Effect of salt reduction on palatability of bread: a double-blind, randomized, crossover study

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Abstract

Background

The targets for average maximum salt intake in UK adults are 6 g/day by 2015 and 3 g/day by 2025. Bread is a major contributor to salt intake. We have tested the hypothesis that the amount of salt in bread could be reduced without unacceptably reducing its palatability.

Methods

In a double-blind, randomized, crossover study, 360 healthy adults tasted each of five different types of fresh white bread made with different amounts of salt (sodium chloride), potassium chloride as a salt substitute, or no salt. They scored them for taste preference using a 100-mm visual analogue scale, with margins of minimally important differences (MID) for palatability set at 5 and 10 mm.

Results

The palatability of the bread was directly related to its sodium content. Bread made with the standard amount of salt currently recommended in the UK (1 g per 100 g bread) had the highest mean palatability score, and that with no salt the least. Bread made with a 50% reduction in salt (0.5 g per 100 g bread) had a mean score within the minimally important difference (MID) compared with the standard bread. Potassium did not restore palatability when it substituted for sodium.

Conclusions

Bread made with 50% less salt than currently recommended in the UK was as palatable as bread made with a standard amount of salt. The salt content of bread could be reduced without a change in acceptability. Consumers could be given a choice of breads with different salt contents.

Introduction

Consumption of salt (sodium chloride) is one of the key modifiable lifestyle factors that if reduced could lower cardiovascular risk in the population with particular relation to hypertension and stroke [1,2]. Higher consumption of salt has also been associated with the risks of, heart failure, kidney disease, obesity, asthma, and stomach cancer [3]. The World Health Organization (WHO) has set a target of a 30% reduction in population salt intake by 2025 [4]. In the UK, the Department of Health's target for adults is to reduce average maximum salt intake to 6 g/day by 2015 and to 3 g/day by 2025 [5,6].

Most dietary salt intake, in some cases up to 80%, comes from processed and restaurant foods, particularly in Western countries [7]. Bread is a major source of salt [8], contributing up to 20% of daily intake [9]. The amounts of salt in commercially available supermarket breads fell from 2001 to 2011, but there was wide variation and room for further improvement [10]. However, potential barriers to widespread reduction in the salt content of bread include its function as an ingredient for palatability and in enhancing dough handling properties [11,12].

Previous studies have shown that small reductions in the salt content of bread can be made without affecting its palatability. In one randomized controlled study a 25% reduction in salt content (from 2 to 1.5 g per 100 g bread) did not noticeably affect palatability [13]. However, there have been no studies of the effects on palatability of a range of salt contents at and below the currently recommended content in the UK of 1 g per 100 g.

We have therefore studied the palatability of bread containing a range of salt contents and the effect of substituting a commercially available salt substitute rich in potassium chloride, since dietary potassium is associated with lower rates of stroke and may reduce the risk of coronary heart disease and total cardiovascular disease [14]. We have also studied the effects of age, sex, and smoking status on bread palatability, since the threshold at which salt is tasted increases with age and is different between the sexes and in smokers [15].

Methods

Design

We conducted a double-blind, randomized, crossover, non-inferiority study with five intervention arms. It was registered in the controlled trials register at http://www.controlled-trials.com/ISRCTN11240937

Participants and setting

Researchers, blind to the intervention, recruited subjects from public spaces in Oxford city centre, including shopping centres, university spaces open to the public, and non-academic office reception areas between May 2012 until March 2013. Subjects were eligible to participate if they were over 18 years old and regularly ate white bread. Exclusion criteria were gluten intolerance and coeliac disease. They gave written informed consent.

Interventions

All the bread was prepared and baked in the same commercial bakery (The Cornfield Bakery, Wheatley, Oxfordshire) by a Master Baker, following a standard recipe. Five different batches of white bread were prepared in exactly the same way, except for salt content (Table 2). Five salt contents were used:

- 1 g salt/100 g bread (based on the current UK recommended content);
- 0.5 g salt/100 g bread;
- a commercially available salt substitute (LoSalt™), containing 66.6% (minimum) potassium chloride and 33.3% (maximum) sodium chloride at 1 g/100 g bread;
- 0.5 g LoSalt/100 g bread;
- no salt.

Participants and trial facilitators were all blinded to the type of bread tasted. To maintain blinding, the batches of bread were labelled A to E by the bakery before delivery. Bread was sliced into approximately 2 x 2 cm cubes and was laid out separately with only the letters A to E placed in front of each bread. Research assistants guided each participant through the tasting process to ensure a predetermined randomized order of tasting in each case (see

Randomization and blinding).

Outcome measures

The primary outcome measure was a 100-mm visual analogue scale (VAS) score for palatability, where 0 mm corresponded to “Definitely dislike” and 100 mm to “Definitely like”. A similar scale has previously been used to assess taste preferences for sourdough bread, food palatability, oral medicines, and solutions [16,17,18,19]. After tasting a sample of bread, participants marked how much they liked its taste on the scale. Between tastings, they cleaned their palate with sips of still water to remove any residual taste. The VAS scores were measured using a 30-cm plastic ruler. The value, rounded to the nearest millimetre, was extracted independently by two trial facilitators blinded to the intervention. An average measurement was taken between the readings and used in the final analysis.

Randomisation and blinding

The order of sampling was determined using a Latin square design. Participants were randomly assigned to 1 of 10 pre-specified sequences (A to E) in which to taste the bread (Figure 1) using a randomization list generated by a statistician in the Clinical Trials Unit of the Nuffield Department of Primary Care Health Sciences, University of Oxford, who worked independently of the data collection and analysis.

Two blinded researchers independently logged the data and entered the results into an Excel™ (Microsoft™, USA) spreadsheet for analysis by the statistical team, who were blinded to the allocation.

Sample size calculation

The sample size calculation was based on a pilot study (n = 21). We assumed that the true mean difference in VAS scores between any two breads was 0. There were ten sequence groups in the Latin Square design, involving five intervention groups and five periods. We took the mean VAS scores of Breads B, C, D, and E and compared them for non-inferiority of palatability with that of the standard bread (Bread A; 1 g salt per 100 g). Accounting for a 10% attrition rate, we estimated that 360 participants would allow us to detect non-inferiority, using a margin of 5 mm, with approximately 90% power and two-tailed significance at P = 0.0125 (0.05/4, using Bonferroni correction to allow for four comparisons). To be conservative, we constructed 99% confidence intervals around estimates.

Statistical methods

We used an intention to treat (ITT) population model to include all participants randomized, irrespective of whether they tasted all five types of bread. If VAS data were missing for all types of bread the participant was excluded from the analysis. We assumed that the scores were normally distributed. The analyses were performed using STATA 12 SE (StataCorp LP, Texas USA). There was no interim analysis. Data distributions and all model assumptions were checked for all analyses.

To assess whether the mean VAS scores for Breads B, C, D, and E were non-inferior to the mean VAS score for the comparator (Bread A), we calculated the two-sided 99% confidence interval of the adjusted difference in mean VAS score for each comparison. We assigned non-inferiority if the lower bound of the 99% CI was greater than the non-inferiority margin of 5 mm in the primary analysis. Since this was a conservative estimate, we also aimed to define the smallest change in the outcomes that a participant would identify as important. Therefore, we also carried out an exploratory analysis involving a minimally important difference (MID) (sometimes reported as the minimally clinically significant difference, MCSD) margin of 10 mm. Sensitivity analyses included investigating the robustness of the results by adjusting for age, sex, and smoking status. We carried out secondary subgroup analyses using an interaction term and considering age group (18–40 years, 41–64 years, 65 and over), sex, and smoking status. Finally, we analysed the proportion of participants who reported that the intervention breads tasted as good as or better than the standard bread or were within the 5-mm non-inferiority margin and the exploratory 10-mm MID margin.

Ethics approval

Ethics approval was given by the University of Oxford Medical Sciences Division

Interdisciplinary Research Ethics Committee (reference MSD/IDREC/C1/2012/47). Research was conducted according to the Declaration of Helsinki.

Results

Of 1150 people who were approached and asked to participate, 360 agreed and were randomized. Their demographic characteristics are shown in Table 1. Of these participants, 357 (99.2%) were eligible for inclusion and 352 (98.6%) were included in the primary outcome analysis; five were excluded because of spoilt papers. There were no withdrawals or losses (Figure 2). Of the 357 participants, information on sex was missing for ten (2.8%), smoking status for five (1.4%), and age for six (1.7%). No adverse events were reported to the study facilitators during the data collection.

Bread A had the highest mean VAS score of 58.8 mm (SD 26.4). There was a dose-related reduction in mean VAS scores as sodium content fell. Bread B, which contained scored the lowest mean VAS score of 38.6 mm (SD 25.1) (Table 2 and Figure 3).

The difference between the mean VAS scores for Bread A (1 g/100 g) and Bread E (0.5 g/100 g) was 5.2 (99% CI 1.0, 9.3), just outside the non-inferiority margin of 5 mm for the primary analysis, but within the 10-mm minimally important difference (MID) in the exploratory analysis. Breads C and D, which contained the salt substitute, had values greater than the non-inferiority margin and MID (Table 2 and Figure 3). The results did not change overall after adjusting for age, sex, and smoking status. However we did observe that based on a MID of 10 mm, non-inferiority would also apply to non-smoking versus smoking or ex-smoker participants.

The proportions of participants who scored the intervention breads as being within 5 mm and 10 mm of their own score for Bread A are shown in Figures 4a and 4b. In all, 42% of the participants thought that Bread E was as good as or better than Bread A. At the 5-mm non-inferiority and 10-mm MID margins, 52% and 61% of participants respectively thought that bread made with 50% less salt (Bread E) was at least as palatable or better as Bread A.

Furthermore, 48% of participants thought that Bread C, which was lower in sodium but richer in potassium, tasted at least as good as, or better than Bread A within the 5mm margin.

As the bread was made in a standardized way (as available in any high street bakery), with the exception of salt content, adverse events related to the interventions were not expected, and none occurred.

Discussion

There are growing worldwide calls to reduce dietary salt consumption [20]. However, salt intake is significantly higher worldwide than recommended by the WHO [4]. This may be partly because many have grown accustomed to the use of salt to enhance the perceived palatability of food, not just through saltiness but also through reduced bitterness and enhanced sweetness [21]. Bread is a major contributor to daily sodium intake, and despite advice to manufacturers to reduce salt, recent data suggest that more could be done [9]. However, salt reduction in bread is thought to be limited by the desire for palatability, as well as the role salt has in producing better dough handling properties [11,12].

We believe that this is the largest randomized controlled study of the effects of reduced salt on the palatability of bread in the general public. Palatability was related to the amount of salt—the less salt the less palatable the bread. However, bread made with 50% less salt was not detectably less palatable than bread made with the standard recommended amount of salt Furthermore, over half of all the participants thought that bread made with 50% less salt tasted as good as or even better than standard bread.

To examine the difference in VAS scores between the different types of bread, we looked for a 5-mm non-inferior margin as the primary outcome, a highly conservative estimate. This value was calculated from a pilot study in 21 individuals. However, we have found no previous studies that defined an MID for tasting salt in bread and therefore carried out a further exploratory analysis using a 10-mm margin. Margins such as 10–20 mm have previously been reported as appropriate MIDs for subjective assessments, including taste

[22,23,24,25].

These results suggest that the current recommended salt content in the UK could be reduced by 50%, since a significant proportion of people are unable to tell the difference. More could be done to emphasize the importance of marketing reduced salt bread, and consumers could be given the option to switch to it as an alternative to standard bread.

While diets higher in sodium have negative effects on health, potassium-rich diets are thought to be beneficial [14]. However, replacing dietary sodium with potassium has conventionally been limited by perceptions of increased bitter, metallic, and astringent tastes associated with potassium [21]. Bread that contained potassium instead of sodium was significantly less palatable than standard bread, although nearly half of the participants in this study scored bread made with potassium chloride as at least as palatable as standard bread. In addition, bread made using the potassium-rich salt substitute looked identical in appearance to the other breads we used.

In subgroup analyses age, sex, and smoking status did not significantly affect these results.

Limitations

We used a 100-mm VAS to assess taste preferences, although there is little evidence that this is a valid method for assessing taste preference for breads made with varying salt contents. To the best of our knowledge, there is no previous information on the minimal important difference (MID) margin to use to assess a taste preference for salt in this context. However, this method has been previously used to assess taste preferences in other scenarios and for other subjective outcomes [16–19]. In one study, 20 healthy volunteers used a 100-mm VAS to score the palatability, pleasantness of taste, and acidity of standard bread and a propionate-rich sourdough bread [19]. There was no significant difference at a threshold of 2–6 mm on a VAS. Minimal important difference ranges of 10–20 mm have previously been used to assess taste and palatability in studies of oral rehydration solutions and antibiotics, and for other subjective outcomes, such as pain and sleep quality [22–25].

Despite attempts to ensure that participants rinsed their mouths with fresh water, there was a risk of a carryover effect between one bread sample and the next. To minimise this potential source of bias we randomized the order in which the bread was tasted for each participant. However, this does not completely exclude a possible residual carryover effect. Rinsing the mouth before the next sample may remove any residual taste, but may not remove the memory of the taste [26].

We used white bread, as it is the most commonly consumed type of bread in the UK [27]. The results cannot necessarily be applied to other types of bread such as brown, wholemeal, and sourdough breads.

The only objective outcome measure in this study was taste. We did not collect quantitative or qualitative data on other features, such as the appearance and texture of the bread. However, every pragmatic attempt was made to ensure that each batch of bread appeared identical.

Conclusions

An economic assessment has shown that salt reduction strategies reduce the long-term burden of coronary heart disease [28]. In particular, recommendations focused on public health campaigns improved food labelling and reductions in the salt contents of processed foods [4,20]. The UK has been a leader in initiating salt reduction strategies at the population level. A Department of Health policy published in 2010 aimed to reduce average maximum salt intake in adults to 6 g/day by 2015 and to 3 g by 2025 [6]. One of the strategies involved salt reduction in bread, which is a major contributor of salt [9]. The salt content of bread has progressively fallen in the UK over the 10 years since 2001, and manufacturers have on the whole reached the Government’s target of 1 g salt per 100 g for white bread; however, there is wide variation, and further reductions have been recommended [9].

The results of this study have important implications. Despite worldwide recognition that bread is a significant contributor to daily salt intake, more can be done to reduce intake. The salt content of bread could be reduced without a change in acceptability. Consumers could be given a choice of breads with different salt contents. Given the quantity of bread that is consumed globally, further reductions are likely to have significant benefits on the health of populations worldwide.

Competing interests

All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

Contributions

KRM conceived the idea for the study. The initial design was built on by KRM and CH. Statistical support as well as trial design was provided by KT and JJ. Data collection was directed by KRM, KG, and DN. The draft submission was written by KRM. All authors contributed to the final submission of this draft.

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Disclaimer

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None of the authors has any connection to the manufacturer of LoSalt™, Klinge Chemicals Ltd.

Transparency declaration

The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Figures and tables

Figure 1 Participant randomisation sequences using a Latin square design

		Bread salt group						Bread salt group				
Sequence	1	A	D	E	B	C	6	C	B	E	D	A
	2	B	C	D	E	A	7	A	E	D	C	B
	3	E	A	C	D	B	8	B	D	C	A	E
	4	C	E	B	A	D	9	D	A	B	E	C
	5	D	B	A	C	E	10	E	C	A	B	D

Figure 2 Participant flow diagram

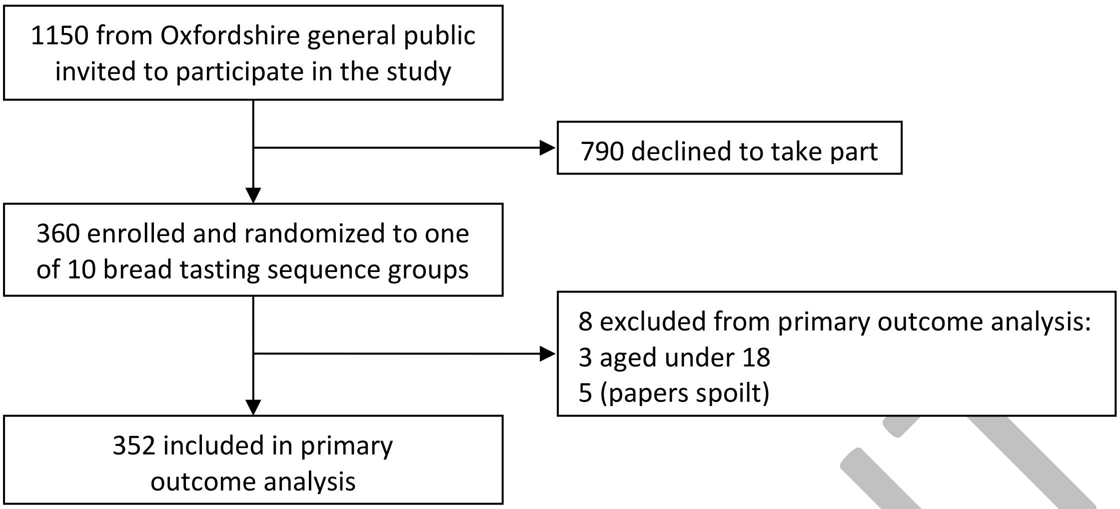


Table 1 Demographic Characteristics

Participants	**Women** N (%)	**Smokers** N (%)	**Non-smokers** N (%)	**Ex-smokers** N (%)	**Age** Mean (SD)
All	224 (64.6)	39 (11.1)	288 (81.8)	25 (7.1)	51.0 (17.8)
ADEBC	17 (48.6)	6 (16.7)	30 (83.3)	0 (0.0)	48.2 (19.1)
AEDCB	24 (64.9)	7 (19.4)	28 (77.8)	1 (2.8)	47.9 (18.1)
BCDEA	22 (64.7)	5 (13.9)	28 (77.8)	3 (8.3)	50.4 (19.7)
BDCAE	19 (51.4)	4 (10.8)	33 (89.2)	0 (0.0)	51.7 (16.7)
CBEDA	27 (79.4)	3 (8.8)	28 (82.4)	3 (8.8)	52.5 (16.2)
CEBAD	19 (55.9)	2 (5.7)	28 (80.0)	5 (14.3)	53.1 (18.7)
DABEC	24 (77.4)	1 (3.1)	28 (87.5)	3 (9.4)	47.4 (18.1)
DBACE	27 (77.1)	3 (8.6)	29 (82.9)	3 (8.6)	48.6 (15.1)
EACDB	23 (65.7)	4 (11.1)	28 (77.8)	4 (11.1)	57.2 (16.2)
ECABD	22 (62.9)	4 (11.4)	28 (80.0)	3 (8.6)	52.9 (19.8)

Table 2 VAS scores for the five types of bread

Bread label	A	E	C	D	B
Standard salt content (g/100 g)	1	0.5	0	0	0
LoSalt™ content (g/100 g)*	0	0	1	0.5	0
Estimated sodium content (mg/100 g)#	393	197	138	69	0
Estimated sodium content (mmol/100 g)#	17	8.5	6	3	0
Mean mm score (SD)	58.8 (26.4)	52.9 (24.9)	49.5 (25)	44.5 (24.6)	38.6 (25.1)
Difference from bread A (99% CI)		5.2 (1.0, 9.3)	8.6 (4.5, 12.7)	13.6 (9.4, 17.7)	19.5 (15.4, 23.6)

*Based on LoSalt™ containing 33.3% (maximum) sodium chloride
1 g sodium chloride = 0.393 g sodium = 17 mmol

Figure 3 The relation between sodium content and the difference in palatability from the standard bread; the higher the difference the less palatable the bread was; the data are shown as means with 99% CI; the line is the best logarithmic fit; horizontal lines are drawn at 5 and 10 mm MID

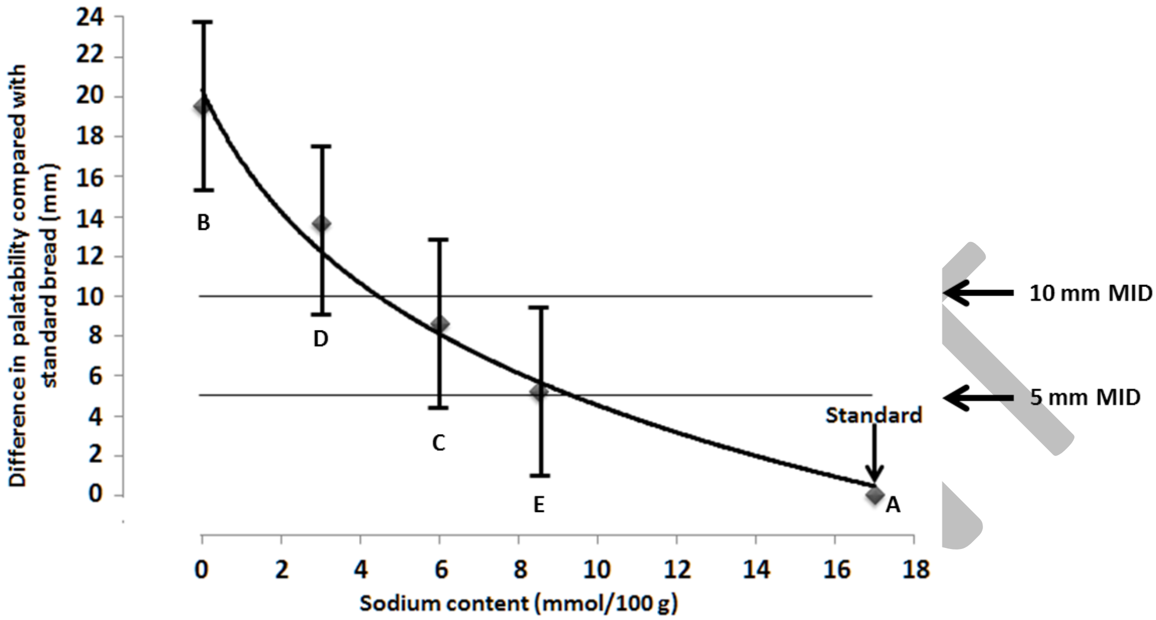
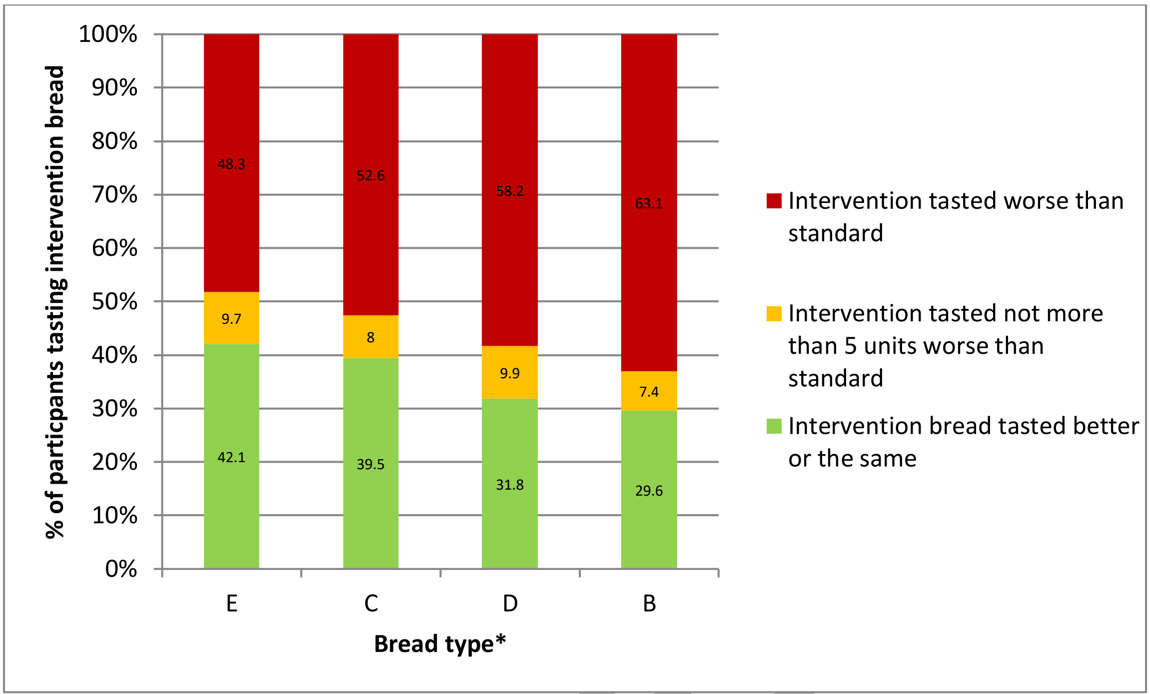
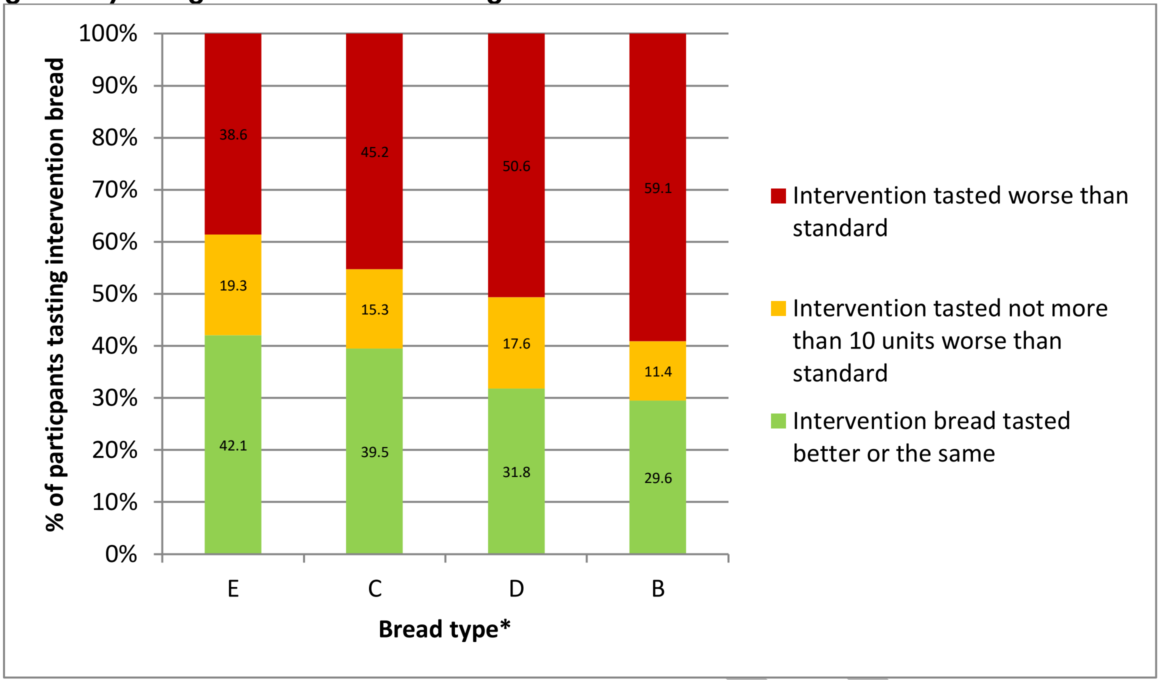


Figure 4a Participants tasting each intervention bread and giving it an equal, higher, or lower VAS score than their own score for standard bread (1 g standard salt per 100 g bread) using the 5-mm non-inferiority margin



* Bread E (0.5 g salt per 100 g bread), Bread C (1 g LoSalt per 100 g bread), Bread D (0.5 g LoSalt per 100 g bread) and Bread B (no salt)

Figure 4b Participants tasting each intervention bread and giving it an equal, higher, or lower VAS score than their own score for standard bread (1 g standard salt per 100 g bread) using the 10-mm MID margin



* Bread E (0.5 g salt per 100 g bread), Bread C (1 g LoSalt per 100 g bread), Bread D (0.5 g LoSalt per 100 g bread) and Bread B (no salt)

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