that we compared changes in consumption within participants and compared this with a control group. The Restaurant of the Future, where participants consumed their breakfast, does not have the appearance of an experimental setting, which may facilitate extrapolation of the results to a real-life situation. A limitation of extrapolation to the general population is that the study population consisted of mostly students. The participating students ate breakfast for free during 4 wk, which may have affected their consumption patterns. Another limitation is that we did not know the habitual salt intake of the participants before the study. In addition, the leftovers (food was left on 24% of the trays) after consumption of breakfast were quantified by estimation of photographs; although we think the estimations were quite accurate ("Methods"), weighing the leftovers would have been be more accurate. The present study focused on breakfast only. Lunch and dinner usually contain a larger variety of foods than breakfast and people are in a different state of hunger. These aspects may be of interest in further studies on salt reduction.

In conclusion, a salt reduction of up to 52% in brown bread established stepwise within 2 wk did not lead to lower consumption or sodium intake compensation with sandwich fillings in the present study. Flavor compensation enabled even larger reductions of salt (up to 67%) in bread while maintaining acceptable taste. The salt reductions in bread led to a 10–12 mmol (0.23–0.27 g sodium; equal to 0.6–0.7 g salt) lower sodium intake during breakfast compared to the control in the present study.

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