Surveys of the salt content in UK bread – Progress made and further reductions possible

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Surveys of the salt content in UK bread

– Progress made and further reductions possible

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ABSTRACT

Objectives: To explore the salt reductions made over time in packaged bread sold in the UK, the biggest contributor of salt to the UK diet.

Study design: Cross-sectional surveys were carried out on the salt content of breads available in UK supermarkets in 2001(40 products), 2006 (138) and 2011 (203).

Main outcome measures: The primary outcome measure was a change in salt content per 100g over time. Further measures included proportion of products meeting salt targets and differences between brands and bread types.

Results: The average salt level of bread was 1.23±0.19g/100g in 2001, 1.05±0.16 in 2006, and 0.98±0.13 in 2011. This shows a reduction in salt/100g of ≈20% between 2001 and 2011. A significant reduction ($p<0.05$) was found when identical products were tracked across each year. Supermarket own-brand bread was found to be lower in salt compared to branded bread (0.95g/100g compared to 1.04g/100g in 2011). The number of products meeting the 2012 targets increased from 31% in 2001 to 71% in 2011.

Conclusions: This study shows that the salt content of bread has been progressively reduced over time, contributing to the evidence base that a target based approach to salt reduction can lead to reductions being made. A wide variation in salt levels was found with many products already meeting the 2012 targets indicating that further reductions can be made. This requires further progressive targets to be set, so that the UK can continue to lead the world in salt reduction and save the maximum number of lives.

Key words: bread, reformulation, public health, food industry, salt, sodium

ARTICLE SUMMARY

Article focus:

- Populations around the world are consuming too much salt, largely as a result of the high salt content of processed foods.
- The UK is leading the world in salt reduction through the implementation of progressively lower voluntary salt targets across >80 categories of foods.
- Bread is the largest contributor of salt to the UK diet – this research uses a series of cross-sectional surveys of the salt content in UK packaged bread to examine the reductions made over time and the progress made towards meeting the 1g/100g target.

Key messages:

- The salt content of bread sold in the UK has been progressively reduced over the last decade.
- The results demonstrate that a target based approach to salt reduction can work to reduce the salt content of popular food.
- Other countries around the world need to follow the UK's lead and set country specific salt targets.

Strengths and limitations of this study:

- This study is the first of its kind, tracking the salt reductions made in bread over time. The results indicate that progressive lower salt targets can work to reduce salt levels of processed foods and can serve as evidence to encourage other countries around the world to follow this approach to salt reduction.

- The data used was based on manufacturers labels; due to product name changes, trend analysis was only possible for a limited number of products; No ingredient information was collected, so changes in formulations could not be examined.

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COMPETING INTERESTS

HB was an employee of Consensus Action on Salt & Health (CASH), a nonprofit charitable organisation at the time of conducting this study. FH is a member of CASH and its international branch World Action on Salt & Health (WASH) and does not receive any financial support from CASH or WASH. GM is Chairman of Blood Pressure Association (BPA), Chairman of CASH and Chairman of WASH. BPA, CASH and WASH are nonprofit charitable organisations. GM does not receive any financial support from any of these organisations. KJ is Campaign Director at CASH, WASH and BPA.

INTRODUCTION

There is strong evidence that a high salt intake increases blood pressure and thereby increases the risk of cardiovascular disease (i.e. strokes, heart attacks and heart failure) and kidney disease.[1, 2] A high salt intake also has other harmful effects on health, e.g. increasing the risk of stomach cancer[3] and indirectly linked to obesity.[4] Furthermore, it has been demonstrated that a reduction in population salt intake is one of the most cost-effective measures to improve public health.[5]

Populations around the world are consuming salt in quantities that far exceed physiological requirements.[6] As such, The World Health Organisation (WHO) has recommended salt reduction as one of the top three priority actions to tackle the non-communicable disease crisis.[7, 8]

Approximately 75% of the salt consumed in the UK and other developed countries comes from processed foods, and is added by food manufacturers prior to consumer purchase.[9] A wide range of food products contain salt, including everyday foods such as bread, breakfast cereals, sauces and processed meat.

The UK has successfully developed a voluntary salt reduction programme which is considered one of "the most successful nutrition policies in the UK since the second world war".[10] First developed by Consensus Action on Salt & Health (CASH), the strategy involves lowering salt intakes by a) reducing the salt levels of processed foods by a gradual reduction in the amount of salt added to the processed foods by 40% and b) reducing salt in cooking/at the table by 40%. In order to reduce salt intake from the 9.5 g/d to the projected target of 6.0 g/d in adults, the Food Standards Agency (FSA) then set a series of progressively lower salt targets for over 80 categories of food,[11, 12] which have now been incorporated as part of the Government's Public Health Responsibility Salt Pledge.[13] Other countries around the world, including Australia, America and Canada, are following the UK's lead and are adopting a similar target based approach to salt reduction.[14]

To date, significant progress has been made by many food manufacturers and retailers in the UK, with salt content being reduced across the board, including by up to 50% in breakfast cereals,

45% in biscuits, 40% in pastry products and 25% in cakes and pasta sauces.[15] Furthermore it has been reported that less salt is being added at the table by consumers.[16] The average salt intake in the UK population is steadily decreasing in parallel, with intakes currently estimated at 8.1g/d,[17] the lowest known accurate figure of any developed country (i.e. measured by 24h urinary sodium excretion).[6] This represents a 15% reduction from 2001 (9.5g).[18] This reduction is estimated to be saving ≈9000 lives every year and resulting in major cost-savings to the UK economy of more than £1.5 billion per year.[19, 20]

Bread is of particular interest to policymakers wishing to introduce a salt reduction strategy. On the one hand bread is an important component of the diets around the world.[21, 22] In the UK for instance, National Diet and Nutrition Surveys (NDNS) shows that bread contributes more than 10% of daily intake of protein, thiamine, niacin, folate, iron, zinc, copper and magnesium; one-fifth of fibre and calcium intakes; and more than one-quarter of manganese intake.[23] However, the NDNS also indicates that bread is the single largest contributor of salt to the UK diet, providing almost a fifth (18%) of salt intake from processed foods (i.e. 18% of 75% total intake). This equates to approximately 1.07g salt per person per day from bread alone. Bread is also the leading contributor in other countries such as America (7.4%),[24] New Zealand (26%)[25] and Australia.[26] Reductions in the salt content of bread would therefore have a significant impact on salt intake and as such has always been a leading focus of the UK's salt reduction strategy.

Despite the important role that bread plays in the UK diet, not only as a source of nutrients but as the leading contributor of salt, very little work has been conducted looking at the changes in the salt content of bread in the UK.

In Australia, where authorities are replicating the UK's salt reduction strategy, a paper published in 2011 explored the changes to sodium content in Australian and New Zealand bread between 2007 and 2010. The paper reported reductions, although only small, to the salt content of bread in these countries.[27] Other studies that focus on salt in bread, have tended to focus on practical issues surrounding salt reduction and exploring the potential. For instance, one study focused on how sodium may be reduced by increasing potassium levels.[22]

Given the importance of bread as a contributor of salt to the UK diet, coupled with perceived success of the UK's salt reduction campaign, the objective of this paper is to describe the progress made in reducing the amount of salt added to bread in the UK and discuss the successes and challenges that lie ahead in the UK in terms of further salt reductions so as to provide recommendations for both the UK and International Governments on salt reduction programmes.

METHODS

Data Collection

Three surveys were carried out, with the first one in 2001, the second one in 2006 and the last one in 2011. The survey in 2001 was carried out by the FSA[28] and the last two surveys by CASH.[29, 30] For all surveys, the data collected for each loaf included the company name, product name, pack weight, serving size, sodium/salt per 100 grams and sodium/salt per portion. When there were missing figures, they were calculated where possible, e.g. the missing sodium or salt values were converted by multiplying by 2.5 (sodium to salt) or dividing by 2.5 (salt to sodium).

All data was double checked after entry, and a further 5% of entries were checked against the original source in a random selection of products.

Inclusion/exclusion criteria: Data were collected from each of the major UK supermarkets (Asda, Sainsburys, Tesco, Waitrose, Morrisons, The Co-operative and Marks and Spencer) to represent salt levels of bread in the UK. Packaged sliced loaves of bread were included, including white, wholemeal, seeded, granary, half and half and brown. Thick and medium sliced breads were included. When two sizes were available, the standard 800g loaves were used. Data were collected for supermarket own brand bread and for branded bread products available. 'Special' breads such as rye and soda bread, ethnic breads and fresh breads were excluded

Product categories: Products were categorised into one of the following 3 groups: White (all white standard loaves), Wholemeal (all wholemeal loaves, including seeded/granary wholemeal), Brown (brown, white granary/seeded, 50:50 and wheatgerm). This was based on the criteria used for the NDNS data collection.[23] 'Other' breads were excluded as data for these breads was not collected in earlier surveys. Data was also categorised separately into branded or supermarket own brand.

Statistics

Comparison among products within each year: Unpaired T-test was used to compare the levels of salt between supermarket own brand and branded products within each year. One Way ANOVA with Bonferroni post hoc adjustment was used to compare the salt levels of different bread types (brown, white and wholemeal).

Comparison of the same products over the years: Repeated Measure ANOVA was used to test whether there was a significant change in salt content of bread over the years. For the purpose of this comparison, only the products with data available in all 3 surveys were included in analysis. In 2 places where a product was available in 2001 and 2011 but not 2006, the 2006 figure was assumed to be the same as 2001.

Data are reported as mean, SD, SE as indicated. Significance in all tests carried out was deemed as being $p<0.05$.

Salt targets: For each year and category, we calculated the total number and percentage of products that met the Department of Health's 2012 salt target for bread (i.e. $\leq$ 1g/100g).[31]

RESULTS

Within year analysis

Table 1 shows the levels of salt in bread for all 3 surveys.

2001

A total of 40 bread products met the inclusion criteria. One outlier was excluded from analysis as the salt level was much lower than all comparable products, and also much lower than those made by the same company. In the remaining 39 bread products, the average salt level per 100g was 1.23±0.19g with a range of 1.00g to 1.75g. Of the 39 products, 18 were branded, 21 were supermarket own brand. The salt level was slightly higher in branded compared with

supermarket own brand (1.27±0.18g vs. 1.19±0.19g), but this difference was not statistically significant (p=0.189).

Of the 39 products, 22 were white, 7 were brown and 10 were wholemeal. There was no significant difference in the salt content per 100g of different bread types (1.22±0.18g, 1.16±0.15g, 1.30±0.23g respectively, p=0.291).

2006

The average salt level per 100g was 1.05±0.16g with a range of 0.55g to 1.50g. Of the 138 products, 51 were branded products and 87 were supermarket own brand. The salt level in branded products was significantly higher compared with that in supermarket own brand (1.12±0.13g vs. 1.02±0.16g, p<0.01).

Of the 138 products, 46 were white, 55 were brown and 37 were wholemeal. No significant difference was found between the salt content per 100g of different bread types (1.09±0.15g, 1.02±0.18g, 1.06±0.11g respectively, p=0.104).

2011

The average salt level per 100g was 0.98±0.13g with a range of 0.58g to 2.03g. Of the 203 products, 78 were branded products and 125 were supermarket own brand. The salt level in branded products was significantly higher compared with that in supermarket own brand (1.04±0.15g vs. 0.95±0.10g, p<0.01).

Of the 203 products included, 75 were white, 71 were brown and 57 were wholemeal. No significant difference was found between the salt content per 100g of these groups (1.00±0.10g, 0.98±0.18g, 0.97±0.09g respectively, p=0.410).

Changes in salt levels in bread over the years

This analysis included only products that had salt levels available in all three surveys (i.e. a total of 18 products). The average salt levels per 100g were 1.24±0.16g in 2001, 1.14±0.25g in 2006 and 1.03±0.25g in 2011, $p<0.05$ by repeated measures ANOVA. Note that these averages are slightly different from those when all products were included in each year and this trend analysis merely reflects reductions made in the same products rather than overall products available.

Comparing with the 2012 targets

The 2012 bread target, as part of the Department of Health's Responsibility Deal, is ≤ 1g salt/100g. In 2001, 30% of products (12/40) met this target, increasing to 52% in 2006 (72/138) and 71% in 2011 (144/203). A greater number of supermarket own brand products compared to branded products met this target in all years: 38% compared to 21% in 2001; 71% compared to 20% in 2006; 89% compared to 42% in 2011.

DISCUSSION

The UK is currently leading the world with salt reduction using a strategy based on a set of voluntary targets which promote the gradual reduction of the amount of salt added to processed foods, in particular those foods that contribute most salt to the UK diet. Our paper, using the example of the biggest contributor of salt to the UK diet – bread, demonstrates that a national

target based approach to reformulation can be a successful method for reducing the content of salt in processed foods.

Significant reductions have been achieved

Our repeated surveys of the same bread products over time demonstrates that significant reductions have been made in the salt content of bread over the last 10years. Further analysis of all the breads surveyed in each year shows that the bread on sale in 2011 contains, on average, 20% less salt than the breads surveyed in 2001. The reductions that have been made since 2001 have gone unnoticed by the general public, with no impact on sales or consumer behaviour. Interestingly, no significant difference in the salt content of white, wholemeal and brown bread was found, despite the common perception that wholemeal and brown bread are healthier alternatives to white bread.

Branded products were found to contain approximately 10% more salt compared to supermarket breads in 2011 (1.04g vs. 0.95g, $p<0.01$). Although brands have made similar reductions compared to supermarkets over the last 10 years (0.23g/100g compared to 0.24g/100g), the branded products started with a higher level of salt, and brands now need to ensure they make further reductions to come in line with the lower levels seen in supermarket own brand breads.

The fact that supermarket own brand breads have been produced with lower levels of salt demonstrates that delivering salt reduction appears not to be a technical issue related to bread manufacture. Corporate decisions about food composition are often based upon factors such as taste and price, rather than health. However, evidence suggests that where salt reductions are

made gradually in bread over time, no reduction in consumer preference is reported.[32, 33] Indeed, a number of studies have shown that gradual reductions can go unnoticed by the consumer. For instance, a controlled study by Girgis et al[32] found that gradual reductions of up to a quarter in the salt content of bread over a 6 week period went largely unnoticed and that further reductions of up to 67% were possible when the bread was served with a sweet or savoury filling. Another study by Tuorila-Ollikainen et al[34] investigated the effect of salt reduction on bread consumption over 12 weeks 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 for the whole of the UK.

Products specifically promoted as 'low/no/reduced salt' are sometimes perceived has having a different taste. This emphasises the need for widespread industry gradual reductions to reduce population salt intake, rather than relying on consumers opting for lower salt versions. To ensure continued consumer acceptance of lower salt foods it is important that all manufacturers, particularly branded bread manufacturers in the UK, continue to reduce the salt content of their bread, in line with the levels found in supermarket breads, so as to ensure the greatest benefit for public health.

Implications for global public health and learnings from the UK

Our study demonstrates that a target based gradual approach to salt reduction can be a successful way to reduce salt in bread. Seventy one percent of the bread products surveyed in 2011 already met the 2012 targets, compared to just 30% of the surveyed products in 2001. The findings

support previous studies that have indicated a reduction in salt in popular household products, such as a reduction of up to 50% in breakfast cereals, 45% in biscuits, 40% in pastry products and 25% in cakes and pasta sauces. [15]

Such a programme, based on a series of gradual reductions across the sector over a period of years, can lead to a large cumulative reduction in salt content of foods and therefore in population salt intakes. Additionally, a program that removes a small amount of salt from every product reduces salt intake in the whole population starting at one year of age when processed food products with added salt are introduced. With the need to address social inequalities in health, both in the UK and worldwide, this programme sees those consuming the largest quantities of the saltiest foods obtaining the greatest benefits. Programs that target the whole food chain such as this also have a significant cost advantage because additional consumer education and behaviour change is not required to achieve results. Furthermore, salt reduction, and the costs associated with it, can be absorbed into the continuous reformulation programmes already undertaken by manufacturers and retailers.

Despite the fact that clear reductions in salt content in bread are being made in the UK, there is still a marked variability in the salt levels of similar bread products as well as differences between branded and supermarket own brand bread. This demonstrates that while a voluntary target based approach works to encourage industry reductions, the targets needs to be coupled with the forceful government or quasi-government agency, e.g. in the UK the Food Standards Agency and subsequently the Department of Health, to ensure all companies are aware of the targets and make reductions to achieve the same low levels in salt content so as to have the

maximum benefit on population health. When countries are looking to set their own targets, they should make sure that a monitoring strategy is included so that all products are reduced across the board, and to ensure that companies feel that there is a level playing field. This can be greatly helped by forceful Non-Government Organisations (e.g. in the UK, CASH) that monitor progress and highlight companies that are not complying.

Technological solutions that enable the production of much lower salt products with no loss in the sensory characteristics of the food may be closely guarded commercial secrets or require investment in research and materials that only large businesses can afford. Despite there being advantages to sharing salt reduction information the competition-based business model does not lend itself to industry-wide dissemination of innovation. A supporting pledge in the Responsibility Deal indicates that information should be shared between companies, but more work could be done and the Department of Health needs to encourage this.

High salt diets are not a problem unique to the UK.[6] Other countries have started to follow the UK's lead by setting some of their own salt reduction targets. In Australia and New Zealand, for instance, bread targets of 400mg sodium/100g (1g salt /100g)and 450mg sodium/100g (1.13g salt/100g) respectively were introduced in 2007. Monitoring reports from these countries (2007-2010) reported a 7% reduction in the salt content of bread in New Zealand, but did not observe a reduction in Australia. However, during the 3 year period, the proportion of products in each country meeting the target increased from 29% to 50% in Australia and 49% to 90% in New Zealand, suggesting that reductions are likely to have occurred not only in New Zealand, but also in Australia, where reductions may have occurred, but not across the board, To highlight this

point, while a reduction of up to 17% was seen in the breads produced by two retailers and one manufacturer included in the research, an increase of 10% was seen in a fourth company. This indicates that, while the first step has been taken to reduce salt via a target based approach, further work in monitoring and engaging all members of the food industry is required to ensure that salt reduction occurs across the board so as to create a level playing field for all of the companies involved and also to see the biggest benefits for public health

Other countries around the world now need to follow suit and set up a target based approach to reducing salt content of processed foods. While the food category emphasis may differ between countries, the concept of using salt targets to achieve a 'level playing field' amongst the industry is universal. A product like bread is widely consumed internationally and this research demonstrates how targets can work to lower the levels of salt.

LIMITATIONS

Our study was based on salt content data provided on bread labels in store, hence we relied on the accuracy of the data provided on the label. However, the study carried out by the Food Standards Agency showed that the analysed figures did match those stated on the labels.[35] It is assumed that the manufacturers provide accurate and up to date information in line with EU Regulations.

In order to track changes in salt levels over time the same products need to be used for analysis. However, due to product name changes it was often hard to ensure that all products available were used as there was no way of determining if a similar named product was a different product

or a newly named product. This also means that a limited number of products were used for trend analysis, but our results from both repeated surveys of the same products and the overall analysis of all products have consistently shown a reduction in salt levels in bread products on sale in the UK.

When collecting data we did not capture ingredients list, this means we are unable to ascertain if salt has been replaced with any other ingredients/additives in the bread that came out lowest. Such data should be collected in future surveys.

There is no evidence available to prove that the salt reduction seen in bread has translated into a reduction in salt intake in the UK population. However, given that there is no evidence of a change in the sales of bread in the UK, that the salt content of bread has declined and that the salt intake of the population has declined in parallel, it is likely that the reductions in salt made in bread have contributed to the measured reductions in population salt intake.

CONCLUSION

This research, using the example of bread, demonstrates how a target based approach to salt reduction can lead to salt reductions being made across the board. There is evidence that companies could substantially reduce the amount of salt further, based on the variation in salt levels found. In the meantime however it is important that companies introduce clear and consistent front of pack labelling across all foods so that consumers can identify lower salt products.

This research presents a clear example of how a salt reduction strategy, based on targets in key food categories, can ensure that salt levels are reduced without loss of sales and no consumer reaction. Governments around the world need now to follow the UK's lead and set targets on the biggest contributors of salt to the diet so as to prevent thousands of deaths every year.

Authors contributions

GM conceived the idea and designed research; HB conducted research; HB and FH analyzed data; HB wrote the first draft of the manuscript and all authors contributed to the interpretation of the results and revision of the manuscript, and approved the final manuscript. GM had primary responsibility for final content.

Data sharing

No additional data available.

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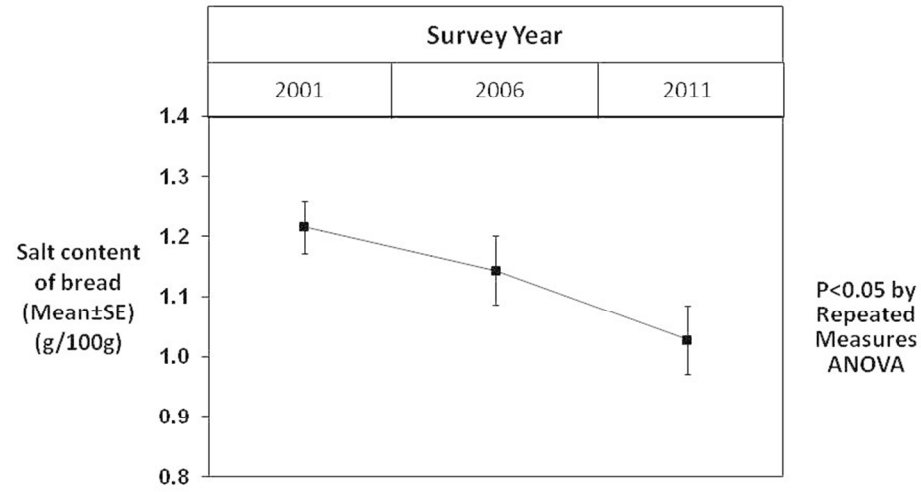
Legend for figure 1: Salt content in bread in repeated surveys, 2001-2011

Table 1. Average salt levels in breads for each year (g salt/100g)

	2001		2006		2011	
	N	Mean±SD (range)	N	Mean±SD (range)	N	Mean±SD (range)
Overall	39	1.23±0.19 (1.00-1.75)	138	1.05±0.16 (0.55-1.50)	203	0.98± 0.13 (0.58-2.03)
Branded	18	1.27±0.18 (1.00-1.50)	51	1.12±0.13 (0.55-1.25)	78	1.04 ±0.15 (0.75-2.03)
Supermarket	21	1.19±0.19 (1.00-1.75)	87	1.02±0.16 (0.60-1.50)	125	0.95 ± 0.10 (0.58-1.20)
White	22	1.22±0.18 (1.00-1.50)	46	1.09±0.15 (0.70-1.50)	75	1.00±0.10 (0.58-1.20)
Brown	7	1.16±0.15 (1.00-1.35)	55	1.02±0.18 (0.55-1.50)	71	0.98±0.18 (0.65-2.03)
Wholemeal	10	1.30±0.23 (1.00-1.75)	37	1.06±0.11 (0.90-1.30)	57	0.97±0.09 (0.74-1.18)

Table 2. Products meeting the 2012 target of ≤ 1g salt/100g in each year

	2001		2006		2011	
	N	N (%) meeting target	N	N (%) meeting target	N	N (%) meeting target
Overall	40	12 (30%)	138	72 (52%)	203	144 (71%)
Branded	19	4 (21%)	51	10 (20%)	78	33 (42%)
Supermarket	21	8 (38%)	87	62 (71%)	125	111 (89%)
White	23	7 (30%)	46	22 (48%)	75	50 (67%)
Brown	7	3 (43%)	55	31 (56%)	71	50 (70%)
Wholemeal	10	2 (20%)	37	19 (51%)	57	44 (77%)



254x190mm (96 x 96 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page Number Reported
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Not applicable
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	Not applicable
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking	Not applicable

		account of sampling strategy	
		(*e*) Describe any sensitivity analyses	6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Not applicable
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-9
		(b) Indicate number of participants with missing data for each variable of interest	7-9
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	9
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	7-9
		Cross-sectional study—Report numbers of outcome events or summary measures	Not applicable
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-9
		(*b*) Report category boundaries when continuous variables were categorized	Tab 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7-9 & Tab 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	9-10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11 & 14
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Surveys of the salt content in UK bread – Progress made and further reductions possible

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Surveys of the salt content in UK bread

– Progress made and further reductions possible

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ABSTRACT

Objectives: To explore the salt reductions made over time in packaged bread sold in the UK, the biggest contributor of salt to the UK diet.

Study design: Cross-sectional surveys were carried out on the salt content of breads available in UK supermarkets in 2001(40 products), 2006 (138) and 2011 (203).

Main outcome measures: The primary outcome measure was the change in salt content per 100g over time. Further measures included proportion of products meeting salt targets and differences between brands and bread types.

Results: The average salt level of bread was 1.23±0.19g/100g in 2001, 1.05±0.16 in 2006, and 0.98±0.13 in 2011. This shows a reduction in salt/100g of ≈20% between 2001 and 2011. In the 18 products which were surveyed in all three years, there was a significant reduction of 17% ($p<0.05$). Supermarket own-brand bread was found to be lower in salt compared to branded bread (0.95g/100g compared to 1.04g/100g in 2011). The number of products meeting the 2012 targets increased from 31% in 2001 to 71% in 2011 ($P<0.001$).

Conclusions: This study shows that the salt content of bread has been progressively reduced over time, contributing to the evidence base that a target based approach to salt reduction can lead to reductions being made. A wide variation in salt levels was found with many products already meeting the 2012 targets indicating that further reductions can be made. This requires further progressive lower targets to be set, so that the UK can continue to lead the world in salt reduction and save the maximum number of lives.

Key words: bread, reformulation, public health, food industry, salt, sodium

ARTICLE SUMMARY

Article focus:

- Populations around the world are consuming too much salt, largely as a result of the high salt content of processed foods.
- The UK is leading the world in salt reduction through the implementation of progressively lower voluntary salt targets across >80 categories of foods.
- Bread is the largest contributor of salt to the UK diet – this research uses a series of cross-sectional surveys of the salt content in UK packaged bread to examine the reductions made over time and the progress made towards meeting the 1g/100g target.

Key messages:

- The salt content of bread sold in the UK has been progressively reduced over the last decade.
- The results demonstrate that a target based approach to salt reduction can work to reduce the salt content of popular food.
- Other countries around the world need to follow the UK's lead and set salt targets.

Strengths and limitations of this study:

- This study tracks the salt reductions made in bread over time. It is the first UK study of this kind, adding to research using the same methodology carried out in Australia and New Zealand. The results indicate that progressive lower salt targets can work to reduce salt levels of processed foods and can serve as evidence to encourage other countries around the world to follow this approach to salt reduction.

- The data used was based on manufacturers labels; due to product name changes, trend analysis was only possible for a limited number of products; No ingredient information was collected, so changes in formulations could not be examined.

FUNDING STATEMENT

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

COMPETING INTERESTS

HB was an employee of Consensus Action on Salt & Health (CASH), a nonprofit charitable organisation at the time of conducting this study. FH is a member of CASH and its international branch World Action on Salt & Health (WASH) and does not receive any financial support from CASH or WASH. GM is Chairman of Blood Pressure Association (BPA), Chairman of CASH and Chairman of WASH. BPA, CASH and WASH are nonprofit charitable organisations. GM does not receive any financial support from any of these organisations. KJ is Campaign Director at CASH, WASH and BPA.

INTRODUCTION

There is strong evidence that a high salt intake increases blood pressure and thereby increases the risk of cardiovascular disease (i.e. strokes, heart attacks and heart failure) and kidney disease.[1 2] A high salt intake also has other harmful effects on health, e.g. increasing the risk of stomach cancer[3] and indirectly linked to obesity.[4] Furthermore, it has been demonstrated that a reduction in population salt intake is one of the most cost-effective measures to improve public health.[5]

Populations around the world are consuming salt in quantities that far exceed physiological requirements.[6] As such, The World Health Organisation (WHO) has recommended salt reduction as one of the top three priority actions to tackle the non-communicable disease crisis.[7 8]

Approximately 75% of the salt consumed in the UK and other developed countries comes from processed foods, and is added by food manufacturers prior to consumer purchase.[9] A wide range of food products contain salt, including everyday foods such as bread, breakfast cereals, sauces and processed meat.

The UK has successfully developed a voluntary salt reduction programme which is considered one of "the most successful nutrition policies in the UK since the second world war".[10] First developed by Consensus Action on Salt & Health (CASH), the strategy involves lowering salt intakes by a) reducing the salt levels of processed foods by a gradual reduction in the amount of salt added to the processed foods by 40% and b) reducing salt in cooking or at the table by 40%. In order to reduce salt intake from the 9.5 g/d to the projected target of 6.0 g/d in adults, the Food Standards Agency (FSA) then set a series of progressively lower salt targets for over 80 categories of food,[11 12] which have now been incorporated as part of the Government's Public Health Responsibility Salt Pledge.[13] Other countries around the world, including Australia, United States and Canada, are following the UK's lead and are adopting a similar target based approach to salt reduction.[6]

To date, significant progress has been made by many food manufacturers and retailers in the UK, with salt content being reduced across the board, including by up to 50% in breakfast cereals,

45% in biscuits, 40% in pastry products and 25% in cakes and pasta sauces.[14] Furthermore, it has been reported that less salt is being added at the table by consumers.[15] The average salt intake in the UK population is steadily decreasing in parallel, with intakes currently estimated at 8.1g/d,[16] the lowest known accurate figure of any developed country (i.e. measured by 24h urinary sodium excretion).[6] This represents a 15% reduction from 2001 (9.5g).[17] This reduction is estimated to be saving ≈9000 lives every year and resulting in major cost-savings to the UK economy of more than £1.5 billion per year.[18 19]

Bread is of particular interest to policymakers wishing to introduce a salt reduction strategy. On the one hand bread is an important component of the diets around the world.[20 21] In the UK for instance, National Diet and Nutrition Surveys (NDNS) shows that bread contributes more than 10% of daily intake of protein, thiamine, niacin, folate, iron, zinc, copper and magnesium; one-fifth of fibre and calcium intakes; and more than one-quarter of manganese intake.[22] However, the NDNS also indicates that bread is the single largest contributor of salt to the UK diet, providing almost a fifth (18%) of salt intake from processed foods (i.e. 18% of 75% total intake). This equates to approximately 1.07g salt per person per day from bread alone. Bread is also the leading contributor in other countries such as United States (7.4%),[23] New Zealand (26%)[24 25] and Australia (≈20%).[26 27] Reductions in the salt content of bread would therefore have a significant impact on salt intake and as such has always been a leading focus of the UK's salt reduction strategy.

Despite the important role that bread plays in the UK diet, not only as a source of nutrients but as the leading contributor of salt, very little work has been conducted looking at the changes in the salt content of bread in the UK.

In Australia, where authorities are replicating the UK's salt reduction strategy, a paper published in 2011 explored the changes to sodium content in Australian and New Zealand bread between 2007 and 2010. The paper reported reductions, although only small, to the salt content of bread in these countries.[27] Other studies that focus on salt in bread, have tended to focus on practical issues related to salt reduction, including technical feasibility and the potential for use of salt replacers.. For instance, one study focused on how sodium may be reduced by increasing potassium levels.[21]

Given the importance of bread as a contributor of salt to the UK diet, coupled with perceived success of the UK's salt reduction campaign, the objective of this paper is to describe the progress made in reducing the amount of salt added to bread in the UK and discuss the successes and challenges that lie ahead in the UK in terms of further salt reductions so as to provide recommendations for both the UK and International Governments on salt reduction programmes.

METHODS

Data Collection

Three surveys were carried out, with the first one in 2001, the second one in 2006 and the last one in 2011. The survey in 2001 was carried out by the FSA[28 29] and the last two surveys by CASH.[30 31] For all surveys, the data was collected from product packaging and nutrient

information panels. The 2011 survey was designed as a comprehensive survey of all breads available in a snapshot in time, using one large store per retailer in the UK. The 2006 survey was also designed as a comprehensive survey, but excluded 'repetition' products e.g. where there were two similar products, for instance two crusty white products, by the same company, or where the same product was available in different sizes. The FSA survey carried out in 2001 was not designed as a comprehensive survey, instead including a single example of a premium and standard white, brown and wholemeal loaf from each of the leading supermarkets and brands. Whilst not comprehensive, the selection of generic products from a number of companies is likely to ensure that the data collected is reflective of the situation at that point in time. For each loaf, the data collected included the company name, product name, pack weight, serving size, sodium/salt per 100 grams and sodium/salt per portion. When there were missing figures, they were calculated where possible, e.g. the missing sodium or salt values were converted by multiplying by 2.5 (sodium to salt) or dividing by 2.5 (salt to sodium). All data was double checked after entry, and a further 5% of entries were checked against the original source in a random selection of products.

Inclusion/exclusion criteria: Data were collected from each of the major UK supermarkets (Asda, Sainsburys, Tesco, Waitrose, Morrisons, The Co-operative and Marks and Spencer) to represent salt levels of bread in the UK. Packaged sliced loaves of bread were included, including white, wholemeal, seeded, granary, half and half, and brown. Thick and medium sliced breads were included. When two sizes were available, the standard 800g loaves were used. Data were collected for supermarket own brand bread and for branded bread products available. 'Special' breads such as rye and soda bread, ethnic breads and fresh breads were excluded

Product categories: Products were categorised into one of the following 3 groups: White (all white standard loaves), Wholemeal (all wholemeal loaves, including wholemeal seeded/granary), Brown (brown, white granary/seeded, 50:50 and wheatgerm). This was based on the criteria used for the NDNS data collection.[22] 'Other' breads were excluded as data for these breads was not collected in earlier surveys. Data was also categorised separately into branded or supermarket own brand.

Statistics

Comparison among products within each year: Unpaired T-test was used to compare the levels of salt between supermarket own brand and branded products within each year. One Way ANOVA with Bonferroni post hoc adjustment was used to compare the salt levels of different bread types (brown, white and wholemeal).

Comparison of the same products over the years: Repeated Measure ANOVA was used to test whether there was a significant change in salt content of bread over the years. For the purpose of this comparison, only the products with data available in all 3 surveys were included in analysis. In 2 places where a product was available in 2001 and 2011 but not 2006, the 2006 figure was assumed to be the same as 2001.

Data are reported as mean, SD, SE as indicated. Significance in all tests carried out was deemed as being $p<0.05$. All data was analysed using SPSS software.

Salt targets: For each year and category, we calculated the total number and percentage of products that met the Department of Health's 2012 salt target for bread (i.e. ≤ 1g/100g).[32]

RESULTS

Within year analysis

Table 1 shows the levels of salt in bread for all 3 surveys.

2001

A total of 40 bread products met the inclusion criteria. One outlier was excluded from analysis as the salt level was much lower than all comparable products, and also much lower than those made by the same company. In the remaining 39 bread products, the average salt level per 100g was 1.23±0.19g with a range of 1.00g to 1.75g.

Table 1 shows the mean salt level for branded and supermarket, as well as salt level by bread type (white, brown and wholemeal). The salt level was slightly higher in branded compared with supermarket own brand, but this difference was not statistically significant (p=0.189). There was no significant difference in the salt content per 100g of different bread types (p=0.291).

2006

The average salt level per 100g was 1.05±0.16g with a range of 0.55g to 1.50g. Of the 138 products, 51 were branded products and 87 were supermarket own brand. The salt level in branded products was significantly higher compared with that in supermarket own brand

(p<0.01) (Table 1). No significant difference was found between the salt content per 100g of different bread types (p=0.104) (Table 1).

2011

The average salt level per 100g was 0.98±0.13g with a range of 0.58g to 2.03g. Of the 203 products, 78 were branded products and 125 were supermarket own brand. The salt level in branded products was significantly higher compared with that in supermarket own brand (p<0.01) (Table 1). No significant difference was found between the salt content per 100g of different bread types (p=0.410) (Table 1).

Changes in salt levels in bread over the years

Taking all products together, there was a gradual reduction in the salt content of bread. On average, salt level was reduced by 20% from 2001 to 2011.

There were 18 products from 9 different companies that had salt levels surveyed in all three years. Ten of the bread products were white, and 8 were wholemeal. Eight of the products were branded and 10 were from retailers. The average salt levels per 100g for these 18 products were 1.24±0.16g in 2001, 1.14±0.25g in 2006 and 1.03±0.25g in 2011 (p<0.05 by repeated measures ANOVA). This represents a reduction of 17% from 2001 to 2011. Note that these averages are slightly different from those when all products were included in each year and this trend analysis merely reflects reductions made in the same products rather than overall products available.

Comparing with the 2012 targets

The 2012 bread target, as part of the Department of Health's Responsibility Deal, is ≤ 1g salt/100g. Our results showed that, from 2001 to 2011, there was a significant increase in the number of products meeting the 2012 targets (Table 2). In 2001, 30% of products (12/40) met this target, increasing to 52% in 2006 (72/138) and 71% in 2011 (144/203). A greater number of supermarket own brand products compared to branded products met this target in all years: 38% compared to 21% in 2001; 71% compared to 20% in 2006; 89% compared to 42% in 2011.

DISCUSSION

The UK is currently leading the world with salt reduction using a strategy, developed in 2003 by the UK Food Standards Agency and CASH, based on a set of voluntary targets which promote the gradual reduction in the amount of salt added to processed foods, in particular those foods that contribute most salt to the UK diet. Our paper, using the example of the biggest contributor of salt to the UK diet – bread, demonstrates that a national target based approach to reformulation can be a successful method for reducing the salt content in processed foods.

Significant reductions have been achieved

Our repeated surveys of the same bread products over time demonstrates that significant reductions have been made in the salt content of bread and that there has been a significant increase in the number of products that meet the salt targets over the last 10years. Further analysis of all the breads surveyed in each year shows that the bread on sale in 2011 contains, on average, 20% less salt than the breads surveyed in 2001. The reductions that have been made since 2001 have gone unnoticed by the general public, with no impact on sales or consumer behaviour.[33] Interestingly, no significant difference in the salt content of white, wholemeal and

brown bread was found, despite the common perception that wholemeal and brown bread are healthier alternatives to white bread.[34]

Branded products were found to contain approximately 10% more salt compared to supermarket breads in 2011 (1.04g vs. 0.95g, $p<0.01$). Although brands have made similar reductions compared to supermarkets over the last 10 years (0.23g/100g compared to 0.24g/100g), the branded products started with a higher level of salt, and brands now need to ensure they make further reductions to come in line with the lower levels seen in supermarket own brand breads.

The fact that supermarket own brand breads have been produced with lower levels of salt demonstrates that delivering salt reduction appears not to be a technical issue related to bread manufacture. Corporate decisions about food composition are often based upon factors such as taste and price, rather than health. However, evidence suggests that where salt reductions are made gradually in bread over time, no reduction in consumer preference is reported.[35 36] Indeed, a number of studies have shown that gradual reductions can go unnoticed by the consumer. For instance, a controlled study by Girgis et al[35] found that gradual reductions of up to a quarter in the salt content of bread over a 6 week period went largely unnoticed and that further reductions of up to 67% were possible when the bread was served with a sweet or savoury filling. Another study by Tuorila-Ollikainen et al[37] investigated the effect of salt reduction on bread consumption over 12 weeks 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.

Products specifically promoted as 'low/no/reduced salt' are sometimes perceived has having a different taste.[38] This emphasises the need for widespread industry gradual reductions to reduce population salt intake, rather than relying on consumers opting for lower salt versions. To ensure continued consumer acceptance of lower salt foods it is important that all manufacturers, particularly branded bread manufacturers in the UK, continue to reduce the salt content of their bread, in line with the levels found in supermarket breads, so as to ensure the greatest benefit for public health.

Implications for global public health and learnings from the UK

Our findings support previous studies that have indicated a reduction in salt in popular household products, such as a reduction of up to 50% in breakfast cereals, 45% in biscuits, 40% in pastry products and 25% in cakes and pasta sauces. [14]

A programme, based on a series of gradual reductions across the sector over a period of years, can lead to a large cumulative reduction in salt content of foods and therefore in population salt intakes. Additionally, a program that removes a small amount of salt from every product reduces salt intake in the whole population starting at one year of age when processed food products with added salt are introduced. With the need to address social inequalities in health, both in the UK and worldwide, this programme sees those consuming the largest quantities of the saltiest foods obtaining the greatest benefits. Programs that target the whole food chain such as this also have a significant cost advantage because additional consumer education and behaviour change is not required to achieve results. Furthermore, salt reduction, and the costs associated with it, can be

absorbed into the continuous reformulation programmes already undertaken by manufacturers and retailers.

Despite the fact that clear reductions in salt content in bread are being made in the UK, there is still a marked variability in the salt levels of similar bread products as well as differences between branded and supermarket own brand bread. This demonstrates that while a voluntary target based approach works to encourage industry reductions, the targets needs to be coupled with the forceful government or quasi-government agency, e.g. in the UK the Food Standards Agency and subsequently the Department of Health, to ensure all companies are aware of the targets and make reductions to achieve the same low levels in salt content so as to have the maximum benefit on population health. When countries are looking to set their own targets, they should make sure that a monitoring strategy is included so that all products are reduced across the board, and to ensure that companies feel that there is a level playing field. This can be greatly helped by forceful Non-Government Organisations (e.g. in the UK, CASH) that monitor progress and highlight companies that are not complying.

Technological solutions that enable the production of much lower salt products with no loss in the sensory characteristics of the food may be closely guarded commercial secrets or require investment in research and materials that only large businesses can afford. Despite there being advantages to sharing salt reduction information the competition-based business model does not lend itself to industry-wide dissemination of innovation. A supporting pledge in the Responsibility Deal indicates that information should be shared between companies, but more work could be done and the Department of Health needs to encourage this.

High salt diets are not a problem unique to the UK.[6] Other countries have started to follow the UK's lead by setting some of their own salt reduction targets. In Australia and New Zealand, for instance, bread targets of 400mg sodium/100g (1g salt /100g) and 450mg sodium/100g (1.13g salt/100g) respectively were introduced in 2010.[39] Monitoring reports from these countries (2007-2010) reported a 7% reduction in the salt content of bread in New Zealand, but did not observe a reduction in Australia.[27] However, during the 3 year period, the proportion of products in each country meeting the target increased from 29% to 50% in Australia and 49% to 90% in New Zealand, suggesting that reductions are likely to have occurred not only in New Zealand, but also in Australia, where reductions may have occurred, but not across the board. To highlight this point, while a reduction of up to 17% was seen in the breads produced by two retailers and one manufacturer included in the research, an increase of 10% was seen in a fourth company. This indicates that, while the first step has been taken to reduce salt via a target based approach, further work in monitoring and engaging all members of the food industry is required to ensure that salt reduction occurs across the board so as to create a level playing field for all of the companies involved and also to see the biggest benefits for public health

Other countries around the world now need to follow suit and set up a target based approach to reducing salt content of processed foods. While the food category emphasis may differ between countries, the concept of using salt targets to achieve a 'level playing field' amongst the industry is universal. A product like bread is widely consumed internationally and this research demonstrates how targets can work to lower the levels of salt.

LIMITATIONS

Our study was based on salt content data provided on bread labels in store, hence we relied on the accuracy of the data provided on the label. However, the study carried out by the Food Standards Agency showed that the analysed figures did match those stated on the labels.[40] It is assumed that the manufacturers provide accurate and up to date information in line with EU Regulations.

In order to provide the most accurate information about the changes in salt levels over time, in particular the reformulation that has occurred, the same products need to be used for analysis. However, due to product name changes it was often hard to ensure that all products available were used as there was no way of determining if a similar named product was a different product or a newly named product. This also means that a limited number of products were used for trend analysis, but our results from both repeated surveys of the same products and the overall analysis of all products have consistently shown a reduction in salt levels in bread products on sale in the UK.

When collecting data we did not capture ingredients list, this means we are unable to ascertain if salt has been replaced with any other ingredients/additives in the bread that came out lowest. Such data should be collected in future surveys.

There is no evidence available to prove that the salt reduction seen in bread has translated into a reduction in salt intake in the UK population. However, given that there is no evidence of a change in the sales of bread in the UK, that the salt content of bread has declined and that the salt

intake of the population has declined in parallel, it is likely that the reductions in salt made in bread have contributed to the measured reductions in population salt intake.

CONCLUSION

This research, using the example of bread, demonstrates how a target based approach to salt reduction can lead to salt reductions being made across the board. There is evidence that companies could substantially reduce the amount of salt further, based on the variation in salt levels found.

This research presents a clear example of how a salt reduction strategy, based on targets in key food categories, can ensure that salt levels are reduced without loss of sales and no consumer reaction. Governments around the world need now to follow the UK's lead and set targets on the biggest contributors of salt to the diet so as to prevent thousands of deaths every year.

Authors contributions

GM conceived the idea and designed research; HB conducted research; HB and FH analyzed data; HB wrote the first draft of the manuscript and all authors contributed to the interpretation of the results and revision of the manuscript, and approved the final manuscript. GM had primary responsibility for final content.

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Competing Interests

HB was an employee of Consensus Action on Salt & Health (CASH), a nonprofit charitable organisation at the time of conducting this study. FH is a member of CASH and its international branch World Action on Salt & Health (WASH) and does not receive any financial support from CASH or WASH. GM is Chairman of Blood Pressure Association (BPA), Chairman of CASH and Chairman of WASH. BPA, CASH and WASH are nonprofit charitable organisations. GM does not receive any financial support from any of these organisations. KJ is Campaign Director at CASH, WASH and BPA.

Data sharing

No additional data available.

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Legend for figure 1: Salt content in bread in repeated surveys, 2001-2011

Table 1. Average salt levels in breads for each year (g salt/100g)

	2001		2006		2011		Change from 2001 to 2011	
	N	Mean±SD (range)	N	Mean±SD (range)	N	Mean±SD (range)	Mean	%
Overall	39	1.23±0.19 (1.00-1.75)	138	1.05±0.16 (0.55-1.50)	203	0.98± 0.13 (0.58-2.03)	0.25	20%
Branded	18	1.27±0.18 (1.00-1.50)	51	1.12±0.13 (0.55-1.25)	78	1.04 ±0.15 (0.75-2.03)	0.23	18%
Supermarket	21	1.19±0.19 (1.00-1.75)	87	1.02±0.16 (0.60-1.50)	125	0.95 ± 0.10 (0.58-1.20)	0.24	20%
White	22	1.22±0.18 (1.00-1.50)	46	1.09±0.15 (0.70-1.50)	75	1.00±0.10 (0.58-1.20)	0.22	18%
Brown	7	1.16±0.15 (1.00-1.35)	55	1.02±0.18 (0.55-1.50)	71	0.98±0.18 (0.65-2.03)	0.18	16%
Wholemeal	10	1.30±0.23 (1.00-1.75)	37	1.06±0.11 (0.90-1.30)	57	0.97±0.09 (0.74-1.18)	0.33	25%

Table 2. Products meeting the 2012 target of ≤ 1g salt/100g in each year

	2001		2006		2011		
	N	N (%) meeting target	N	N (%) meeting target	N	N (%) meeting target	P value by χ^2 test
Overall	39	12 (30%)	138	72 (52%)	203	144 (71%)	p<0.001
Branded	18	4 (21%)	51	10 (20%)	78	33 (42%)	P<0.01
Supermarket	21	8 (38%)	87	62 (71%)	125	111 (89%)	P<0.01
White	22	6 (27%)	46	22 (48%)	75	50 (67%)	P<0.01
Brown	7	3 (43%)	55	31 (56%)	71	50 (70%)	P<0.01
Wholemeal	10	2 (20%)	37	19 (51%)	57	44 (77%)	P<0.01

Surveys of the salt content in UK bread

– Progress made and further reductions possible

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Running title: Salt reduction in UK bread

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ABSTRACT

Objectives: To explore the salt reductions made over time in packaged bread sold in the UK, the biggest contributor of salt to the UK diet.

Study design: Cross-sectional surveys were carried out on the salt content of breads available in UK supermarkets in 2001(40 products), 2006 (138) and 2011 (203).

Main outcome measures: The primary outcome measure was the change in salt content per 100g over time. Further measures included proportion of products meeting salt targets and differences between brands and bread types.

Results: The average salt level of bread was 1.23±0.19g/100g in 2001, 1.05±0.16 in 2006, and 0.98±0.13 in 2011. This shows a reduction in salt/100g of ≈20% between 2001 and 2011. In the 18 products which were surveyed in all three years, there was a significant reduction of 17% ($p<0.05$). Supermarket own-brand bread was found to be lower in salt compared to branded bread (0.95g/100g compared to 1.04g/100g in 2011). The number of products meeting the 2012 targets increased from 31% in 2001 to 71% in 2011 ($P<0.001$).

Conclusions: This study shows that the salt content of bread has been progressively reduced over time, contributing to the evidence base that a target based approach to salt reduction can lead to reductions being made. A wide variation in salt levels was found with many products already meeting the 2012 targets indicating that further reductions can be made. This requires further progressive lower targets to be set, so that the UK can continue to lead the world in salt reduction and save the maximum number of lives.

Key words: bread, reformulation, public health, food industry, salt, sodium

ARTICLE SUMMARY

Article focus:

- Populations around the world are consuming too much salt, largely as a result of the high salt content of processed foods.
- The UK is leading the world in salt reduction through the implementation of progressively lower voluntary salt targets across >80 categories of foods.
- Bread is the largest contributor of salt to the UK diet – this research uses a series of cross-sectional surveys of the salt content in UK packaged bread to examine the reductions made over time and the progress made towards meeting the 1g/100g target.

Key messages:

- The salt content of bread sold in the UK has been progressively reduced over the last decade.
- The results demonstrate that a target based approach to salt reduction can work to reduce the salt content of popular food.
- Other countries around the world need to follow the UK's lead and set salt targets.

Strengths and limitations of this study:

- This study tracks the salt reductions made in bread over time. It is the first UK study of this kind, adding to research using the same methodology carried out in Australia and New Zealand. The results indicate that progressive lower salt targets can work to reduce salt levels of processed foods and can serve as evidence to encourage other countries around the world to follow this approach to salt reduction.

- The data used was based on manufacturers labels; due to product name changes, trend analysis was only possible for a limited number of products; No ingredient information was collected, so changes in formulations could not be examined.

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This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

COMPETING INTERESTS

HB was an employee of Consensus Action on Salt & Health (CASH), a nonprofit charitable organisation at the time of conducting this study. FH is a member of CASH and its international branch World Action on Salt & Health (WASH) and does not receive any financial support from CASH or WASH. GM is Chairman of Blood Pressure Association (BPA), Chairman of CASH and Chairman of WASH. BPA, CASH and WASH are nonprofit charitable organisations. GM does not receive any financial support from any of these organisations. KJ is Campaign Director at CASH, WASH and BPA.

INTRODUCTION

There is strong evidence that a high salt intake increases blood pressure and thereby increases the risk of cardiovascular disease (i.e. strokes, heart attacks and heart failure) and kidney disease.[1 2] A high salt intake also has other harmful effects on health, e.g. increasing the risk of stomach cancer[3] and indirectly linked to obesity.[4] Furthermore, it has been demonstrated that a reduction in population salt intake is one of the most cost-effective measures to improve public health.[5]

Populations around the world are consuming salt in quantities that far exceed physiological requirements.[6] As such, The World Health Organisation (WHO) has recommended salt reduction as one of the top three priority actions to tackle the non-communicable disease crisis.[7 8]

Approximately 75% of the salt consumed in the UK and other developed countries comes from processed foods, and is added by food manufacturers prior to consumer purchase.[9] A wide range of food products contain salt, including everyday foods such as bread, breakfast cereals, sauces and processed meat.

The UK has successfully developed a voluntary salt reduction programme which is considered one of "the most successful nutrition policies in the UK since the second world war".[10] First developed by Consensus Action on Salt & Health (CASH), the strategy involves lowering salt intakes by a) reducing the salt levels of processed foods by a gradual reduction in the amount of salt added to the processed foods by 40% and b) reducing salt in cooking or at the table by 40%. In order to reduce salt intake from the 9.5 g/d to the projected target of 6.0 g/d in adults, the Food Standards Agency (FSA) then set a series of progressively lower salt targets for over 80 categories of food,[11 12] which have now been incorporated as part of the Government's Public Health Responsibility Salt Pledge.[13] Other countries around the world, including Australia, United States and Canada, are following the UK's lead and are adopting a similar target based approach to salt reduction.[6]

To date, significant progress has been made by many food manufacturers and retailers in the UK, with salt content being reduced across the board, including by up to 50% in breakfast cereals,

45% in biscuits, 40% in pastry products and 25% in cakes and pasta sauces.[14] Furthermore, it has been reported that less salt is being added at the table by consumers.[15] The average salt intake in the UK population is steadily decreasing in parallel, with intakes currently estimated at 8.1g/d,[16] the lowest known accurate figure of any developed country (i.e. measured by 24h urinary sodium excretion).[6] This represents a 15% reduction from 2001 (9.5g).[17] This reduction is estimated to be saving ≈9000 lives every year and resulting in major cost-savings to the UK economy of more than £1.5 billion per year.[18 19]

Bread is of particular interest to policymakers wishing to introduce a salt reduction strategy. On the one hand bread is an important component of the diets around the world.[20 21] In the UK for instance, National Diet and Nutrition Surveys (NDNS) shows that bread contributes more than 10% of daily intake of protein, thiamine, niacin, folate, iron, zinc, copper and magnesium; one-fifth of fibre and calcium intakes; and more than one-quarter of manganese intake.[22] However, the NDNS also indicates that bread is the single largest contributor of salt to the UK diet, providing almost a fifth (18%) of salt intake from processed foods (i.e. 18% of 75% total intake). This equates to approximately 1.07g salt per person per day from bread alone. Bread is also the leading contributor in other countries such as United States (7.4%),[23] New Zealand (26%)[24 25] and Australia (≈20%).[26 27] Reductions in the salt content of bread would therefore have a significant impact on salt intake and as such has always been a leading focus of the UK's salt reduction strategy.

Despite the important role that bread plays in the UK diet, not only as a source of nutrients but as the leading contributor of salt, very little work has been conducted looking at the changes in the salt content of bread in the UK.

In Australia, where authorities are replicating the UK's salt reduction strategy, a paper published in 2011 explored the changes to sodium content in Australian and New Zealand bread between 2007 and 2010. The paper reported reductions, although only small, to the salt content of bread in these countries.[27] Other studies that focus on salt in bread, have tended to focus on practical issues related to salt reduction, including technical feasibility and the potential for use of salt replacers.. For instance, one study focused on how sodium may be reduced by increasing potassium levels.[21]

Given the importance of bread as a contributor of salt to the UK diet, coupled with perceived success of the UK's salt reduction campaign, the objective of this paper is to describe the progress made in reducing the amount of salt added to bread in the UK and discuss the successes and challenges that lie ahead in the UK in terms of further salt reductions so as to provide recommendations for both the UK and International Governments on salt reduction programmes.

METHODS

Data Collection

Three surveys were carried out, with the first one in 2001, the second one in 2006 and the last one in 2011. The survey in 2001 was carried out by the FSA[28 29] and the last two surveys by CASH.[30 31] For all surveys, the data was collected from product packaging and nutrient

information panels. The 2011 survey was designed as a comprehensive survey of all breads available in a snapshot in time, using one large store per retailer in the UK. The 2006 survey was also designed as a comprehensive survey, but excluded 'repetition' products e.g. where there were two similar products, for instance two crusty white products, by the same company, or where the same product was available in different sizes. The FSA survey carried out in 2001 was not designed as a comprehensive survey, instead including a single example of a premium and standard white, brown and wholemeal loaf from each of the leading supermarkets and brands. Whilst not comprehensive, the selection of generic products from a number of companies is likely to ensure that the data collected is reflective of the situation at that point in time. For each loaf, the data collected included the company name, product name, pack weight, serving size, sodium/salt per 100 grams and sodium/salt per portion. When there were missing figures, they were calculated where possible, e.g. the missing sodium or salt values were converted by multiplying by 2.5 (sodium to salt) or dividing by 2.5 (salt to sodium). All data was double checked after entry, and a further 5% of entries were checked against the original source in a random selection of products.

Inclusion/exclusion criteria: Data were collected from each of the major UK supermarkets (Asda, Sainsburys, Tesco, Waitrose, Morrisons, The Co-operative and Marks and Spencer) to represent salt levels of bread in the UK. Packaged sliced loaves of bread were included, including white, wholemeal, seeded, granary, half and half, and brown. Thick and medium sliced breads were included. When two sizes were available, the standard 800g loaves were used. Data were collected for supermarket own brand bread and for branded bread products available. 'Special' breads such as rye and soda bread, ethnic breads and fresh breads were excluded

Product categories: Products were categorised into one of the following 3 groups: White (all white standard loaves), Wholemeal (all wholemeal loaves, including wholemeal seeded/granary), Brown (brown, white granary/seeded, 50:50 and wheatgerm). This was based on the criteria used for the NDNS data collection.[22] 'Other' breads were excluded as data for these breads was not collected in earlier surveys. Data was also categorised separately into branded or supermarket own brand.

Statistics

Comparison among products within each year: Unpaired T-test was used to compare the levels of salt between supermarket own brand and branded products within each year. One Way ANOVA with Bonferroni post hoc adjustment was used to compare the salt levels of different bread types (brown, white and wholemeal).

Comparison of the same products over the years: Repeated Measure ANOVA was used to test whether there was a significant change in salt content of bread over the years. For the purpose of this comparison, only the products with data available in all 3 surveys were included in analysis. In 2 places where a product was available in 2001 and 2011 but not 2006, the 2006 figure was assumed to be the same as 2001.

Data are reported as mean, SD, SE as indicated. Significance in all tests carried out was deemed as being $p<0.05$. All data was analysed using SPSS software.

Salt targets: For each year and category, we calculated the total number and percentage of products that met the Department of Health's 2012 salt target for bread (i.e. ≤ 1g/100g).[32]

RESULTS

Within year analysis

Table 1 shows the levels of salt in bread for all 3 surveys.

2001

A total of 40 bread products met the inclusion criteria. One outlier was excluded from analysis as the salt level was much lower than all comparable products, and also much lower than those made by the same company. In the remaining 39 bread products, the average salt level per 100g was 1.23±0.19g with a range of 1.00g to 1.75g.

Table 1 shows the mean salt level for branded and supermarket, as well as salt level by bread type (white, brown and wholemeal). The salt level was slightly higher in branded compared with supermarket own brand, but this difference was not statistically significant (p=0.189). There was no significant difference in the salt content per 100g of different bread types (p=0.291).

2006

The average salt level per 100g was 1.05±0.16g with a range of 0.55g to 1.50g. Of the 138 products, 51 were branded products and 87 were supermarket own brand. The salt level in branded products was significantly higher compared with that in supermarket own brand

(p<0.01) (Table 1). No significant difference was found between the salt content per 100g of different bread types (p=0.104) (Table 1).

2011

The average salt level per 100g was 0.98±0.13g with a range of 0.58g to 2.03g. Of the 203 products, 78 were branded products and 125 were supermarket own brand. The salt level in branded products was significantly higher compared with that in supermarket own brand (p<0.01) (Table 1). No significant difference was found between the salt content per 100g of different bread types (p=0.410) (Table 1).

Changes in salt levels in bread over the years

Taking all products together, there was a gradual reduction in the salt content of bread. On average, salt level was reduced by 20% from 2001 to 2011.

There were 18 products from 9 different companies that had salt levels surveyed in all three years. Ten of the bread products were white, and 8 were wholemeal. Eight of the products were branded and 10 were from retailers. The average salt levels per 100g for these 18 products were 1.24±0.16g in 2001, 1.14±0.25g in 2006 and 1.03±0.25g in 2011 (p<0.05 by repeated measures ANOVA). This represents a reduction of 17% from 2001 to 2011. Note that these averages are slightly different from those when all products were included in each year and this trend analysis merely reflects reductions made in the same products rather than overall products available.

Comparing with the 2012 targets

The 2012 bread target, as part of the Department of Health's Responsibility Deal, is ≤ 1g salt/100g. Our results showed that, from 2001 to 2011, there was a significant increase in the number of products meeting the 2012 targets (Table 2). In 2001, 30% of products (12/40) met this target, increasing to 52% in 2006 (72/138) and 71% in 2011 (144/203). A greater number of supermarket own brand products compared to branded products met this target in all years: 38% compared to 21% in 2001; 71% compared to 20% in 2006; 89% compared to 42% in 2011.

DISCUSSION

The UK is currently leading the world with salt reduction using a strategy, developed in 2003 by the UK Food Standards Agency and CASH, based on a set of voluntary targets which promote the gradual reduction in the amount of salt added to processed foods, in particular those foods that contribute most salt to the UK diet. Our paper, using the example of the biggest contributor of salt to the UK diet – bread, demonstrates that a national target based approach to reformulation can be a successful method for reducing the salt content in processed foods.

Significant reductions have been achieved

Our repeated surveys of the same bread products over time demonstrates that significant reductions have been made in the salt content of bread and that there has been a significant increase in the number of products that meet the salt targets over the last 10years. Further analysis of all the breads surveyed in each year shows that the bread on sale in 2011 contains, on average, 20% less salt than the breads surveyed in 2001. The reductions that have been made since 2001 have gone unnoticed by the general public, with no impact on sales or consumer behaviour.[33] Interestingly, no significant difference in the salt content of white, wholemeal and

brown bread was found, despite the common perception that wholemeal and brown bread are healthier alternatives to white bread.[34]

Branded products were found to contain approximately 10% more salt compared to supermarket breads in 2011 (1.04g vs. 0.95g, $p<0.01$). Although brands have made similar reductions compared to supermarkets over the last 10 years (0.23g/100g compared to 0.24g/100g), the branded products started with a higher level of salt, and brands now need to ensure they make further reductions to come in line with the lower levels seen in supermarket own brand breads.

The fact that supermarket own brand breads have been produced with lower levels of salt demonstrates that delivering salt reduction appears not to be a technical issue related to bread manufacture. Corporate decisions about food composition are often based upon factors such as taste and price, rather than health. However, evidence suggests that where salt reductions are made gradually in bread over time, no reduction in consumer preference is reported.[35 36] Indeed, a number of studies have shown that gradual reductions can go unnoticed by the consumer. For instance, a controlled study by Girgis et al[35] found that gradual reductions of up to a quarter in the salt content of bread over a 6 week period went largely unnoticed and that further reductions of up to 67% were possible when the bread was served with a sweet or savoury filling. Another study by Tuorila-Ollikainen et al[37] investigated the effect of salt reduction on bread consumption over 12 weeks 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.

Products specifically promoted as 'low/no/reduced salt' are sometimes perceived has having a different taste.[38] This emphasises the need for widespread industry gradual reductions to reduce population salt intake, rather than relying on consumers opting for lower salt versions. To ensure continued consumer acceptance of lower salt foods it is important that all manufacturers, particularly branded bread manufacturers in the UK, continue to reduce the salt content of their bread, in line with the levels found in supermarket breads, so as to ensure the greatest benefit for public health.

Implications for global public health and learnings from the UK

Our findings support previous studies that have indicated a reduction in salt in popular household products, such as a reduction of up to 50% in breakfast cereals, 45% in biscuits, 40% in pastry products and 25% in cakes and pasta sauces. [14]

A programme, based on a series of gradual reductions across the sector over a period of years, can lead to a large cumulative reduction in salt content of foods and therefore in population salt intakes. Additionally, a program that removes a small amount of salt from every product reduces salt intake in the whole population starting at one year of age when processed food products with added salt are introduced. With the need to address social inequalities in health, both in the UK and worldwide, this programme sees those consuming the largest quantities of the saltiest foods obtaining the greatest benefits. Programs that target the whole food chain such as this also have a significant cost advantage because additional consumer education and behaviour change is not required to achieve results. Furthermore, salt reduction, and the costs associated with it, can be

absorbed into the continuous reformulation programmes already undertaken by manufacturers and retailers.

Despite the fact that clear reductions in salt content in bread are being made in the UK, there is still a marked variability in the salt levels of similar bread products as well as differences between branded and supermarket own brand bread. This demonstrates that while a voluntary target based approach works to encourage industry reductions, the targets needs to be coupled with the forceful government or quasi-government agency, e.g. in the UK the Food Standards Agency and subsequently the Department of Health, to ensure all companies are aware of the targets and make reductions to achieve the same low levels in salt content so as to have the maximum benefit on population health. When countries are looking to set their own targets, they should make sure that a monitoring strategy is included so that all products are reduced across the board, and to ensure that companies feel that there is a level playing field. This can be greatly helped by forceful Non-Government Organisations (e.g. in the UK, CASH) that monitor progress and highlight companies that are not complying.

Technological solutions that enable the production of much lower salt products with no loss in the sensory characteristics of the food may be closely guarded commercial secrets or require investment in research and materials that only large businesses can afford. Despite there being advantages to sharing salt reduction information the competition-based business model does not lend itself to industry-wide dissemination of innovation. A supporting pledge in the Responsibility Deal indicates that information should be shared between companies, but more work could be done and the Department of Health needs to encourage this.

High salt diets are not a problem unique to the UK.[6] Other countries have started to follow the UK's lead by setting some of their own salt reduction targets. In Australia and New Zealand, for instance, bread targets of 400mg sodium/100g (1g salt /100g) and 450mg sodium/100g (1.13g salt/100g) respectively were introduced in 2010.[39] Monitoring reports from these countries (2007-2010) reported a 7% reduction in the salt content of bread in New Zealand, but did not observe a reduction in Australia.[27] However, during the 3 year period, the proportion of products in each country meeting the target increased from 29% to 50% in Australia and 49% to 90% in New Zealand, suggesting that reductions are likely to have occurred not only in New Zealand, but also in Australia, where reductions may have occurred, but not across the board. To highlight this point, while a reduction of up to 17% was seen in the breads produced by two retailers and one manufacturer included in the research, an increase of 10% was seen in a fourth company. This indicates that, while the first step has been taken to reduce salt via a target based approach, further work in monitoring and engaging all members of the food industry is required to ensure that salt reduction occurs across the board so as to create a level playing field for all of the companies involved and also to see the biggest benefits for public health

Other countries around the world now need to follow suit and set up a target based approach to reducing salt content of processed foods. While the food category emphasis may differ between countries, the concept of using salt targets to achieve a 'level playing field' amongst the industry is universal. A product like bread is widely consumed internationally and this research demonstrates how targets can work to lower the levels of salt.

LIMITATIONS

Our study was based on salt content data provided on bread labels in store, hence we relied on the accuracy of the data provided on the label. However, the study carried out by the Food Standards Agency showed that the analysed figures did match those stated on the labels.[40] It is assumed that the manufacturers provide accurate and up to date information in line with EU Regulations.

In order to provide the most accurate information about the changes in salt levels over time, in particular the reformulation that has occurred, the same products need to be used for analysis. However, due to product name changes it was often hard to ensure that all products available were used as there was no way of determining if a similar named product was a different product or a newly named product. This also means that a limited number of products were used for trend analysis, but our results from both repeated surveys of the same products and the overall analysis of all products have consistently shown a reduction in salt levels in bread products on sale in the UK.

When collecting data we did not capture ingredients list, this means we are unable to ascertain if salt has been replaced with any other ingredients/additives in the bread that came out lowest. Such data should be collected in future surveys.

There is no evidence available to prove that the salt reduction seen in bread has translated into a reduction in salt intake in the UK population. However, given that there is no evidence of a change in the sales of bread in the UK, that the salt content of bread has declined and that the salt

intake of the population has declined in parallel, it is likely that the reductions in salt made in bread have contributed to the measured reductions in population salt intake.

CONCLUSION

This research, using the example of bread, demonstrates how a target based approach to salt reduction can lead to salt reductions being made across the board. There is evidence that companies could substantially reduce the amount of salt further, based on the variation in salt levels found.

This research presents a clear example of how a salt reduction strategy, based on targets in key food categories, can ensure that salt levels are reduced without loss of sales and no consumer reaction. Governments around the world need now to follow the UK's lead and set targets on the biggest contributors of salt to the diet so as to prevent thousands of deaths every year.

Authors contributions

GM conceived the idea and designed research; HB conducted research; HB and FH analyzed data; HB wrote the first draft of the manuscript and all authors contributed to the interpretation of the results and revision of the manuscript, and approved the final manuscript. GM had primary responsibility for final content.

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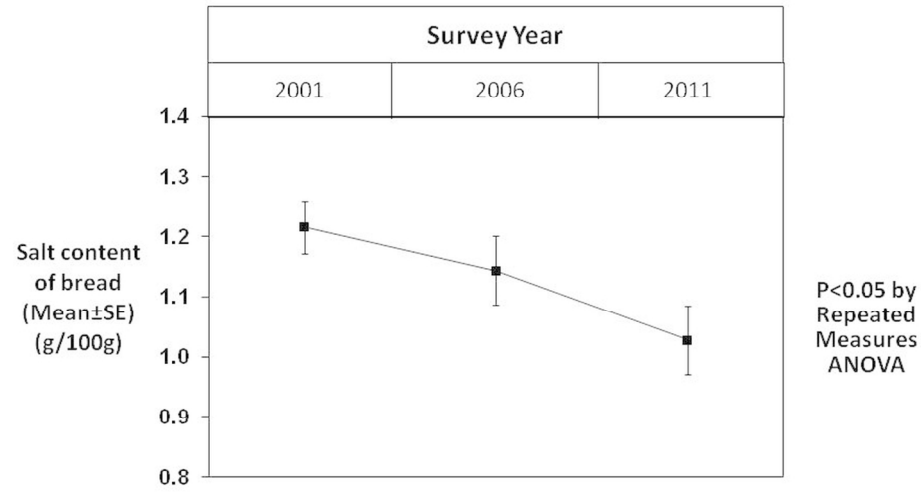
Legend for figure 1: Salt content in bread in repeated surveys, 2001-2011

Table 1. Average salt levels in breads for each year (g salt/100g)

	2001		2006		2011		Change from 2001 to 2011	
	N	Mean±SD (range)	N	Mean±SD (range)	N	Mean±SD (range)	Mean	%
Overall	39	1.23±0.19 (1.00-1.75)	138	1.05±0.16 (0.55-1.50)	203	0.98± 0.13 (0.58-2.03)	0.25	20%
Branded	18	1.27±0.18 (1.00-1.50)	51	1.12±0.13 (0.55-1.25)	78	1.04 ±0.15 (0.75-2.03)	0.23	18%
Supermarket	21	1.19±0.19 (1.00-1.75)	87	1.02±0.16 (0.60-1.50)	125	0.95 ± 0.10 (0.58-1.20)	0.24	20%
White	22	1.22±0.18 (1.00-1.50)	46	1.09±0.15 (0.70-1.50)	75	1.00±0.10 (0.58-1.20)	0.22	18%
Brown	7	1.16±0.15 (1.00-1.35)	55	1.02±0.18 (0.55-1.50)	71	0.98±0.18 (0.65-2.03)	0.18	16%
Wholemeal	10	1.30±0.23 (1.00-1.75)	37	1.06±0.11 (0.90-1.30)	57	0.97±0.09 (0.74-1.18)	0.33	25%

Table 2. Products meeting the 2012 target of ≤ 1g salt/100g in each year

	2001		2006		2011		
	N	N (%) meeting target	N	N (%) meeting target	N	N (%) meeting target	P value by χ^2 test
Overall	39	12 (30%)	138	72 (52%)	203	144 (71%)	p<0.001
Branded	18	4 (21%)	51	10 (20%)	78	33 (42%)	P<0.01
Supermarket	21	8 (38%)	87	62 (71%)	125	111 (89%)	P<0.01
White	22	6 (27%)	46	22 (48%)	75	50 (67%)	P<0.01
Brown	7	3 (43%)	55	31 (56%)	71	50 (70%)	P<0.01
Wholemeal	10	2 (20%)	37	19 (51%)	57	44 (77%)	P<0.01



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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page Number Reported
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Not applicable
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	Not applicable
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking	Not applicable

		account of sampling strategy	
		(*e*) Describe any sensitivity analyses	6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Not applicable
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-9
		(b) Indicate number of participants with missing data for each variable of interest	7-9
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	9
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	7-9
		Cross-sectional study—Report numbers of outcome events or summary measures	Not applicable
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-9
		(*b*) Report category boundaries when continuous variables were categorized	Tab 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7-9 & Tab 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	9-10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11 & 14
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.