Public Health England

Protecting and improving the nation's health

Sugar Reduction: The evidence for action

Annexe 5: Food supply

About Public Health England

Public Health England exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. It does this through world-class science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. PHE is an operationally autonomous executive agency of the Department of Health.

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Annexe 5a. Salt reduction case study

In 2003, SACN published its report on ‘Salt and health’.[1] This concluded that a reduction in average salt intakes to 6g per day, with lower levels set for children, would lower population blood pressure levels and reduce the risk of cardiovascular disease. The UK Food Standards Agency (FSA) and Department of Health (DH) commited to a programme encouraging reformulation of foods to reduce salt content, supported by a campaign to raise awareness and offer guidance to the public.

Reformulation

Salt model: This model was devised to support the development of the reformulation programme.[2] It showed the contributions of food categories to intakes and included an ‘illustrative average target level’ for each category. This, together with a 40% reduction in discretionary salt use, showed one way in which the 6g per day target intake for adults could be achieved. The model proved useful in prompting initial feedback from industry about the practicalities and limitations of reformulation and demonstrated the depth of work required across the industry on a whole to reduce intakes.

Salt reduction targets: To date, four sets of targets have been published (2006, 2009, 2011 and 2014) covering around 80 individual product categories. These provided guidance to industry on the levels of salt that they should be aiming to achieve and resulted in gradual, stepwise reductions in salt levels being made across the categorya and provided a basis for monitoring progress.

The targets were set based on various types of evidence including: the salt content of foods from food label data; major contributors to salt intakes from dietary survey and market share data; estimates of dietary intake from urinary analysis. Data was uniform and enabled net effect to be assessed. Additional information that was considered included reductions achieved to date, the timing of reformulation cycles and the costs associated with reformulation.

A mix of average and maximum targets were used:

- maximum targets stimulate manufacturers to look at products that are high in sodium, benchmark them against competitors and make reductions
- average targets aim to lower the overall salt levels in a category, while maintaining flexibility to allow for variation between individual products (eg ready meals)

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[a] After some consideration it was concluded that no separate targets were needed for children’s foods. These were felt to be difficult to identify and the same foods generally contributed to intakes of adults and children.

The salt reduction targets encouraged removal of salt without replacement with potassium chloride or other ‘salt replacers’, so that palates gradually adjusted to a lower salt flavour and those with renal insufficiency[b] were not put at risk.

Individual food groups present different challenges to reformulation and after early relatively ‘easy wins’ were achieved, progress has slowed. In addition, the use of salt replacers has increased in the last couple of years of the programme. Nevertheless, the commitment to continued action by the food industry should not be underestimated.

Key to the success of the reformulation programme were:

- the collaborative but authoritative approach taken by the FSA and DH in consultation with industry. This helped with understanding and resolving technical and other issues. Close consultation encouraged engagement and produced challenging but achievable targets
- use of market share analysis to determine where to focus efforts although the targets included a broad range of product types and applied to all food businesses
- the clear monitoring through a ‘salt commitments table’ enabling organisations to demonstrate progress using transparent, meaningful data, and enabling an even playing field, to avoid issues of competition
- the strong evidence base for action on a broad front encouraged continued engagement

While retailers and manufacturers were engaged from the start, commitment from the out of home sector has been more limited. The sector considers that it works and provides food in different ways to that available through food retail and that consumers have different expectations of the food eaten when “out for a treat”. In addition, many businesses didn’t have salt data for their products and dishes. Although some businesses adopted the targets, many considered that these could not work for them. Significant efforts were made to work with this sector in different ways leading to the establishment of different parameters for “achievement”, and devising different work programmes and targets for this sector specifically. Despite these efforts, many in the out of home sector remain unengaged.

Public awareness

The public awareness campaign aimed to raise consumers’ awareness of the health risks associated with high salt intakes, provide practical information to help them make reductions, and support reformulation by explaining why foods may change. There were four phases to the campaign, run in 2004, 2005, 2007 and 2009; after this messaging

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[b] Most salt replacers include potassium. Those with renal insufficiency – those with kidney disease, older people and the very young – are not able to process potassium properly and therefore need to avoid salt replacers.

was included in the Change4Life health marketing campaign. The presentation of each phase was different, but all used consistent key messages based on the 6g per day intake target. Each phase was informed by focus groups and consumer testing to ensure that messages resonated with the key audiences.

All four phases of the campaign used a mixture of methods and materials to get the message across, including advertising, generating news and broader press coverage, distributing information, an interactive roadshow and dedicated website.

Evaluation of the campaigns demonstrated that they had been successful in highlighting the link between eating too much salt and higher blood pressure and in changing consumer attitudes and actions.

Key elements contributing to the success of the campaign included:

- the fresh approach taken, both in the key messages and the visual approach
- the audience's journey. Key facts were included in every phase but these were made broader and deeper with additional information to help make changes with each subsequent stage
- the work to make the messages clear to the main audience by targeting the most appropriate communication channels
- capitalising on the 'newness' of the messages in the early stages
- rigorous evaluation of each stage to inform the development of the next phase

International context

It is important to recognise the worldwide impact that the UK salt reduction programme has had. Other countries have copied the UK approach including Australia, Canada, the US, South Africa and collectively across South America. The European Commission also established a framework for action on salt based on the UK programme.

The World Health Organization (WHO) has been encouraging global reduction to reduce salt intakes and holds up the UK work as an example of good practice.[3] The UK was invited by WHO to set up and chair a Europe-wide salt reduction action group, and to host a pivotal international conference on salt reduction in 2010 which fed into the development of a toolkit for use internationally.

With an increasingly international food chain, the UK will benefit from salt reduction work being extended worldwide. Reductions in foods available in the UK through multinational companies will complement the actions of domestic producers.

Overall result of programme

The salt reduction programme overall has so far proved to be successful. Intakes have significantly reduced between 2001 and 2011.[4] A reduction in blood pressure, and the incidence of stroke and coronary heart disease, has been attributed by some to the success of the salt reduction programme.[5]

Annexe 5b. A secondary analysis of the National Diet and Nutrition Survey (NDNS) to assess the potential impact of reformulation on sugar intakes

Approach

This preliminary analysis examined the impact on sugar[c] intakes in adults and children of reducing the sugar content of eight food categories, both singly and in combination. Eight categories, based on National Diet and Nutrition Survey (NDNS) food groups that contribute to sugar intake, were identified:

- soft drinks
- biscuits
- buns, cakes, pastries, fruit pies and puddings
- sugar confectionery
- chocolate confectionery
- yogurt, fromage frais and dairy desserts
- breakfast cereals
- table sugar[d]

Using the NDNS years 1 to 4 (2008/09 to 2011/12) dataset,[6] the impact of reducing the sugar content of each food group by 50%[b] was calculated at population average level for adults and children in the following age groups: 1½ to 3 years; 4 to 10 years; 11 to 18 years; 19 to 64 years; 65 years and over. A 50% reduction was used as initial work had suggested that a reduction of this magnitude to the sugar intake from soft drinks would make a substantial impact on sugar intake in most age groups. It was decided to apply the same level of reduction in all food groups for simplicity. However, no assessment has been made of the feasibility of achieving these reductions.

The calculations assumed that the energy lost from reducing the sugar content of products is not replaced by increased intake of fat, starch, protein or alcohol elsewhere in the diet (ie no energy substitution). If some energy substitution did occur the fall in the percentage of energy from sugar would be slightly larger (by 0.3% to 0.6% in the all categories scenario).

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[c] For the purposes of this analysis sugar is defined as non-milk extrinsic sugars (NMES) as reported in the NDNS
[d] Calculations for table sugar assume reduced consumption rather than reformulation

The same level of reduction in sugar intake could be achieved by reducing consumption of the categories instead of or as well as reformulation.[b] However, for products containing fat, starch or protein as well as sugar the impact on the percentage of energy from sugar would depend on the nutrient composition of the foods of which consumption is reduced. This has not been taken into account in the calculations.

Findings

The results are presented in Table 1.

Reducing the sugar intake from soft drinks by 50% on average would result in:

- adults aged 19 to 64 years: sugar intake reduces by 5g/day; to 11.6% food energy
- children aged 11 to 18 years: sugar intake reduces by 11g/day; to 13.8% food energy
- children aged 4 to 10 years: sugar intake reduces by 5g/day; to 13.9% food energy

Reducing sugar intake from all the categories in table 1 combined by 50% would result in:

- adults aged 19 to 64 years: sugar intake reduces by 17g/day; to 9.2% food energy
- children aged 11 to 18 years: sugar intake reduces by 26g/day; to 10.9% food energy
- children aged 4 to 10 years: sugar intake reduces by 19g/day; to 10.7% food energy

Table 1. Sugar intakes post reformulation scenarios resulting from 50% reductions in the sugar content of key food groups

Age:	**1½ to 3 years**			**4 to 10 years**			**11 to 18 years**			**19 to 64 years**			**65 years +**		
Current sugar intakes:[e]	36.1g/day; 12.0% food energy			60.8g/day; 14.9% food energy			74.2g/day; 15.8% food energy			58.8g/day; 12.5% food energy			51.6g/day; 11.8% food energy		
Food Group	new sugar intake g/day	sugar saving g/day	new % food energy from sugar[f]	new sugar intake g/day	sugar saving g/day	new % food energy from sugar	new sugar intake g/day	sugar saving g/day	new % food energy from sugar	new sugar intake g/day	sugar saving g/day	new % food energy from sugar	new sugar intake g/day	sugar saving g/day	new % food energy from sugar
Soft drinks	34.3	1.9	11.5	56.0	4.8	13.9	63.5	10.7	13.8	54.2	4.6	11.6	49.6	2.0	11.4
Biscuits	34.7	1.4	11.6	58.5	2.3	14.4	71.6	2.6	15.3	57.1	1.7	12.2	49.9	1.7	11.5
Cakes, pastries puddings etc	35.0	1.1	11.7	58.1	2.7	14.3	72.2	2.0	15.4	57.0	1.8	12.2	48.8	2.8	11.2
Sugar confectionery	35.3	0.8	11.8	58.6	2.2	14.4	72.3	1.9	15.5	58.3	0.5	12.4	51.3	0.3	11.8
Chocolate confectionery	34.9	1.3	11.7	58.5	2.3	14.4	71.1	3.0	15.3	56.7	2.1	12.1	50.6	1.0	11.6
Yogurts, dairy desserts etc	33.8	2.4	11.3	58.9	1.9	14.5	73.2	0.9	15.6	57.8	1.0	12.3	50.4	1.2	11.6
Breakfast cereals	35.0	1.1	11.7	58.5	2.3	14.4	71.8	2.3	15.4	57.3	1.5	12.2	50.4	1.2	11.6
Table sugar	35.7	0.5	11.9	59.9	0.9	14.7	71.9	2.2	15.4	54.9	3.9	11.8	48.2	3.4	11.1
All	**25.6**	**10.5**	**8.8**	**41.5**	**19.3**	**10.7**	**48.5**	**25.6**	**10.9**	**41.6**	**17.2**	**9.2**	**38.1**	**13.5**	**9.0**

[e] Current % energy from sugar has been recalculated on a global average basis to be comparable with the modelled figures
[f] New % food energy from sugar assumes that there is no substitution of energy intake from sugar with energy from other sources. If energy substitution occurred then the percentage of energy from sugar would be slightly (0.3 to 0.6 percentage points) lower than shown here

Annex 5c. Literature review of ‘sweetness’

Summary

High intakes of sugar are associated with increased risk of dental caries and a higher daily energy intake, contributing to an increased risk of overweight or obesity. The purpose of this paper was to provide an overview of the literature and to ascertain the available evidence testing:

- whether a preference for food/drink high in sugar can be reduced over time
- whether the addition of sweeteners to foods/drinks prevents this adaptation to less sweet foods
- alternatively whether the desired goal of a reduction in intake of sugar might be facilitated by the addition of no/low calorie sweeteners in maintaining consumer acceptance of sweet food/drink while mitigating the adverse effects of sugar

The PubMed database was searched using key search terms: ‘sweetne*’, ‘adapt*’, ‘innate’, ‘taste’, ‘addiction’. A snowballing methodology was then applied to identify any other relevant papers. A more intricate combination of search terms and a systematic method of searching for papers was not used for this review due to limited time and resources. This review does not seek, therefore, to cover the whole evidence base, merely to identify some key themes in the literature and provide a broad overview.

The review found that we have an innate desire for sweet foods, which seems to be heightened in childhood relative to later life. Although it would seem logical from experience of gradual reduction to the salt content of foods, further research is required to determine whether individuals’ taste preferences would adapt to a gradual reduction of the content of sugar or overall sweetness of foods and drinks or whether any adaptation would influence choice towards lower calorie foods and drinks. Evidence from randomised controlled trials suggests that replacing foods and drinks sweetened with sugar with those sweetened with no/low calorie sweeteners can be useful in weight management as they reduce the calorie content of the product while maintaining the desired sweet taste. How these study outcomes reflect behaviour in real life is however unclear. The evidence does not support the view that sugar is addictive in the same way as some drugs can be.

Introduction

The Scientific Advisory Committee on Nutrition (SACN) followed strict inclusion and exclusion criteria in its report ‘Carbohydrates and health’ to ensure the evidence considered was of sufficient quality to be able to draw sound conclusions. The committee therefore only assessed evidence from randomised control trials (RCTs) and prospective cohort studies. It concluded based on evidence from randomised control trials (RCTs) that as consumption of sugar[g] increases, daily energy intake increases thus contributing to a risk of overweight or obesity. Specific studies cited to support this included a number of RCTs in children and adolescents that found consumption of drinks sweetened with sugar as compared with those containing non-caloric sweeteners results in greater weight gain and increases in body mass index (BMI). It also found consistent evidence from prospective cohort studies that consumption of sugar increases the risk of dental caries and that consumption of sugar sweetened drinks increases risk of type 2 diabetes mellitus.[7] Reducing intakes of sugar would therefore be beneficial for public health. In terms of reducing intakes of sugar there are four options:

1. Encourage consumers not to add sugar to foods and drinks and to choose foods and drinks with a lower sugar content
2. Replace sugar within foods and drinks with non-caloric sweeteners
3. Gradually lower the content of sugar (and sweetness level) of food and drinks
4. A combination of all the above

A gradual step-wise approach to reducing the salt content of foods has successfully resulted in a significant reduction of the nation’s salt intake from 2001 to 2011.[8] There is research evidence showing that as exposure to salt decreases, individuals become accustomed to this and preferred levels of salt in food declines.[9,10] It is therefore possible that this is occurring in the population as salt intakes decrease and, by analogy that a gradual reduction in the sugar content of foods could result in a similar adjustment of the nation’s palates. For sugar, however, the picture is more complicated. In reducing the sugar content of foods, some manufacturers already replace some or all of the sugar with non-caloric or low-calorie sweeteners, which, while in some cases will reduce the calorie content (eg sugary drinks), maintains the high sweetness of the food. Salt levels in foods have generally been reduced and not replaced with lower-sodium formulations. It is important to note that the nature of sweet taste acceptance and effects of sweetness exposure on preferred levels may not be the same as for salt.

To explore this issue further a review of the evidence was performed to scope out the answers to key questions around sugar, sweetness and non-caloric or low calorie sweeteners. The purpose of this paper is to provide an overview of the literature and to ascertain the available evidence testing:

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[g] For the purposes of this review, ‘sugar’ is defined as free sugars. This includes all sugars added to foods plus those naturally present in fruit juices, syrups and honey. It does not include the sugars naturally present in intact fruit and vegetables or dairy products.

- whether a preference for food/drink high in sugar can be reduced over time
- whether the addition of sweeteners to foods/drink prevents this adaptation to less sweet foods
- or alternatively whether the desired goal of a reduction in sugar intake might be facilitated by the addition of (no/low calorie) sweeteners in maintaining consumer acceptance of sweet food/drink while mitigating the adverse effects of sugar

Methods

As the brief for this review was very broad, an initial search for papers published on PubMed was carried out using the following key search terms: 'sweetne*', 'adapt*', 'innate', 'taste', 'addiction'. There was no specific cut-off date for publication. A snowballing methodology was then applied to identify any other relevant papers. This is a method by which the papers identified in the initial search provide new references and names of authors in the relevant areas as well as those identified by colleagues and experts in the field. These were then identified through PubMed and in the grey literature including conference reports and press articles. This method requires judgement as to which papers are relevant to the review. It is not a systematic approach and risks 'cherry picking' certain papers while excluding others that may be of key interest. It is, however, a useful approach in obtaining a broad overview of a topic area when resources are scarce and time is limited. A more intricate combination of search terms and a systematic method of searching for papers was not used for this review, because it was intended to be a scoping paper to identify whether a full systematic review on the topic would be useful. This review does not seek, to cover the whole evidence base, but merely to identify some key themes in the literature. It therefore gives priority to the systematic reviews and meta-analyses identified on the subject. The review only considered peer review articles published in English.

Results

All types of studies have been included in this paper to illustrate some of the areas of research carried out to date. A number of good quality systematic reviews and randomised controlled trials (RCTs) were identified covering some topics, although in other areas these were limited. Some large (n>1000) prospective studies were also included, although many of the primary research papers found were small (ie n<100 in each study group). Caution should be applied when reading these sections due to the limitations of the small study samples. Numerous animal studies have been published on this topic, some of which are mentioned in this review. These studies should be treated with caution as the findings are not directly applicable to humans. A summary of the papers mentioned in this review are listed in tables 1 to 7.

The main themes that developed during the review have been arranged to answer a number of questions. These questions form the structure of the results section as follows:

- what drives food consumption?
- sweetness
- to what extent is observed variation in preferred levels of sweetness innate?
- how much does this inherently vary with age?
- what are the other key sources of individual variation?
- to what extent does variation in preferred levels of sweetness predict intakes of sweetened foods/drinks?
- does variation in environmental exposure to sweetness itself result in corresponding desire/intake of sweetened foods?
- is sweetness addictive?
- what is the effect of using low energy sweeteners on satiety, energy intake and energy balance?

What drives food consumption?

Before considering sweetness it is useful to consider what drives our food consumption. A narrative review carried out by Lowe & Butyrn (2007) concludes that "a*s the growing prevalence of global obesity suggests, an increasing proportion of human food consumption appears to be driven by pleasure, not just by the need for calories*".[11] In other words, there is a distinction between eating because we need to refuel following a prolonged period of food deprivation (homeostatic hunger) and eating out of enjoyment (hedonic hunger). Our inbuilt physiological mechanisms seem to be more effective at preventing starvation than excess consumption.[12,13,14] It seems that the abundance and continuous presence of highly palatable food may be enough to trigger hedonic hunger and, along with the easy affordability and social acceptability to consume energy-rich food and drink whenever, wherever and however one wants, provides the perfect recipe for an obesity epidemic.[15]

Food choice is dictated by many different factors including availability, cost, social occasion, convenience, environment, health, allergies, habit, culture, hunger and mood as well as sensations such as appearance, smell and taste.[16,17] Taste is, however, a key factor and perception of taste seems to vary from one person to another and under different conditions. Capaldi (1996) states that one way in which preference for food can be modified is flavour-flavour learning ie flavours that are repeatedly associated with an already preferred flavour, such as sweetness, will themselves become preferred, ie sweetness promotes the acquisition of liking for the flavours associated with it in food and drink.[18]

Sweetness

Sweetness is one of the five taste sensations (ie sweet, sour, salty, bitter and umami (eg monosodium glutamate)), mediated by receptors on the tongue.[19] Sweetness is typically associated with consumption of sugar naturally present in foods (such as fruits) or added to foods and drinks in manufacture, in cooking or at the table (mainly in the form of sucrose, a disaccharide made up of glucose and fructose). Different substances produce varying levels of sweet tastes compared to sucrose per calorie: some have a less sweet taste (glucose); comparable sweetness (some sugar alcohols eg sorbitol; high fructose corn syrups) or an even sweeter taste (fructose; maltitol, xylitol; intense sweeteners eg aspartame, saccharin and sweeteners from natural origin eg Stevia/steviol glycosides).[20] Sweetening agents that offer a sweeter taste per calorie of sweetener compared to sucrose enable manufacturers and individuals to reduce the sugar and potentially the calorie content of foods while maintaining the sweet taste.

Although approved as safe by worldwide regulatory bodies there is still a great deal of confusion among consumers as to the effect of low calorie/non-caloric sweeteners on health and wellbeing.[21] A study carried out in the US between 1998 and 1999 found 36% of adults (n=872) perceived foods containing artificial sweeteners to be 'not acceptable'.[22] It therefore seems some individuals may avoid consuming foods and drinks containing non-caloric sweeteners due to perceived health concerns and would prefer to consume higher calorie, sugar-containing foods and drinks. However, purchasing of low-calorie sweetened products has increased continuously in the US over recent years.[23,24] There have been numerous studies investigating their effects on energy balance, discussed later in this section.

To what extent is observed variation in preferred levels of sweetness innate?

Heightened preference for sweet tasting foods in infancy and childhood seems to be innate and is evident worldwide.[25] This predisposition to sweet taste is likely to have evolved in order to ensure acceptance of sweet, energy dense foods such as maternal milk, fruits and other foods at a young and vulnerable age and perhaps to reject bitter tasting foods that could potentially be toxic.[26] During a period of rapid growth, such as adolescence, high energy sources may also be favoured.[27]

Genetic testing has found that preference for sweet foods varies by genotype.[28,29, 30] Individuals with an increased sweet perception tend to prefer less sweet foods compared to less sensitive individuals. A number of other aspects have been thought to affect the interpreted 'sweetness' of a product, including temperature.[31]

How much does sweetness preference inherently vary with age?

Mennella et al. (2014) carried out a two day, single blind, intervention trial of children (n=108) and their mothers (n=83). Subjects were individually tested on two separate days for the concentration of sucrose most preferred in water on one day and in jellies on the other, following abstinence from eating for an hour. To summarise the preference method, they presented participants with pairs of differing sucrose (5ml) concentrations.

They tasted each item for five seconds and then pointed to which they preferred, without knowledge of the difference between the solutions. They found that the children preferred the sweeter concentrations of water and jellies compared to the adults.[32] Longitudinal data show that the higher levels of sweetness preferred by individuals during childhood and adolescence decline by early adulthood.[33] It is not known whether children and adolescents have a preference for more intense sweetness or whether they perceive less sweetness and thus require more sweetener to achieve the same level of perceived sweetness as adults.

A systematic review found taste perception declined in adulthood with increasing age, however the extent and significance of the decline varied between tastes (ie sweet, sour, etc); substances tasted (ie sugar for sweet, salt for salty etc); and the types of studies included. Only one third of studies concerning sucrose found perceived intensity of sweet taste specifically diminished within adulthood with advanced age.[34]

What are the other key sources of individual variation in sweetness preference?

A recently published systematic review found no clear relationship between sensitivity/perception of sweet taste and weight status.[35] Authors stated that there is a major methodological limitation in that most studies exposed participants to test stimuli solutions, which enables taste sensitivity to be directly comparable between subjects, but does not necessarily relate to habitual food choices. The authors suggest there is a need for further research using ‘comprehensive descriptions of the sensory attributes of a wide range of foods representative of diets’.

A narrative review provided by Bartoshuk et al. (2006) discusses the limitations of methods used to identify taste preferences and thresholds.[36] Taste perception is subjective and difficult to compare. As it is not possible to share individual experiences of sweetness directly with others, it is necessary to resort to indirect comparisons such as the use of labelled scales (for example a rating of ‘one’ representing no taste and a rating of ‘five’ representing very strong taste.[37] The authors suggest that such scales can provide valid within-subject and group comparisons where the labels denote the same intensities across the group ie they are tasting the same solutions. However, problems occur when comparing across groups or studies where the labels are likely to refer to differing intensities of solutions.

In summary, preference for sweet taste is innate, and evidence suggests preference varies due to a number of factors including age and genetics, but not weight. It is difficult to accurately compare the perceived ‘sweetness’ of a substance without using methods such as graded sucrose concentrations which does not allow meaningful comparisons between different studies.

To what extent does variation in preferred levels of sweetness predict intakes of sweetened foods/drinks?

Studies looking at whether heightened preference for sweetness results in greater consumption of sweet foods found mixed results. Some studies have found subjects preferring higher levels of sucrose tend to have higher dietary intakes of sugar and sweet foods[38,39] while others have found no such association.[40,41,42] Mennella et al. (2014) suggest that sweetness preference may not be linked to reported sucrose intake due to the use of non-sugar sweeteners in the food supply or as a result of parental control over the content of sugar in the diet.[32]

Does variation in environmental exposure to sweetness itself result in corresponding desire/intake of sweetened foods?

It is hypothesised that the more an individual is exposed to sweet foods and drinks, the more they will be accustomed to the taste, resulting in a greater preference for sweet food and vice versa. Anecdotal examples of this include individuals adjusting to having tea or coffee with/without added sugar/sweetener. An eight day intervention trial found that preferences for sweet foods can be promoted in children (n=59), but not in young adults (n=46) by repeated exposure to sweet foods.[43] In addition, changed taste preferences from repeated exposure in infancy are likely to be stable over a duration of 4 to 5 years.[44,45] A small trial (n=26) showed high short-term reproducibility of a simple, 5-level sucrose concentration procedure for measuring sweet taste preferences, suggesting that sweetness preference is consistent over three to seven days.[46]

It is interesting to link research into preferences for sweet food with preferences for salty food. A longitudinal study (8 weeks) (n=63)[47] and a five month sodium restriction experimental study (n=14)[48] found that a preference for less salty foods developed overtime from exposure to foods containing reduced levels of salt. In the UK, the setting of salt reduction targets for a wide range of foods commonly consumed in the UK diet has resulted in a significant reduction in salt intake from 2001 to 2011.[49]

Also of interest is whether regular consumption of intensely sweet foods, such as sugar sweetened drinks, in childhood influences taste preferences later in life. A prospective cohort study (n=1163)[50] found that a higher juice intake (≥16oz/day) at aged one year was statistically significantly associated with a higher juice intake; higher sugar sweetened drinks intake; and greater BMI during early and mid-childhood, when adjusted for maternal age, education, pre-pregnancy BMI, household income, child age, sex race/ethnicity and weight for length score at one year. Authors suggest that fruit juice can act as a gateway drink, encouraging a pattern for drinking sugar sweetened drinks later in life (which can lead to excess calorie intake) potentially through the impact of developing taste preferences at a young age. It should be noted that this is only one study and further evidence is required to confirm this finding.

The effect of restriction of foods on individuals' preferences is also of interest. Fisher and Birch (1999) assessed the impact of complete restriction of access to a palatable sweet food against a control.[51] Apple and peach bar cookies were tested to be neither highly desired nor disliked and were chosen as two highly similar variants of the same type of food to be given over a five week period to children aged three to five years (n=31). They looked at children's eating behaviour before, during and after a five week period of restricted access to a visible snack food (ie either apple or peach bar cookie depending on the group) placed in a jar in the middle of the table. They found that, compared to a highly similar non-restricted control food item (ie either an apple or peach bar cookie), the restricted food elicited significantly more positive comments, requests for it and attempts to obtain it during the five week restricted period. Therefore completely restricting access to a highly visible type of food might increase the desire for it and increase consumption in the long term when children are left to make their own food choices. The authors state that more research is needed to look into the effect of restricting access to non-visible foods ie those kept out of the home and away from supermarket checkouts.

In contrast to the effects of restricting access to sweet foods, one study suggests that exposure to a sweet drink compared to water may, in the short term, lead to greater restraint when presented with opportunities to consume a greater quantity of sweet food or drink. In a six month, single blinded Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial,[52] participants (n=169) in both arms of the trial, ie those in one arm consuming water and those in the other arm consuming low calorie sweetened drinks, had significantly reduced consumption of desserts at three months compared to baseline consumption, but the group consuming low calorie sweetened drinks had a significant reduction in dessert consumption at six months compared to the water group. A 12 week randomised control trial (n=303) demonstrated that consumption of drinks containing low calorie sweeteners was more effective at achieving weight loss than consuming water.[53] These two studies conflict with the hypothesis that consumption of non-caloric sweeteners promotes a desire for sweet foods, and the authors suggest the outcome may reflect effects of access to sweetened beverages on dietary adherence.

A double blinded trial[54] (n=30) looking at self-restraint mechanisms found that rinsing the mouth with a glucose mouthwash led to better immediate self-control compared to a non-caloric sweetened mouthwash. There were no significant differences across the mouth-rinse conditions on taste perceptions of the solutions. The proposed hypothesis for this is that the glucose triggers brain activity in areas associated with reward, motivation and regulation of motor activity. The authors suggest that as the glucose does not need to be ingested, rinsing the mouth with glucose could be a useful mechanism for individuals dieting or reducing sugar consumption. It should, however, be noted that mouth rinsing with glucose would not be advisable due to the link between free sugar and dental caries.

In summary, it seems that consuming highly sweet foods early in childhood may influence preference for, and consumption of, sweet foods and drinks later in childhood. However restriction of visible sweet foods seems to increase desirability in children, which may lead to an increase in consumption when left to their own devices. Evidence from two RCTs suggests that consumption of sweet drinks containing non-caloric sweeteners compared to consuming water may satisfy a desire for sweetness in the short term thus preventing consumption of a higher calorie treat at a later eating occasion.

Is sweetness addictive?

One of the bases for the possibility of food or drink being ‘addictive’ is the behaviour of ‘craving’ and the compulsion to consume a food. When investigating reported food cravings Benton (2010) found in his narrative review that it is not just sweet foods that are craved, but others including foods that are both sweet and high in fat. It seems to be the palatability of a food rather than its sweetness or sucrose content alone that influences preference for a food.[55] An indicator that food or specifically sugar is not ‘addictive’ in the same way as some drugs can be, is that food cravings appear to diminish with calorie restriction, as opposed to increasing, as an addiction model would predict. Cravings also do not appear after an overnight fast, but are more likely to be reported in the afternoon or evening. In addition, food cravings do not occur regularly enough to explain habitual food intake and thus explain the rise in levels of obesity on a global scale. In their narrative review, Corwin & Grigson (2009) identify that it also does not appear to be the food itself, but the manner in which it is consumed that seems to entrain an addiction-like process ie repeated, intermittent and ‘gorging’.[56] This is in line with the conclusions of a narrative review by Hebebrand (2014) that “eating addiction” is a more appropriate term than ‘food addiction’ or ‘sugar addiction’.[57]

In a published report of a symposium held on the evidence of food addiction by the British Nutrition Foundation,[58] the chair Professor Blundell and colleagues discuss the varying definitions used to express ‘addiction’ including the colloquial definition used to describe anything done to excess. The authors conclude that the mere concept of food addiction is not helpful to consumers as it may remove personal responsibility and undermines self-control. They state that there is a growing understanding of the neurological pathways that encode reward and pleasure and those that can differentiate between liking and wanting. These pathways are stimulated upon consumption of palatable food, as well as through drug use, which has raised questions as to whether food is addictive as is the case with certain drugs. These reward pathways are thought to have evolved from the need to maintain blood levels of nutrients essential for survival including the constant supply of glucose to the brain and therefore serve as a basis for behaviours leading to food acquisition. It is not surprising therefore, that consumption of food generates activity in these areas of the brain. It is more likely that the drugs are exploiting the food-reward pathways and not the other way around.

A narrative review published by Yang (2010) looked at the evidence of brain activity in individuals during periods of sugar craving and the difference in the response following consumption of sugar compared to non-caloric sweeteners.[59] It concludes that non-caloric sweeteners do not seem to activate food reward pathways in the same way as sugar. The evidence on this topic is further reviewed in the next section.

Research in rodents has also provided a basis for the theory that food or specifically sugar can be ‘addictive’. Models have found similar behaviours in response to consuming some foods as to drugs.[60,61] These studies however have limited application to the complex human behaviour of eating.[62]

In summary, high quality evidence (systematic reviews and RCTs) in this area was lacking. However from the limited evidence available, it seems that sweetness itself is unlikely to be ‘addictive’ in the same way as some drugs can be. It is therefore more helpful to use terms like craving and liking when referring to sweetness rather than addiction.

What is the effect of using low energy sweeteners on satiety, energy intake, energy balance?

There are a number of hypotheses detailed in narrative reviews suggesting non-caloric sweeteners may lead to ingestion of more calories than consuming foods sweetened with sugar, implying that non-caloric sweeteners do not satisfy hunger and cravings as effectively as sugar leading to excessive calorie compensation.[63,64,65] However, these theories seem to be contradicted by high quality RCTs. SACN systematically reviewed the evidence in relation to consumption of sweetened foods and drinks and the effect on energy balance as part of their report on carbohydrates and health. Specific studies cited to support this included a number of RCTs in children and adolescents that found that consumption of sugar sweetened foods and drinks as compared to non-calorically sweetened foods and drinks results in weight gain and increases in BMI.[66] With specific reference to satiety, an 18 month double blind randomised trial in children (n=146) found that provision of non-caloric sweetened drinks versus sugar sweetened drinks produced less weight gain, but similar feelings of satiety.[67,68] The committee did not look at any other aspects in relation to non-caloric sweeteners as this was not within the remit of the report.

Some epidemiological studies following large (for the included studies n>3000) cohorts of individuals for a period of time have raised the hypothesis that consumption of non-caloric sweeteners is associated with weight gain.[69,70,71] However the largest and most detailed analysis of prospective cohort data reported that the use of non-caloric sweeteners was statistically significantly associated with reduced weight gain.[72] Findings from cohort studies carry significant limitations as there may be many confounding factors. For example the choice of an individual to consume foods and drinks containing sweeteners may be linked to wanting to reduce/control weight. These consumers of non-caloric sweeteners might therefore be a group more likely to fail to control their weight than non-consumers during the period assessed, even with the help of non-caloric sweeteners.

A recently published meta-analysis including 15 RCTs and nine prospective cohorts examined low-calorie sweeteners from food, drink or as table top sweeteners.[73] It concluded that observational studies (prospective cohort studies) showed no association between intake of these sweeteners and body weight and a statistically significant small positive association with BMI. However, RCTs found that replacing foods and drinks sweetened with sugar for low-calorie sweetened versions resulted in modest weight loss. Five of the 15 RCTs looked at foods as opposed to drinks and in all of these five studies the subjects were aware of the purpose of the study.

A systematic review and meta-analysis carried out by Rogers et al. (In press) found from short-term (≤1 day) intervention studies (118 comparisons) that total energy intake was reduced when a low energy sweetened food or drink was consumed before an ad libitum meal, as compared with a food or drink sweetened with sugar. No difference was found between total energy intake for the low energy food/drink and water. This was consistent with the longer (>1 day) intervention studies (10 comparisons). Overall, the balance of evidence from all sources considered in Rogers' et al. review indicates that use of low calorie sweeteners in place of sugar, in children and adults, leads to reduced energy intake and body weight.[74]

A systematic review published in 2011[75] looking at the effect of sweeteners on glycemic response and clinically relevant outcomes reported that two (4wks n=133; 10wks n=41) out of the 53 eligible trials reported BMI changes for recipients of non-caloric sweeteners compared to caloric sweeteners. They concluded based on these two trials that non-caloric sweeteners significantly reduced energy intake compared to sucrose groups by about 250 to 500kcal per day over four to 10 weeks. The 10 week study reported a significant reduction in BMI of participants in the non-caloric sweeteners group, compared to an increase in BMI in the sugar group.

In a narrative review Mattes & Popkin (2009) concluded that the addition of non-nutritive or low calorie sweeteners to diets offers no benefit in weight loss unless energy intake is reduced. They also conclude that there was no evidence at that point to support theories that inclusion of these sweeteners in the diet promotes energy intake or contributes to obesity. They found that replacing sugar with non-caloric sweeteners seems to elicit incomplete energy compensation (resulting in 5% to 15% reductions in energy intake), but that evidence of long-term efficacy for weight management was not available.[76]

In their consensus paper Gibson et al. (2014) concluded that low calorie sweeteners help to reduce energy when used in place of higher energy ingredients and that based on the evidence considered, low calorie sweeteners do not increase appetite and have no discernible effect on satiety. They concluded that low- and no-calorie drinks may suppress appetite for about an hour, but do not appear to affect food intake at the next meal. By contrast, they concluded that a caloric drink will suppress appetite in the short term and may or may not reduce energy intake at the next meal. The authors concluded that more research is needed into possible habituation to the effects of low calorie sweeteners on appetite, satiety and food intake.[77]

Gibson et al. (2014) express concern about the generalizability of blinded experimental studies, when cognitive and social factors may have more influence on consumption in real life. However, a four week study looking at whether awareness of the calorie content (no-calorie vs. standard) of drinks affected consumption did not find any effect of awareness on energy intake.[78]

Also of interest is the effect of perceived ‘healthiness’ of a product on energy consumption. A cross-over study compared estimated portion size, perceived energy density and anticipated consumption guilt for adults (n=186) following one meal occasion where subjects were presented with three pairs of isoenergy-dense foods (breakfast cereals; drinks and coleslaws) one ‘healthier’ and one standard (Special K vs. Frosties; semi-skimmed milk vs. Sprite; reduced fat coleslaw vs. standard coleslaw).[79] Subjects were blinded to the purpose of the study. The ‘healthier foods’ were perceived to be lower in energy density than their standard food even though they were isocaloric. The portion sizes participants estimated to be appropriate for themselves were larger for the ‘healthier’ coleslaw compared to the standard. Although this study did not look at the effect of non-caloric sweeteners specifically, it raises the question of whether foods considered ‘healthier’ by their label, for example ‘reduced sugar’, provide a ‘health halo’ effect leading consumers to believe that they have a lower energy density and can therefore consume a larger portion than the standard version of the same food with no adverse effects. This may be valid in relation to energy balance, provided the ‘healthier’ version is much lower in calories compared to the standard product.

Hill et al. (2014) provide details of three experiments looking at the way non-caloric sweeteners influence how individuals think about and respond to food. The authors propose that consumption of foods and drinks containing non-caloric sweeteners may result in short term weight loss if used as a replacement for high-calorie products.

However, they suggest that over time they may lead to excess calorie intake and weight gain either due to psychological influences (as seen in their own studies looking at cognition, product choice and subjective responses to foods sweetened with sugar following consumption of foods or drinks containing non-caloric sweeteners) or through calorie compensation.[80]

In summary, from the evidence reviewed, including the conclusions of SACN, it seems that consumption of foods or drinks containing non-caloric sweeteners in place of sugar may result in partial compensation of calorie intake, whether subjects are blinded or non-blinded. As this compensation seems to be only partial, ie not all of the calories saved through consuming the low calorie food/drink are replaced, the result is an overall reduction in energy intake. Non-caloric sweeteners may therefore help in weight loss/preventing weight gain.

Other areas of interest

Another theory relevant to the association of non-caloric sweeteners and metabolic syndrome is their effect on glucose sensitivity. A systematic review of the evidence by the American Dietetic Association concluded that intake of non-nutritive sweeteners in humans does not affect glycemic responses.[81]

A recently published study in rodents[82] reported that high consumption of saccharin drives the development of glucose intolerance through induction of compositional and functional alterations to the intestinal microbiota. However, a review by Renwick & Molinary (2010) concluded that data from extensive in vivo studies in human subjects show that low-energy sweeteners do not have any of the adverse effects (including effects on appetite or subsequent food intake, insulin release or blood pressure in normal subjects) predicted by in vitro, in situ or knockout studies in animals.[83]

Discussion

An environment has been created where highly palatable food and drinks that are high in sugar are ubiquitous and we have to exert self-control to resist the temptation to consume them, otherwise we risk consuming excess calories and becoming over weight. We have an inbuilt desire to consume sweet foods; some individuals more than others, and in some conditions more so than others. As Benton (2010) suggests '…*although evolution predisposed us to like sweetness, it did not prepare the body for the highly palatable foods that have been manufactured in more recent times*' and we therefore need to adapt to our changing environment and/or adapt our environment to manage our innate needs.

We have an inbuilt tendency to seek out sweet foods. The brain requires glucose in order to function and it seems we have neurological mechanisms that elicit a feeling of reward in response to consuming glucose. Whether we gain this form of reward from all sweet sources of energy (including food containing low calorie sweeteners) is uncertain. It has been hypothesised that replacing sugar with non-caloric sweeteners may interfere with these mechanisms resulting in over consumption of foods in the hope of reaching the same level of satisfaction, although supporting evidence for this hypothesis is lacking.

There are two key issues in relation to the use of non-caloric sweeteners: physiological and social compensation. Physiological compensation is the unconscious phenomenon of an individual consuming additional food/drink to compensate for a lack of calories achieved from previous consumption of a food/drink containing non-caloric sweetener. Social compensation is the phenomenon of an individual consuming additional food/drink to compensate for having a food or drink item perceived as 'healthier' which contains a non-caloric sweetener through self-licencing or the 'health halo' effect.[84]

Good quality blind RCTs that replace calorie-sweetened with low-calorie/non-caloric sweetened foods/drinks suggest that individuals do not make up for all the calories saved through consuming non-caloric sweeteners. Physiological compensation is therefore incomplete, resulting in weight loss or less weight gain. Studies with non-caloric sweeteners where subjects were aware of the intervention (ie non-blinded studies) do not seem to show evidence of over-compensation. Evidence from small, poor quality, experimental studies suggest that social compensation may exist and that if individuals are aware they are consuming a food or drink labelled or marketed as 'healthier', they may consume more to compensate at the next meal or over the next 24 hours to make up for the calories they think they are (and in many cases they are) saving.

It is worth considering whether the effect of compensation may vary for different types of foods or eating occasions. SACN's review of carbohydrates and health found consistent evidence from RCTs in children and adolescents to show that drinks sweetened with sugar are linked to weight gain, suggesting there maybe something about these drinks that specifically leads to excess energy intake. Drinks containing high levels of sugar may therefore impact on appetite and energy intake in different ways to foods containing high levels of sugar and it may be misleading to group them together in primary studies and reviews. For example, having a non-calorically sweetened drink instead of drink sweetened with sugar may not result in compensation for the saved calories because the individual may not have been expecting or need the calories from the drink in the first place, so the calories provided in the sugar sweetened drink may have been surplus to the individual's requirements. Evidence suggests that individuals consuming a sugar sweetened drink before a meal do not necessarily compensate by consuming proportionally less during the meal.[85] More research is needed to unravel these differences between foods and drinks specifically looking at the impact of replacing sugary confectionery, sweet snacks and desserts, ie the types of foods chosen when we desire foods high in sugar, with non-calorically sweetened alternatives, to see whether these alternatives can satisfy desire for sweet foods or whether we do compensate by eating more at later eating occasions. In addition, it could be argued that we initially consume sugary drinks for hydration ie from a physiological need for fluids rather than to satisfy a desire for sugary foods. If sweet drinks, as opposed to water, become the habitual way of satisfying thirst, this may lead to the development of an expectation of sweetness linked to hydration. Existing research in this area needs to be considered further.

There is an overarching limitation in determining conclusions from the evidence in these areas because it is difficult to replicate real life scenarios in a controlled study environment. There are many different factors that may dictate whether non-caloric sweeteners may or may not result in weight gain. A blinded RCT removes the element of social compensation that may occur in real life. A non-blinded RCT may introduce confounding due to knowledge of the study design and the introduction of social compensation. Perhaps the foods/drinks chosen for use in such studies are chosen for the ease of assessment (such as replacing sugary drinks with non-calorically sweetened drinks) as opposed to foods which might be chosen by individuals to satisfy a desire for sweetness. In addition, measuring and comparing preference for sweet taste is difficult when attempting to reflect real life food choices.

Some manufacturers have already begun to reduce the sugar content of some foods and drinks gradually (ie without the consumer being aware they are consuming a reduced sugar product), removing the likelihood of social compensation. Others have labelled products as ‘reduced sugar’ (a term defined in the nutrition claims legislation),[86] which enables consumers to easily identify products containing less sugar.

Manufacturers have done this for some products (eg sweetened drinks) either by just reducing the content of sugar or by replacing some or all of the sugar removed with low calorie/non-caloric sweeteners. In some foods manufacturers have replaced some of the sugar with other ingredients (with varying impacts on the energy provided per 100g depending on the energy provided by the substitute ingredient). Non-caloric sweeteners may be of benefit in weight loss programmes as they may enable an individual to consume fewer calories while maintaining the level of sweetness the individual desires. However reducing the sugar content and not replacing with another form of sweetener may encourage the adaptation of palates to lower sugar foods, although there is currently little available evidence to support this theory. A good quality trial, similar to the studies by Blais et al. (1986) and Bertino et al. (1982) on salt, is required to test the hypothesis that palates can adapt over time to prefer less sweet foods and also look at whether a reduced preference for sweet foods results in reduced consumption and reduced energy intake.

An issue worth considering is the potential impact that changes to the common agricultural policy (CAP) may have on the future use of sugar in Europe. The 2013 CAP reform agreed to abolish quotas on caloric sweeteners in 2017, liberalising the EU sugar market. This includes sugar and high fructose corn syrups, although the latter are currently not frequently used in the UK. This will effectively reduce the price of sugar and it has been proposed that this reduction in price could see the replacement of non-caloric/low-calorie sweeteners with caloric sweeteners therefore having a negative impact on initiatives to reduce sugar consumption.[87]

There does not seem to be any robust evidence supporting the theory that sugar or sweetness is ‘addictive’ in the same way as some drugs can be.

A more detailed full systematic review on these topics is not necessary at this time, as there seem to be a number of recently published systematic reviews in each of the different topic areas. Although further primary research in specific areas mentioned in this paper would be useful to expand the evidence base in relation to the impact of non-caloric/low calorie sweeteners on preferences and food choices.

In conclusion, although it is possible individuals would adapt to less sweet foods over time (in the context of the likely maintenance of an innate desire for sweet foods to some extent) as has been seen with salt reduction, there is little current evidence to support this. Robust evidence from RCTs suggests non-caloric sweeteners are useful in weight maintenance/loss as they enable the calorie content of foods and drinks to be reduced while maintaining the same sweet taste desired by consumers. How these study outcomes reflect behaviour in real life is however unclear. There is no evidence to suggest that by maintaining the sweet taste through the use of non-caloric sweeteners individuals are subsequently more likely to make higher calorie food and drink choices.

Table 1: List of reviews included. Studies are listed in order of strength of study type then ordered by date and alphabetically

Reference	Study type	Relevant topic discussed	Effect seen/Conclusions
Rogers et al. (2015)	Systematic review and meta-analysis	Effect of low energy sweeteners on energy intake and body weight	Short-term (≤1 day) intervention studies (211 comparisons) showed that total energy intake was reduced when a low energy sweetened food or drink compared with sugar sweetened food or drink was consumed before an ad libitum meal, with no difference when compared with water. This was consistent with the 10 longer (>1 day) intervention studies.
Miller & Perez (2014)	Meta-analysis	Sweeteners and body weight and composition	Observational studies showed no association between intake of these sweeteners and body weight and a statistically significant small positive association with BMI. RCTs found that substituting sugar sweetened versions for low-calorie sweetened versions resulted in modest weight loss.
Methven et al. (2012)	Systematic review	Aging and taste	Taste perception declines in adulthood with increasing age, however the extent and significance of the decline varied between tastes (ie sweet, sour, etc.); substances tasted to reflect these tastes (ie sugar for sweet, salt for salty etc.); and the studies included. Only one third of studies concerning sucrose found perceived intensity of sweet taste specifically diminished with age.
Wiebe et al. (2011)	Systematic review	Effect of sweeteners on glycemic response and clinically relevant outcomes including BMI	Two (4wks n=133; 10wks n=41) out of the 53 eligible trials reported a change in BMI for recipients of non-caloric sweeteners compared to caloric sweeteners. Non-caloric sweeteners reduced energy intake compared to sucrose groups by about 250-500kcal per day (95% CI 153, 806).
Franz et al. (2010)	Systematic review	Effect of non-nutritive sweeteners on glycemic response	Three studies in human subjects found non-caloric sweeteners intake had no effect on the glycemic responses and plasma lipid levels in adults with diabetes when added to diets as compared to control diets.

Reference	Study type	Relevant topic discussed	Effect seen/Conclusions
Cox et al. (2015)	Comprehensive review	Sweet taste and weight status	No clear relationship between sensitivity/perception of sweet taste and weight status.
Ferreira et al. (2014)	Narrative review	Low calorie drinks cheating the enteral brain axis	Uncoupling energy content from sweet taste may lead to 'incomplete calorie compensation' therefore activating food reward pathways and simulating greater food intake. However many studies do not support this assumption and the mechanisms underlying the interaction between low calorie drinks and the enteral-brain axis remain to be defined.
Hebebrand (2014)	Narrative review	Addiction	"Eating addiction" is a more appropriate term than "food addiction" or sugar addiction
Hill et al. (2014)	Narrative review	Three experiments looking at the way non-caloric sweeteners influence how individuals think about and respond to food	Consumption of foods and drinks containing non-caloric sweeteners may result in short term weight loss if used as a replacement for high-calorie products, but that over time they may promote weight gain either due to psychological influences or through calorie compensation.
SACN (2015)	Narrative review	Carbohydrates and health report	Consumption of sugar sweetened drinks in place of non-calorically sweetened drinks results in weight gain
Cowin et al. (2011)	Narrative review	Addiction models from animal studies	Similar behaviours are seen in rats in response to consuming foods as to drugs
Feeney et al. (2011)	Narrative review	Genetic variation in taste perception	Food choice is governed by a number of factors including mood, the environment, health, allergies, convenience, hunger, cost, pregnancy, habit, cultural influences, sensory attributes, but taste is a highly influential factor.
Ventura & Mennella (2011)	Narrative review	Innate and learned preferences for sweet taste	Heightened preference for sweet tasting foods in infancy and childhood seems to be innate and is evident worldwide. This genetic predisposition to sweet taste is likely to have evolved in order to ensure acceptance of sweet, energy dense foods such as maternal milk, fruits and other foods at a young and vulnerable age and perhaps to reject bitter tasting foods that could potentially be toxic.

Reference	Study type	Relevant topic discussed	Effect seen/Conclusions
Benton (2010)	Narrative review	Addiction	It is likely to be the palatability of a food rather than its sweetness or sucrose content alone that is key in preference to a food.
Renwick & Molinary (2010)	Narrative review	Effects of low-energy sweeteners on metabolic factors	Data from extensive in vivo studies in human subjects show that low-energy sweeteners do not have any of the adverse effects (including increased appetite or subsequent food intake, cause insulin release or affect blood pressure in normal subjects) predicted by in vitro, in situ or knockout studies in animals.
Yang (2010)	Narrative review	Neurobiology of sugar cravings	Non-caloric sweeteners do not seem to activate food reward pathways in the same way as sugar, suggesting that ingestion of non-caloric sweeteners do not satisfy hunger and cravings as effectively as sugar.
Corwin & Grigson (2009)	Narrative review	Addiction	It does not appear to be the food itself but the manner in which it is consumed that appears to entrain an addiction like process ie repeated, intermittent and ‘gorging’
Mattes & Popkin (2009)	Narrative review	Effect of non-caloric sweetener on appetite and food intake	Replacing caloric sweetener with non-caloric sweetener generally leads to incomplete energy compensation. Sweeteners will only be useful in weight loss if energy intake is restricted. Concerns regarding sweeteners promoting energy intake and obesity are not supported by current evidence. Long term RCTs would be required to resolve this issue.
Avena et al. (2008)	Narrative review	Addiction	Similar behaviours seen in rat studies in response to consuming foods as to drugs
Egan and Margolskee, (2008)	Narrative review	Effect of non-caloric sweeteners on the taste cells of the gut and gastrointestinal chemosensation	Consuming foods/drinks containing non-caloric sweeteners may prepare the gut for the presence of food and nutrients in the same way as the sugar sweetened foods/drinks would, but, in the absence of a source of energy/sucrose, the balance between taste receptor activation, nutrient assimilation and appetite may be unbalanced leading to an increase in appetite and over consumption of calories when they are readily available.

Reference	Study type	Relevant topic discussed	Effect seen/Conclusions
Lowe & Butyrn (2007)	Narrative review	Hedonic hunger	As the growing prevalence of global obesity suggests, an increasing proportion of human food consumption appears to be driven by pleasure, not just by the need for calories
Bartoshuk et al. (2006)	Narrative review	Limitations of methods used to identify taste preferences and thresholds	As it is not possible to share individual experiences of sweetness directly with others, it is necessary to resort to indirect comparisons such as the use of labelled scales. Such scales can provide valid within-subject and group comparisons where the labels denote the same intensities across the group ie they are tasting the same solutions, problems occur when comparing across groups, where the labels may refer to differing intensities of solutions.
Nelson et al. (2001)	Narrative review	Mammalian sweet taste receptors	This study looks in depth at the genetic sequences of receptors detecting sweet taste located on the mammalian tongue.
Gibson et al. (2014)	Conference consensus paper	Benefit of sweeteners	Low calorie sweeteners help to reduce energy when used in place of higher energy ingredients
Blundell et al. (2014)	Symposium report	Addiction	Drugs exploit the food-reward pathways and not the other way around
Cornelsen & Carreido, 2015)	Analysis report	Common Agriculture reform	The 2013 CAP reform agreed to abolish quotas on caloric sweeteners will effectively reduce the price of sugar which is contrary to the recommendations of global nutrition and health policies
Walters (2013)	Online book	Lists types of sweeteners	Lists types of commonly used sweetening agents stating their comparable sweetness to sucrose per kcal.
Capaldi,(1996)	Book	Why we eat what we eat: the psychology of eating.	Preference for food can be modified by flavour-flavour learning ie flavours that are repeatedly associated with an already preferred flavour, such as a sweetener, will themselves become preferred, ie a sweetener produces a liking in almost any other food with which it is mixed.

Table 2: Intervention trials

Reference	Study type	Randomised /blinded	Study design?	Relevant topic discussed	Effect seen/conclusions
Peters et al. (2014)	RCT 12 week weight loss treatment programme (n=303)	Randomised/ non-blinded	Participants received a comprehensive cognitive weight loss intervention (The Colorado Weigh). Participants were either asked to consume 24 fluid ounces of non-nutritive sweetened drinks or water per day, depending on their group allocation. Weight was recorded at baseline and at 12 weeks post intervention.	Effects of Water and Non-Nutritive Sweetened drinks on Weight loss	Consumption of drinks containing low calorie sweeteners were more effective at achieving weight loss than consuming water (5.95 kg versus 4.09 kg; P<0.0001)
Hagger & Chatzisarantis (2013)	RCT female students (Study 1 n=27)	Randomised/ Double blinded	Study 1: Participants were asked to squeeze a handgrip apparatus used to demonstrate self- control capacity. They were then presented with 100ml solution and asked to rinse their mouth for 10 seconds and then spit out. The two groups either had a glucose or a placebo of non-caloric sweetener mouth rinse. They then repeated the handgrip task.	Self-control mechanisms	Rinsing the mouth with a glucose mouthwash led to better immediate self-control compared to a non-caloric sweetened mouthwash (p<0.001).
Piernas et al. (2013b)	RCT 6 months of adults (n=169 at 6 months)	Randomised/ Single blinded	Choose Healthy Options Consciously Everyday (CHOICE) clinical trial. Groups were asked to substitute 2 or more servings of caloric sweetened drinks with either water or low calorie sweetened drinks.	Effect of diet drink on dietary consumption patterns	Participants consuming both water and low calorie sweetened drinks had significantly reduced consumption of desserts at month 3 (P, 0.01), but the group consuming sweetened water had a significant reduction in dessert consumption at month 6 (P-group-by time, 0.01) compared to the water group.

Reference	Study type	Randomised /blinded	Study design?	Relevant topic discussed	Effect seen/conclusions
De Ruyter (2012); de Ruyter (2013)	RCT-Double blind 18 month trial in children aged 7-11 years (n=146)	Randomised/ Double blind	Subjects received 250ml of non-caloric or calorically sweetened drink. Satiety was measured on a 5 point scale by questionnaire at 0, 6 and 18 months and before intake, 1 minute after and 15 minutes after intake.	Sugar free sweeteners on satiety	Substituting sugar sweetened drinks for non-caloric-sweetened drinks produced similar satiety, no statistical differences between the two groups.
Faulkner et al. (2014)	Cross over study carried out in one day in adults (n=186)	Room order was randomised/ Single blinded	Subjects were presented with three pairs of isoenergy dense foods (breakfast cereal; drinks and coleslaw) one ‘healthier’ and one standard (Special K vs. Frosties; semi-skimmed milk vs. Sprite; reduced fat coleslaw vs. standard coleslaw) and asked to estimate the number of portions for each food was presented; the portion size appropriate for themselves and the energy content of each food portion served.	Perceptions of the ‘healthiness’ of foods and drinks.	The ‘healthier foods’ were perceived to be lower in energy density than their standard food ($p<0.05$) even though they were isocaloric. The portion sizes participants estimated to be appropriate for themselves were larger for the ‘healthier’ coleslaw compared to the standard ($p<0.001$).
Mennella et al. (2014)	Experimental study single (two days) of children aged 5-10 years (n=108) and their mothers (n=83)	Non randomised/Blinded	Following abstinence from eating for an hour subjects were individually tested on 2 separate days for concentration of sucrose and salt most preferred in water and broth on one day and in jellies and crackers on the other.	Elevation of preference for sweet food during childhood	Children preferred higher concentrations of sucrose in water ($p=0.005$) than did their mothers. Sucrose preference was not found to be linked to reported sugar intake, probably due to the use of artificial sweeteners in the food supply or as a result of parental control over the sugar content in the diet. Individuals who liked salty foods were also found to like sweet foods, not one or the other.

Reference	Study type	Randomised /blinded	Study design?	Relevant topic discussed	Effect seen/conclusions
Asao et al. (2012)	Experimental study adults (n=26)	Sugar concentration were presented in a random order/non blinded	Subjects sweet taste preference was measured using 5 different sucrose concentrations (a series of comparisons between 2 different solutions). This was repeated 3-7 days later.	Short term (7 days) reproducibilit y of sweet taste preference	High short term reproducibility of a simple 5-level procedure for measuring sweet taste preferences
Cicerale et al. (2012)	Experimental study students (n=85)	No	A food and diet questionnaire, 2x24hr food records a food variety survey and a perceived sweetness intensity measurement was completed	Association between perceived sweetness intensity and dietary intake	No correlation was observed with regards to sweetness intensity and mean energy intake, percent energy from fat, saturated fat, protein, carbohydrate among other nutrients.
Reid et al. (2007)	Experimental study in women (n=133)	Yes	1 week collecting base line data Over 4 weeks half the group were given sucrose, half given an aspartame drink, half correctly told the content, halt incorrectly told the content- a counter balanced design	Whether awareness of the energy content of the drinks affect overall calorie intake	Individuals consuming the sucrose drink consumed more than those consuming the diet drinks with no difference between those who were correctly informed of the type of drink they were consuming.
Liem & de Graaf (2004)	Experimental study (8 days) in children (n=59), and young adults (n=46)	Randomised into intervention groups/non blinded	Subjects were divided into 3 groups, one consumed a drink with a sweet taste, another consumed a drink with a sour taste and the third did not consume any drink. Preference for a series of drinks and yogurts were measured at baseline and after the intervention.	Self-reported sweet and sour preferences: role of repeated exposure	After 8 days exposure to sweet orangeade (0.42M sucrose), children's preferences for this drink significantly increased ($p<0.05$). The taste preference for adults did not change.

Reference	Study type	Randomised /blinded	Study design?	Relevant topic discussed	Effect seen/conclusions
Liem & Mennella (2002)	Experimental study-forced choice sip and swallow trial in children aged 4-7 years (n=83)	The order of the drinks presented was randomised/ Single blinded	Preference of the subject to sourness and sweetness was measured using different concentrations of solutions, by presenting all possible pairs of solutions on each of the 2 testing days. The child was asked to point to which one they preferred. Mothers completed a questionnaire on child's eating habits and preferences.	Sweet and sour choices in childhood	Children whose mothers reported adding sugar to their children's foods on a routine basis were significantly more likely to prefer apple juices with added sugar ($p<0.05$) and reported they preferred a cereal with a significantly higher sugar content ($p<0.05$) compared to children whose parents reported they do not add sugar.
Mennella & Beauchamp (2002)	Experimental study of children aged 4-5 years (n=104)	Non randomised/ Single blinded	Used taste tests to examine preferences for flavours for group of 4-5 year olds who were fed milk; protein hydrolysate; or soy based formulas during infancy (n=27;50;27 respectively)	Relationship between flavour experiences during formula feeding and preferences during childhood	The type of formula children were fed as infants influences their preferences for the flavour of the formula during the taste test ($p=0.02$). Flavour experiences influence subsequent flavour preferences even several years after the early experience.
Holt et al. (2000)	Experimental study Caucasian (n= 69) and Malaysian (n=63) students living in Australia	Solutions were presented to subjects in a random order/ Non-blinded	Sucrose solutions, orange juice samples, custard samples and shortbread biscuits were provided to subjects with 4-5 varying sucrose contents. Subjects then rated for intensity of sweetness and preference for the sweetness. Subjects completed a short food frequency questionnaire	Association between perception of and preference for sweet foods and drinks and dietary intakes of sugar and sweet foods	Frequency of consumption of sweet foods and drinks predicted the preferred level of sucrose in solution and the total preferred level of sucrose across the four stimuli as did intake of refined sugar.

Reference	Study type	Randomised /blinded	Study design?	Relevant topic discussed	Effect seen/conclusions
Foltin et al. (1998)	Experimental (n=6), adult males, 14 days	Non randomised/ Double blinded	Two groups of 3 males were fed food in residential laboratory conditions for 14 days. Days 6-11 one group was fed lower calorie items reducing overall intake by 500kcal.	Compensation when presented with calorie restricted food compared to higher calorie foods.	Subjects immediately compensated when provided with lower calorie foods, but when diet returned to usual level subjects failed to compensate for increased calorie intake.
Caputo et al. (1992)	Experimental study adults aged 19-48 years (n=16)	Non randomised/ Single blinded to purpose of the study	4 sets of 5 day periods of midday meal provision: (1) high carbohydrate; (2) low carbohydrate; (3) high fat and (4) low fat	Difference in energy intake when provided with high or low energy meals.	Mean daily energy intake differed only from baseline when high energy lunch was consumed ($p<0.05$).
Fisher a& Birch (1999)	Two arm experimental design trial children aged 3-5 years. 5 wk restriction (n=31)	Randomised/ Non blinded	Apple and peach bar cookies were tested to be neither highly desired or disliked and were chosen as two highly similar variants of the same type of food over a five week period in three to five year olds (n=31). They looked at children's eating behaviour before, during and after a five week period of restricted access to a visible snack food (ie either apple or peach depending on the group) placed in a jar in the middle of the table.	Restricted access to palatable foods on children's desire for the restricted food	Compared to a highly similar non-restricted control food item (ie either apple or peach) the restricted food elicited more positive comments, requests for it and attempts to obtain it, ($p<0.05$).

Reference	Study type	Randomised /blinded	Study design?	Relevant topic discussed	Effect seen/conclusions
Stone & Pangborn (1990)	Experimental study in students (n=100)	No	Lemonade and broth of varying sucrose and salt concentration respectively were rated on a hedonic scale. Frequency of consumption of a wide variety of salty and sweet foods was estimated by 2 questionnaires	Preferences and intake measures of salt and sugar, and their relation to personality traits.	Whereas salt intake was related to preference for salt in broth, a similar relationship was not found for sugar intake and preference for sucrose in lemonade.
Mattes et al. (1988)	Cross over study, adults (n=10), 2x 2 weeks	Randomised/ Non blinded	Lunches were provides for 2 x 14 day periods containing 66% more or less calories	Compensation of daily energy intake following changes to calorie content of midday meal	Relative to baseline the subjects consumed more calories during the high-calorie lunch fortnight ($p<0.01$). Differences during the calorie deficit fortnight were not statistically different to baseline.
Mattes & Mela (1986)	Experimental males (n=25)		Seven day diet records and provided hedonic responses to lists of foods and coffee, oatmeal and water samples of varying sweetness	Association between preference and intakes of sweet foods and drinks	There were significant positive correlations between calories from sweet foods and drinks and preferred sweetness levels in oatmeal ($p<0.01$). The mean preferred sucrose concentration in coffee was significantly correlated with calories from sweet foods ($p<0.01$). Final sucrose concentrations of water were positively correlated with percent sweet calories ingested ($p<0.001$).

Reference	Study type	Randomised /blinded	Study design?	Relevant topic discussed	Effect seen/conclusions
Bartoshuk et al. (1982)	Experimental study adults (n=47)	No	Three separate experiments whereby subjected were asked to either ‘sip and spit’ or ‘sip and swallow’ for different concentrations of sucrose warmed or cooled to different temperatures. Subjects were asked to record magnitude estimates for ‘tasteless’, ‘salty’, ‘sweet’, ‘sour’, ‘bitter’, and ‘other responses’.	Effect of temperature on sweetness perception	When data from all experiments were pooled a given concentration of sucrose served at room temperature is detected to taste sweeter than the same concentration of sucrose served at room temperature ($p=0.00012$).
Bertino et al. (1982)	Experimental study young adults (n=14)	Sodium solutions presented in random order/Non blinded	Diet of moderate sodium restriction for 5 months Sodium taste was measured prior to sodium restriction and then again at 2, 3, 4 and 5 months after the introduction of the low sodium diet.	Long-term reduction in dietary sodium alters the taste of salt.	Between the time before the diet and the first test after two months, a preference shift to a lower preferred salt concentration was seen for soup ($p=0.04$) and crackers ($p=0.11$). By the third month, the subjects and controls differed ($p<0.05$) for both soups and crackers.

Table 3: Prospective cohorts

Reference	Sample size	Relevant topic discussed	Effect seen/Conclusions
Sonneville et al. (2015)	1,162	Association between juice consumption in infancy and SSB consumption later in childhood	A higher juice intake at one year of age was associated with higher juice intake (p<0.0001) and (p=0.0002); sugar sweetened drink intake (p<0.0001) and (p<0.0001); and BMI (p=0.04) and (p=0.01) during early and mid-childhood respectively when adjusted for maternal age, education, pre-pregnancy BMI, household income, child age, sex race/ethnicity and weight for length score at 1 year.
Pan et al. (2013)	50,013 (1986-2006 Nurses' Health study); 52,987 (1991-2007 Nurses' Health study II); 21,988 (1986-2006 Health Professionals follow up study).	Long term consumption of low calorie sweeteners and weight loss	Over 16-20 years follow up, use of non-caloric sweeteners was statistically significantly associated with reduced weight gain (Pooled results weight change -0.10kg; -0.14; -0.06) (p=0.03).
Fowler et al. (2008)	5,158	Sweetener use and weight gain	Adjusted change in BMIs were 47% greater among artificial sweetener users than nonusers (*P* < 0.0001).
Colditz et al. (1990)	31,940	Diet and patterns of weight change	Consumption of saccharin was significantly related to weight gain over the periods assessed (1978-1980 β=0.0027 & 1980-1984 β=0.0024).
Stellman & Garfinkel (1986)	78,694	Sweetener use and one year weight gain	The rate of weight gain in sweetener users was significantly greater than in non-users irrespective of initial weight ranging from 2.7% in leanest quintile (p=0.008) to 9.1% (p<0.001) in the most obese quintile.

Table 4: Longitudinal

Reference	Study design	Relevant topic discussed	Effect seen/Conclusions
Piernas et al. (2013a)	Used US longitudinal data from Nielsen Homescan 2000-2010 and cross-sectional consumption data from NHANES from 2003-2010	Trends in purchases and intake of food and drink containing low-calorie sweeteners	Increase in purchasing and consumption of low-calorie sweeteners over the period assessed, particularly for households containing children.
Ng et al. (2012)	Use of US longitudinal data from Nielsen Homescan 2005-09	Trends in purchases of food and drink containing low-calorie sweeteners	Purchase trends over this period show a shift towards purchasing of foods containing non-caloric sweeteners.
Blais et al. (1986)	63 subjects consumed either their normal diet (control N=20) or a low sodium diet (N=43) adopted after attending weekly intervention group meetings for the first 10 weeks, then bi-weekly for 1 month, then bi-monthly for the rest of one year	Effect of dietary sodium restriction on taste responses to sodium chloride:	The study found that the mean concentration of ad-libitum salt mixed into soup by the sodium-restricted group (N=43) decreased progressively ($F_{7,267} = 22.93$, $p < 0.0001$) throughout the study period from 0.72% at baseline to 0.33% at week 24. From week 8 onwards the amount of added salt is significantly lower when compared to week 0, 1 and 3 ($p<0.0001$). Also, from week 8 onwards, compared to baseline there is significantly lower hedonic response ($p<0.05$) from the low sodium group upon tasting a salty soup (1.4% added salt).
Desor & Beauchamp (1986)	Preference for sweetness was tested in 44 subjects aged 11-15 years and at 19-25 years	Sweetness preference declines with age	Over 9-10 years from age 11-15 years to 19-25 years the level of sucrose most preferred declined ($p<0.05$).

Table 5: Cross-sectional studies

Reference	Study design	Relevant topic discussed	Effect seen/conclusions
Department of Health (2012)	Cross sectional survey of adults in England (n=547)	Urinary sodium	15% reduction of the nation's salt intake from 9.5g in 2001 to 8.1g in 2011
Overberg et al. (2012)	Cross sectional study of obese (n=99) and normal weight adults (n=94). Sensitivity examined by taste strips on a five point rating scale	Taste sensitivity of obese vs. non-obese children and adolescents	Obese subjects showed a reduced ability to identify correct sweetness qualities compared to the control group (p<0.001)
Fushan et al. (2009)	Cross-sectional study to analyse thresholds of sensitivity to sucrose by genotype (n=144)	Genetics and variation in sucrose sensitivity	Inherited genetic differences account for a substantial fraction of worldwide differences in human sweet taste perception
Keskitalo et al. (2007)	Cross sectional study testing sweetness preference of 26 families (n=146)	Genetics and variation in sweet taste preference	Sweet taste preferences are partly inherited. A logarithm of odds score of 3.5 (p=0.00003) was detected for use of sweet foods by a specific chromosome.
Mennella et al. (2005)	Cross sectional study examining DNA and sweet taste preference children and their mothers (n=143)	Genetics and environmental determinants of sweet preferences	There was a significant effect of genotype on sucrose preference in children (p=0.01). The genotype and race/ethnicity interaction on mother's preference for sucrose (p=0.03) was explained by a difference in preference between ethnicity ie black mothers preferred higher levels of sucrose than white mothers of the same genotype.
Moe et al. (2001)	Cross sectional survey of adults (n=872). Attitudes measured on 3 point scale (very acceptable to health, somewhat acceptable and not acceptable to health	Consumer attitudes about the acceptability of artificial sweeteners	36% of adults perceived foods containing artificial sweeteners to be 'not acceptable'.

Table 6: Social research

Reference	Study design	Relevant topic discussed	Effect seen/conclusions
Connors et al. (2001)	Qualitative interviews (n=86)	Assessing how people manage values in making food choices	Within the personal food systems identified to be used by participants, people managed the five main food-related values of taste, health, cost, time and social relationships, and other less prominent values of symbolism, ethics, variety, safety, waste and quality to determine food choice.

Table 7: Primary animal studies

Reference	Study design	Relevant topic discussed	Effect seen/conclusions
Suez et al. (2014)	Series of experimental studies looking at association between glucose tolerance and intestinal microflora in rats and humans	Sweeteners and glucose intolerance	Found that consumption of non-caloric artificial sweeteners developed glucose intolerance compared to those fed water, glucose and sucrose ($p<0.001$). Authors propose this is through the induction of compositional and functional alterations to the intestinal microbiota.

Annex 5d. Fat/sugar see-saw product comparisons

Summary

Food manufacturers provide a range of low/reduced fat foods. There is a commonly held belief that as the fat content of a product decreases, the sugar content increases, which is often called a fat/sugar see-saw. This may be for technical or palatability purposes in order to achieve a lower calorie content. This project aimed to test the hypothesis that reduced fat alternatives to standard products contain higher levels of sugar compared to their standard equivalents.

In December 2014, PHE looked at a number of food labels using online sources. This included 192 products in total (94 ‘standard’ and 98 ‘reduced fat’ products) in the following categories: biscuits; cake bars; desserts; cereal bars; fruit yogurts; dips; mayonnaise; salad cream; coleslaw; potato salad and chilled ready meals. Twenty seven (25%) of the 107 product comparisons showed that the reduced fat products contained greater[h] amounts of sugar per 100g than their standard equivalents, 39 (36%) showed they contained less and there was no difference for 41 (38%). The comparisons presented here therefore indicate that for the product categories examined there was no overall trend for reduced fat products to contain more sugar than their standard equivalents. There was substantial variation between product categories and manufacturers and within individual product categories.

These findings suggest that reduced fat products offered by the food industry do not generally contain more sugar than standard products, at least for those considered here.

The comparisons presented here are illustrative only. No statistical analysis has been undertaken. Reduced fat direct equivalents of individual products are not always available and in many cases comparisons are made between broadly similar product types. These provide a broad brush illustration within the area and are not intended to be representative of the full range of products from an individual manufacturer or across the market as a whole. A larger sample with the inclusion of a wider variety of product categories may provide a more robust analysis in relation to the existence of a fat/sugar see-saw when comparing reduced fat equivalents of standard products.

[h] A product was described as having a ‘higher’ or ‘lower’ sugar content than its comparator if the total sugar value on the label was numerically higher or lower. Recognising that minor differences could be the result of analytical variation and may not be nutritionally significant, where figures differ by less than 1g/100g they are considered to be the same. This working convention was adopted for this piece of work only and has no wider significance.

Methods

Food labels available through online sources were examined in December 2014 to provide a snapshot of available standard products and their reduced fat, low fat or fat free equivalents.[i,88] For the purpose of this exercise there was no recognition of market share. Information was initially sourced from UK retailer websites including Asda, Morrisons, Ocado, Sainsbury's and Tesco. Nutrition information for branded products was confirmed with data provided on individual manufacturer websites. Products for which online nutrition information was not available were not included and no data collection was carried out in store. No laboratory analyses were carried out.

Data were collected for products in the following categories: biscuits; cake bars; desserts; cereal bars; fruit yogurts; dips; mayonnaise; salad cream; coleslaw; potato salad and chilled ready meals. Comparisons were made as far as possible within brands/retailers (ie Tesco standard versus Tesco reduced fat). However for some categories comparisons between similar products of different brands were included. All nutrition information was collected per 100g. The weight of individual products as sold was not collected. Information for the energy, carbohydrate, sugar, fat, and saturated fat were recorded for each product. Products were only included if there was a standard and reduced fat equivalent available for comparison. In some instances a similar, but not identical product was included for comparison (for example Alpen raspberry and yogurt cereal bar compared to Alpen light cherry bakewell cereal bar; Sainsbury's sweet and sour chicken with rice ready meal compared to Sainsbury's My Goodness! Katsu chicken curry and lemongrass rice ready meal). No statistical analyses were carried out.

It should be noted that product label data for sugar refers to total sugar, and so includes milk sugar and the sugar in fruit and vegetables. For products such as yogurt and potato salad, the total sugar content on the label will include sugar from these sources, which are excluded from the SACN definition of free sugars.[j]

Results

Data was collected for 192 products, including 94 standard products and 98 reduced fat, low fat or fat free equivalents. One hundred and seven comparisons were made. Nutrition information and ingredients for each product category are contained in tables 1 to 18 below.

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[i] Definitions: Reduced fat- may only be made where the reduction in content is at least 30% compared to a similar product; Low fat- contains no more than 3g/100g fat for solids or 1.5g/100ml fat for liquids (1.8g/100ml fat for semi-skimmed milk); Fat free- contains no more than 0.5g/100g/ml fat.
[j] SACN defined free sugars as all sugars added to foods plus those naturally present in fruit juices, syrups and honey. It does not include the sugars naturally present in intact fruit and vegetables or dairy products.

Biscuits: Fourteen individual products (seven standard, seven reduced fat) were compared. Two reduced fat products had a higher sugar content, one was lower and four had the same sugar content than their standard equivalents.

Cake bars: Due to the large number and variety of cake bars available from individual brands and supermarkets, only cake bars from Weight Watchers (five reduced fat) and Mr Kipling (five standard) were used for comparison. Of the five comparisons made, two Weight Watchers products had a higher sugar content per 100g than the Mr Kipling equivalents, two had lower sugar content and there was no difference for the remaining comparison.

Desserts: Ten rice pudding (five standard, five reduced/low fat), eight custard (four standard, four reduced/low fat) and eight mousse products (four standard and four reduced fat) were compared. For eight of the 13 comparisons made, the reduced/low fat products had a lower sugar content per 100g than their standard equivalents. For the remaining five, the sugar content was the same as the standard product.

Cereal bars: Eighteen products (nine standard and nine reduced fat) were compared. For one of the nine comparisons made, the sugar content was higher in the reduced fat product than the standard equivalent; for 11 the sugar content was lower; and for the remaining comparison the sugar content was the same for the reduced fat product and the standard equivalent.

Yogurts: Seven luxury, four standard, seven low fat and four fat free yogurt products were compared. Of the 17 comparisons made, three of the reduced/low fat products had a higher sugar content, 11 had a lower sugar content and three had the same sugar content as the standard/luxury products.

Dips: Ten hummus and 10 sour cream and chive dip products (five standard, five reduced fat for each) were compared. Two reduced fat products had a higher sugar content than their standard equivalents. The sugar content of the eight remaining reduced fat products was the same as their standard equivalents.

Mayonnaise and salad cream: Data were collected for 17 mayonnaise products (seven standard, nine reduced fat or “light” and one “extra light”). Of the 12 comparisons made, the sugar content was higher for eight reduced fat products than their standard equivalents and there was no difference for the remaining four. When comparing all 11 salad cream products (five standard, six reduced fat), the sugar content was lower for all reduced fat products than their standard equivalents.

Coleslaw and potato salad: Ten coleslaw products were compared (five standard and five reduced fat). For three of the five comparisons made, the reduced fat products had a higher sugar content, for the remaining two, there was no difference between the sugar content of the reduced fat products and the standard equivalents. Across the eight potato salad products collected (four standard, four reduced fat), the sugar content was higher in two of the four reduced fat products than their standard equivalents. There was no difference between the sugar content of the remaining two reduced fat products and their standard equivalents.

Ready meals: Thirty six ready meals were compared (18 standard, 18 reduced fat). For four of the 18 comparisons made, the reduced fat products had a higher sugar content, for three the reduced fat products had a lower sugar content and for 11 the sugar content was the same as the standard equivalents.

Discussion

The results of this work indicate that 27 (25%) of the 107 comparisons showed reduced fat products to contain greater amounts of sugar per 100g than the standard equivalent, 39 (36%) contained less and there was no difference for 41 (38%) across a number of different categories. For the categories examined there was no overall trend for reduced fat products to contain more sugar than their standard equivalents. There was substantial variation between categories and manufacturers and within individual categories. Contrary to what might have been expected in the desserts, yogurts, cereal bars and salad cream food categories, the sugar content of the reduced fat products was generally lower than the standard equivalents. There were no clear conclusions that could be drawn regarding the relationship between the fat and sugar content of the biscuits, cake bars, dips, coleslaw, potato salad, and ready meals categories. For the mayonnaise category, there was a trend for the reduced fat products to have higher sugar contents than the standard equivalents.

The sample was small, including only retailers and manufacturers that present nutritional information online, and so the conclusions drawn for each food category may not be representative of all products available on the market, as it was often difficult to find comparable products. Collecting data in store was not possible due to time restrictions of the project, but may have broadened the sample as well as provided an opportunity to check the online data collected. A greater sample size and wider coverage of different product categories may have provided scope for a more in depth analysis in relation to the examination of the existence of a fat/sugar see-saw. Use of label data for total sugar is also a limitation for product categories containing a significant proportion of dairy and/or intact fruit and vegetables.

This online review has provided a limited overview of the potential relationship between the sugar content of standard products compared to their reduced/low fat equivalents.

Tables 1 to 18 – Based on data collected in December 2014

Table 1: Biscuits	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
McVitie's Digestives	481	2014	62.9	16.6	21.3	10.1
McVitie's Digestives Light	447	1880	69.7	20.2	14.4	1.5
Difference (g/100g)				**(+3.6)**	**(-6.9)**	
Tesco Digestives	491	2057	63.5	18.5	22.4	10.1
Tesco Reduced Fat Digestives	460	1930	71.3	21.0	15.6	6.9
Difference (g/100g)				**(+2.5)**	**(-6.8)**	
McVitie's Digestives Milk Chocolate	495	2071	62.2	29.5	23.6	12.4
McVitie's Digestives Light Milk Chocolate	456	1919	69.7	30.1	15.8	8.2
Difference (g/100g)				**(+0.6)**	**(-7.8)**	
Sainsbury's Plain Chocolate Digestives	498	2084	61.9	28.0	24.1	12.4
Sainsbury's 30% Less Fat Plain Chocolate Digestives	455	1913	68.8	28.6	16.0	8.3
Difference (g/100g)				**(+0.6)**	**(-8.1)**	
McVitie's Rich Tea Classic	459	1929	71.3	20.2	15.5	1.5
McVitie's Rich Tea Light	434	1832	75.3	20.1	10.7	1.2
Difference (g/100g)				**(-0.1)**	**(-4.8)**	
Rich Tea essential Waitrose	448	1885	73.1	21.1	13.4	6.2
Low Fat Rich Tea essential Waitrose	417	1762	76.7	19.0	8.9	3.3
Difference (g/100g)				**(-2.1)**	**(-4.5)**	
Tesco Rich Tea Fingers	455	1914	72.7	20.7	14.4	6.7
Tesco Reduced Fat Rich Tea	425	1795	76.7	20.1	8.7	3.3
Difference (g/100g)				**(-0.6)**	**(-5.7)**	

Summary	Total (n)
Standard products	7
Reduced fat products	7
Total comparisons made	7
Higher sugar in lower fat product	2
Lower sugar content in lower fat product	1
Same sugar content (differ by less than 1g/100g)	4

Table 2: Cake bars	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Mr Kipling Angel Slices	409	1716	58.3	39.1	18.1	6.1
Weight Watchers Angel Slices	327	1387	71.8	47.4	2.4	1.2
Difference (g/100g)				**(+8.3)**	**(-15.7)**	
Mr Kipling Lemon Layered Slices	397	1670	62.7	44.3	15.0	3.3
Weight Watchers Lemon Cake Slices	307	1302	68.1	44.0	2.0	0.8
Difference (g/100g)				**(-0.3)**	**(-13.0)**	
Mr Kipling Bakewell Slice	408	1714	58.4	35.2	17.4	7.8
Weight Watchers Bakewell Slice	324	1375	71.0	46.8	2.4	1.3
Difference (g/100g)				**(+11.6)**	**(-15.0)**	
Mr Kipling Country Slices	384	1614	56.9	39.9	15.1	5.1
Weight Watchers Country Cake Slices	330	1360	68.8	32.9	3.7	0.6
Difference (g/100g)				**(-7.0)**	**(-11.4)**	
Mr Kipling Victoria Slices	442	1857	69.2	40.7	16.0	5.6
Weight Watchers Individual Victoria Slices	343	1436	57.2	31.4	8.3	0.8
Difference (g/100g)				**(-9.3)**	**(-7.7)**	

Summary	Total (n)
Standard products	5
Reduced fat products	5
Total comparisons made	5
Higher sugar in lower fat product	2
Lower sugar content in lower fat product	2
Same sugar content (differ by less than 1g/100g)	1

Table 3: Rice pudding	Energy (kcal)	Energy (kJ)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Ambrosia Rice Original	104	440	17.1	9	2.5	1.5
Ambrosia Light Rice Pot	86	364	16.0	7.9	0.9	0.5
Difference (g/100g)				**(-1.1)**	**(-0.6)**	
Sainsbury's Rice Pudding	96	404	16.9	10.3	1.7	1.2
Sainsbury's Rice Pudding, Low Fat, Be Good To Yourself	81	345	15.5	7.8	0.6	0.3
Difference (g/100g)				**(-2.5)**	**(-1.1)**	
Asda Chosen By You Creamed Rice Pudding	93	391	16.6	9.4	1.4	0.8
Asda Good for You Rice Pudding	79	334	15.5	7.8	0.6	0.2
Difference (g/100g)				**(-1.6)**	**(-0.8)**	
Tesco Creamed Rice Pudding	105	430	17.2	10.2	2.2	1.3
Tesco Low Fat Rice Pudding	95	395	16.9	10.1	1.3	0.8
Difference (g/100g)				**(-0.1)**	**(-0.9)**	
Rachels Divine Rice	142	598	20.5	11.5	5.2	3.3
Müller Rice Original	101	428	16.1	10.0	2.6	1.5
Difference (g/100g)				**(-1.5)**	**(-2.6)**	

Summary	Total (n)
Standard products	5
Reduced fat products	5
Total comparisons made	5
Higher sugar in lower fat product	0
Lower sugar content in lower fat product	4
Same sugar content (differ by less than 1g/100g)	1

Table 4: Ready to eat custard	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Ambrosia Custard (longlife)	100	420	16.0	11.5	2.9	1.6
Ambrosia Low Fat Custard (longlife)	89	378	15.4	11.1	1.8	1
Difference (g/100g)				**(-0.4)**	**(-1.1)**	
Sainsbury's Ready To Eat Custard	103	436	16.4	11.8	3.0	1.6
Sainsbury's Ready To Eat Lighter Custard	90	379	16.4	11.8	1.5	0.8
Difference (g/100g)				**0**	**(-1.5)**	
Morrisons Ready To Serve Custard	104	439	17.0	10.0	2.7	1.7
M NuMe Ready to Eat Custard	83	351	15.0	9.4	1.5	0.8
Difference (g/100g)				**(-0.6)**	**(-1.2)**	
Tesco Ready To Serve Custard	98	412	15.7	11.5	2.9	1.5
Tesco Low Fat Ready To Serve Custard	86	362	15.8	11.5	1.5	0.8
Difference (g/100g)				**0**	**(-1.4)**	

Summary	Total (n)
Standard products	4
Reduced fat products	4
Total comparisons made	4
Higher sugar in lower fat product	0
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	4

Table 5: Mousse	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Sainsbury's Mousse Chocolate	185	776	23.8	21.0	7.5	5.8
Sainsbury's Mousse Lighter Chocolate	115	487	16.8	15.4	2.6	1.4
Difference (g/100g)				**(-5.6)**	**(-4.9)**	
ASDA Chocolate Mousse	176	640	23.2	22.0	6.9	4.7
ASDA 40% Less Fat Chocolate Mousse	105	442	13.0	12.3	2.9	2
Difference (g/100g)				**(-9.7)**	**(-4.0)**	
Morrisons Chocolate Mousse	185	778	25.2	21.4	7.3	5.7
M NuMe Chocolate Mousse	124	525	20.8	19.4	2.1	1.4
Difference (g/100g)				**(-2)**	**(-5.2)**	
Tesco Milk Chocolate Mousse	187	784	25.9	22.2	7.4	5.6
Tesco Healthy Living Chocolate Mousse	125	528	20.8	19.4	2.1	1.4
Difference (g/100g)				**(-2.8)**	**(-5.3)**	

Summary	Total (n)
Standard products	4
Reduced fat products	4
Total comparisons made	4
Higher sugar in lower fat product	0
Lower sugar content in lower fat product	4
Same sugar content (differ by less than 1g/100g)	0

Table 6: Alpen cereal bars	**Energy (kcal/100g)**	**Energy (kJ/100g)**	**Carbohydrate (g/100g)**	**Total sugars (g/100g)**	**Fat (g/100g)**	**Saturated Fat (g/100g)**
Alpen Blueberry & Cranberry	423	1784	75.0	63.0	11.0	6.3
Alpen Light Summer Fruits	335	1406	59.0	23.0	4.1	1.5
Difference (g/100g)				**(-40.0)**	**(-6.9)**	
Alpen Chocolate & Coconut	443	1863	66.0	28.0	16.0	7.9
Alpen Light Chocolate & Fudge	342	1435	55.0	21.0	6.5	2.7
Difference (g/100g)				**(-7.0)**	**(-9.5)**	
Alpen Raspberry & Yoghurt	425	1790	76.0	37.0	11.0	6.1
Alpen Light Cherry Bakewell	341	1430	56.0	18.0	5.6	1.7
Difference (g/100g)				**(-19.0)**	**(-5.4)**	

Summary	**Total (n)**
Standard products	3
Reduced fat products	3
Total comparisons made	3
Higher sugar in lower fat product	0
Lower sugar content in lower fat product	3
Same sugar content (differ by less than 1g/100g)	0

Table 7: Cereal bars – Retail own brand	**Energy (kcal/100g)**	**Energy (kJ/100g)**	**Carbohydrate (g/100g)**	**Total sugars (g/100g)**	**Fat (g/100g)**	**Saturated Fat (g/100g)**
Sainsbury's Raspberry & Yogurt Cereal Bars	412	1736	70.9	30.3	11.0	7.3
Sainsbury's Red Fruit Balance Cereal Bars	372	1572	76.6	30.5	5.5	3.1
DIFFERENCE (g/100g)				**(+0.2)**	**(-5.5)**	
Sainsbury's Basics Chocolate Chip Cereal Bars	397	1673	70.0	24.6	9.0	4.3
Sainsbury's Chocolate Chip Balance Cereal Bars	381	1609	76.0	27.0	5.6	3.2
DIFFERENCE (g/100g)				**(+2.4)**	**(-3.4)**	
ASDA Chosen by Kids Yummy Yoggy Brekky Bars Strawberry & Apple	369	1551	65.0	21.7	6.4	2.9
ASDA Vitality Apple & Raspberry	355	1412	66.0	17.3	2.8	0.9
DIFFERENCE (g/100g)				**(-4.4)**	**(-3.6)**	
Morrisons Chocolate Cereal Bar	433	1820	67.4	36.4	14.4	8.1
M NuMe Chewy Chocolate and Fudge Cereal Bars	353	1481	56.8	19.0	6.8	4.0
DIFFERENCE (g/100g)				**(-17.4)**	**(-7.6)**	
Tesco Strawberry & Yogurt Flavoured	425	1770	68.0	29.9	12.3	9.6
Tesco Healthy Living Strawberry & Apple Cereal Bars	309	1293	48.2	16.8	5.0	3.6
DIFFERENCE (g/100g)				**(-13.2)**	**(-7.4)**	
Tesco Popcorn Bar Toffee & Pecan Half Coated Chocolate	454	1908	71.5	32.0	16.1	6.6
Tesco Healthy Living Chocolate & Caramel Cereal Bars	325	1360	48.8	16.9	6.9	3.8
DIFFERENCE (g/100g)				**(-15.1)**	**(-9.3)**	

Summary	**Total (n)**
Standard products	6
Reduced fat products	6
Total comparisons made	6
Higher sugar in lower fat product	1
Lower sugar content in lower fat product	4
Same sugar content (differ by less than 1g/100g)	1

Table 8: Fruit yogurts	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Activia Strawberry	99	416	13.6	13.3	3.3	2.3
Activia 0% Strawberry	56	237	9.0	8.6	0.1	0.0
Difference (g/100g)				**(-4.7)**	**(-3.2)**	
Muller Amore Strawberry & Cream Yoghurt	138	577	17.8	16.7	6.3	3.9
Muller Corner Strawberry Yoghurt	112	470	14.9	14.9	3.8	2.4
Difference (g/100g)				**(-1.8)**	**(-2.5)**	
Muller Corner Strawberry Yoghurt	112	470	14.9	14.9	3.8	2.4
Muller Light Strawberry Yoghurt	51	217	8.1	7.0	0.1	0.1
Difference (g/100g)				**(-7.9)**	**(-3.7)**	
Muller Amore Strawberry & Cream Yoghurt	138	577	17.8	16.7	6.3	3.9
Muller Light Strawberry Yoghurt	51	217	8.1	7.0	0.1	0.1
Difference (g/100g)				**(-9.7)**	**(-6.2)**	
Onken Wholegrain Biopot Strawberry	111	468	15.9	13.6	2.8	1.7
Onken Fat Free Strawberry Yoghurt	79	334	13.4	12.8	0.1	0.1
Difference (g/100g)				**(-0.8)**	**(-2.7)**	
Yeo Valley Blueberry Yoghurt	109	458	13.8	13.5	3.8	2.4
Yeo Valley 0% Fat British Blackcurrant Yoghurt	73	310	13.0	12.4	0.0	0.0
Difference (g/100g)				**(-1.1)**	**(-3.8)**	
Sainsburys Taste The Difference Strawberry Yoghurt	127	530	12.4	12.4	7.2	5.0
Sainsburys Low Fat Fabulously Fruity Yoghurt	87	366	14.1	13.3	1.2	0.8
(no fat free variety available)						
Difference (g/100g)				**(+0.9)**	**(-6)**	
Tesco Finest Strawberry & Cream Yoghurt	143	597	14.6	14.3	7.7	5.1
Tesco Low Fat Strawberry Yoghurt	79	333	15.2	12.3	1.0	0.7
Difference (g/100g)				**(-2.0)**	**(-6.7)**	
Tesco Finest Strawberry & Cream Yoghurt	143	597	14.6	14.3	7.7	5.1
Tesco Healthy Living Strawberry Yoghurt	49	208	7.0	6.3	0.2	0.1
Difference (g/100g)				**(-8.0)**	**(-7.5)**	

Table 8: Fruit yogurts cont.	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Tesco Low Fat Strawberry Yoghurt	79	333	15.2	12.3	1.0	0.7
Tesco Healthy Living Strawberry Yoghurt	49	208	7.0	6.3	0.2	0.1
Difference (g/100g)				**(-6.0)**	**(-0.8)**	
ASDA Extra Special Strawberry West Country Yogurt	124	517	13.0	13.0	6.7	4.4
ASDA Low Fat Strawberry Yogurt	74	313	11.9	8.6	1.3	0.9
Difference (g/100g)				**(-4.4)**	**(-5.4)**	
ASDA Extra Special Strawberry West Country Yogurt	124	517	13.0	13.0	6.7	4.4
ASDA Smartprice Low Fat Strawberry	72	307	13.8	11.6	0.6	0.4
Difference (g/100g)				**(-1.4)**	**(-6.1)**	
ASDA Low Fat Strawberry Yogurt	74	313	11.9	8.6	1.3	0.9
ASDA Smartprice Low Fat Strawberry	72	307	13.8	11.6	0.6	0.4
Difference (g/100g)				**(-3.0)**	**(-0.7)**	
Waitrose West Country Strawberry Yoghurt	137	573	15.0	14.1	7.1	4.4
Essential Waitrose Strawberry Yoghurts	84	355	14.5	13.8	1.2	0.7
(no fat free variety available)						
Difference (g/100g)				**(+0.3)**	**(-5.9)**	
Morrisons Signature Strawberries & Cream Yogurt	122	511	12.1	10.7	6.8	4.5
Morrisons Low Fat Strawberry Yogurt	101	428	18.0	18.0	1.3	0.6
Difference (g/100g)				**(+7.3)**	**(-5.5)**	
Morrisons Low Fat Strawberry Yogurt	101	428	18.0	18.0	1.3	0.6
M NuMe Fat Free Strawberry Yogurts	80	338	14.4	13.9	0.1	0.0
Difference (g/100g)				**(-4.1)**	**(-1.2)**	
Morrisons Signature Strawberries & Cream Yogurt	122	511	12.1	10.7	6.8	4.5
M NuMe Fat Free Strawberry Yogurts	80	338	14.4	13.9	0.1	0.0
Difference (g/100g)				**(+3.2)**	**(-6.7)**	

Summary	Total (n)
Standard & Luxury products	11
Reduced fat, low fat, fat free products	11
Total comparisons made	17
Higher sugar in lower fat product	3
Lower sugar content in lower fat product	11
Same sugar content (differ by less than 1g/100g)	3

Table 9: Dips	**Energy (kcal/100g)**	**Energy (kJ/100g)**	**Carbohydrate (g/100g)**	**Total sugars (g/100g)**	**Fat (g/100g)**	**Saturated Fat (g/100g)**
Sainsbury's Houmous	278	1150	10.6	0.7	22.0	2.7
Sainsbury's Houmous, Be Good To Yourself	180	749	11.0	0.5	10.5	1.2
Difference (g/100g)				**(-0.2)**	**(-11.5)**	
ASDA Chosen By You Houmous	336	1391	10.1	0.6	28.2	2.6
ASDA Chosen By You Houmous 30% Less Fat	262	1088	12.7	0.6	18.5	2.0
Difference (g/100g)				**0**	**(-9.7)**	
Tesco Houmous	320	1323	8.8	0.6	27.2	2.6
Tesco Healthy Living Reduced Fat Houmous	233	967	12.0	1.0	15.6	1.7
Difference (g/100g)				**(+0.4)**	**(-11.6)**	
Morrisons Classic Houmous	325	1344	10.2	0.8	27.1	2.6
M NuMe Reduced Fat Houmous	255	1060	11.7	1.0	18.3	1.9
Difference (g/100g)				**(+0.2)**	**(-8.8)**	
Houmous essential Waitrose	309	1277	8.1	0.5	25.9	2.6
Reduced Fat Houmous essential Waitrose	216	895	9.3	0.7	15.0	1.7
Difference (g/100g)				**(+0.2)**	**(-10.9)**	
Sainsbury's Soured Cream & Chive Dip	284	1171	6.1	2.6	27.7	6.5
Sainsbury's Soured Cream & Chive Dip, Be Good To Yourself	176	731	7.3	3.6	14.6	4.0
Difference (g/100g)				**(+1)**	**(-13.1)**	
ASDA Chosen by You Sour Cream & Chive Dip	210	869	6.8	3.4	19.3	7.4
ASDA Sour Cream & Chive Dip 30% Less Fat	155	644	7.2	2.7	12.7	5.4
Difference (g/100g)				**(-0.7)**	**(-6.6)**	
Morrisons Soured Cream & Chive Dip	292	1203	5.0	2.3	29.2	7.3
Morrisons NuMe Reduced Fat Soured Cream & Chive Dip	138	575	5.8	2.8	11.0	1.2
Difference (g/100g)				**(+0.5)**	**(-18.2)**	
Tesco Soured Cream & Chive Dip	280	1156	6.0	2.6	27.4	9.0
Tesco Reduced Fat Sour Cream & Chive Dip	190	786	7.8	3.6	16.2	5.8
Difference (g/100g)				**(+1)**	**(-11.2)**	
Sour Cream & Chive Dip essential Waitrose	327	1348	5.7	2.4	32.6	10.2
Half Fat Sour Cream & Chive Dip essential Waitrose	161	699	6.1	2.4	13.1	2.9
Difference (g/100g)				**0**	**(-19.5)**	

Summary	Total (n)
Standard products	10
Reduced fat products	10
Total comparisons made	10
Higher sugar in lower fat product	2
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	8

Table 10: Mayonnaise	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Hellmann's Real Mayonnaise	722	2970	1.5	1.3	79.1	6.6
Hellmann's Light Mayonnaise	297	1230	6.5	2.2	29.8	3.0
Difference (g/100g)				**(+0.9)**	**(-49.3)**	
Hellmann's Light Mayonnaise	297	1230	6.5	2.2	29.8	3.0
Hellmann's Extra Light Mayonnaise	73	300	11.0	4.8	3.0	0.5
Difference (g/100g)				**(+2.6)**	**(-26.8)**	
Hellmann's Real Mayonnaise	722	2970	1.5	1.3	79.1	6.6
Hellmann's Extra Light Mayonnaise	73	300	11.0	4.8	3.0	0.5
Difference (g/100g)				**(+3.5)**	**(-73.1)**	
Heinz Mayonnaise	660	2716	3.0	2.9	71.5	5.4
Heinz Light Mayonnaise	278	1147	8.2	3.8	26.6	2.3
Difference (g/100g)				**(+0.9)**	**(-44.9)**	
Sainsbury's Mayonnaise Squeezy	677	2785	3.5	1.0	73.2	5.2
Sainsbury's Mayonnaise Light	279	1151	7.2	2.7	27.5	2.4
Difference (g/100g)				**(+1.7)**	**(-45.7)**	
Sainsbury's Mayonnaise Squeezy	677	2785	3.5	1.0	73.2	5.2
Sainsbury's Mayonnaise Squeezy, Be Good To Yourself	375	90	12.0	2.9	4.5	0.6
Difference (g/100g)				**(+1.9)**	**(-68.7)**	
Sainsbury's Mayonnaise Light	279	1151	7.2	2.7	27.5	2.4
Sainsbury's Mayonnaise Squeezy, Be Good To Yourself	90	375	12.0	2.9	4.5	0.6
Difference (g/100g)				**(+0.2)**	**(-23)**	
ASDA Chosen by You Mayonnaise	707	2907	2.4	1.8	77.0	5.8
ASDA Chosen by You Light Mayonnaise	342	1414	16.8	7.6	30.0	2.5
Difference (g/100g)				**(+5.8)**	**(-47)**	
Morrisons Squeezy Mayonnaise	687	2824	2.0	1.5	74.8	5.4
Morrisons NuMe Mayonnaise Squeezy	156	681	13.5	6.1	10.8	1.1
Difference (g/100g)				**(+4.6)**	**(-64)**	

Table 10: Mayonnaise cont.	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Tesco Mayonnaise	680	2790	2.1	1.5	74.0	5.2
Tesco Light Mayonnaise	270	1100	6.3	1.9	26.5	2.6
Difference (g/100g)				**(+0.4)**	**(-47.5)**	
Mayonnaise essential Waitrose	685	2820	5.9	2.3	73.0	4.9
Half Fat Mayonnaise essential Waitrose	331	1367	10.9	4.5	31.5	2.1
Difference (g/100g)				**(+2.2)**	**(-41.5)**	
Mayonnaise essential Waitrose	685	2820	5.9	2.3	73.0	4.9
Mayonnaise Light Squeezy essential Waitrose	322	1330	10.5	5.4	30.6	3.8
Difference (g/100g)				**(+3.1)**	**(-42.4)**	

Summary	Total (n)
Standard products	7
Reduced fat, low fat, fat free products	10
Total comparisons made	12
Higher sugar in lower fat product	8
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	4

Table 11: Salad cream	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Heinz Salad Cream	366	1349	20.4	17.5	27	2
Heinz Light Salad Cream	236	967	14.2	10.5	18.5	1.6
Difference (g/100g)				**(-7.0)**	**(-8.5)**	
Heinz Salad Cream	366	1349	20.4	17.5	27	2.0
Heinz Salad Cream 70% Less Fat	144	601	15.8	8.2	7.3	0.8
Difference (g/100g)				**(-9.3)**	**(-19.7)**	
Heinz Light Salad Cream	236	967	14.2	10.5	18.5	1.6
Heinz Salad Cream 70% Less Fat	144	601	15.8	8.2	7.3	0.8
Difference (g/100g)				**(-2.3)**	**(-8.2)**	
Sainsbury's Salad Cream	397	1643	22.0	20.0	34.0	2.5
Sainsbury's Salad Cream Be Good To Yourself	183	758	12.1	9.2	14.1	1.1
Difference (g/100g)				**(-10.8)**	**(-19.9)**	
ASDA Chosen by You Salad Cream	315	1308	19.1	16.6	26.2	2.1
ASDA Chosen by You Light Salad Cream	156	651	19.8	14.8	8.3	0.3
Difference (g/100g)				**(-1.8)**	**(-17.9)**	
Morrisons Squeezy Salad Cream	251	1043	15.9	13.2	19.9	2.8
Morrisons Squeezy Light Salad Cream	165	687	10.4	7.1	12.6	1.6
Difference (g/100g)				**(-6.1)**	**(-7.3)**	
Tesco Salad Cream	335	1385	21.8	16.8	26.9	2.7
Tesco Healthy Living Salad Cream	132	551	12.4	9.5	7.9	0.8
Difference (g/100g)				**(-7.3)**	**(-19)**	

Summary	Total (n)
Standard products	5
Reduced fat products	6
Total comparisons made	7
Higher sugar in lower fat product	0
Lower sugar content in lower fat product	7
Same sugar content (differ by less than 1g/100g)	0

Table 12: Coleslaw	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Sainsbury's Deli-Style Coleslaw	181	746	5.4	4.5	17	1.9
Sainsbury's Deli-Style Coleslaw, Be Good To Yourself	103	428	5.0	4.3	8.4	0.7
Difference (g/100g)				**(-0.2)**	**(-8.6)**	
ASDA Creamy Coleslaw	264	1087	5.5	5.2	26.1	2.3
ASDA 50% Less Fat Creamy Coleslaw	135	558	5.3	5.3	11.9	1.1
Difference (g/100g)				**(-0.1)**	**(-14.2)**	
Morrisons Classic Coleslaw	762	184	6.7	5.3	16.8	1.5
Morrisons Reduced Fat Coleslaw	126	523	7.6	7.1	10.0	1.0
Difference (g/100g)				**(+1.8)**	**(-6.8)**	
Tesco Coleslaw	277	1143	5.2	3.0	27.9	3.1
Tesco Healthy Living Coleslaw	127	527	5.3	5.2	11.0	1.6
Difference (g/100g)				**(+2.2)**	**(-8.6)**	
Coleslaw essential Waitrose	272	1124	5.8	5.1	27.2	2.2
Half Fat Creamy Coleslaw essential Waitrose	130	539	8.3	8.0	10.2	0.9
Difference (g/100g)				**(+2.9)**	**(-17)**	

Summary	Total (n)
Standard products	5
Reduced fat products	5
Total comparisons made	5
Higher sugar in lower fat product	3
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	2

Table 13: Potato salad	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Sainsbury's Potato Salad	140	583	10.6	1.2	10.2	1.5
Sainsbury's Potato Salad, Be Good To Yourself	104	435	11.9	2.5	5.5	0.4
Difference (g/100g)				**(+1.3)**	**(-4.7)**	
ASDA Creamy Potato Salad	151	627	11.3	2.6	10.7	1
ASDA Creamy Potato Salad 30% Less Fat	107	446	9.6	1.9	6.7	0.6
Difference (g/100g)				**(-0.7)**	**(-4)**	
Morrisons Deli Potato Salad	208	862	10.4	2.4	17.5	1.4
Morrisons Reduced Fat Potato Salad	105	438	12.6	3.3	5.3	0.7
Difference (g/100g)				**(+0.9)**	**(-12.2)**	
Tesco Potato Salad	180	745	11.1	1.1	14.2	1.2
Tesco Healthy Living Potato Salad	110	460	12.5	2.2	5.9	0.8
Difference (g/100g)				**(+1.1)**	**(-8.3)**	

Summary	Total (n)
Standard products	4
Reduced fat products	4
Total comparisons made	4
Higher sugar in lower fat product	2
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	2

Table 14: Ready meals lasagne	Energy (kcal/100 g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Sainsbury's Beef Lasagne	676	162	10.6	3.2	9.0	4.4
Sainsbury's Beef Lasagne, Be Good To Yourself	104	440	11.8	3.0	2.6	1.3
Difference (g/100g)				(-0.2)	(-6.4)	
ASDA Italian Beef Lasagne	634	152	10.7	2.7	7.9	1.4
ASDA Chosen by You Reduced Calorie Lasagne	78	392	8.1	2.2	2.4	1.2
Difference (g/100g)				(-0.5)	(-5.5)	
Morrisons M Kitchen Italian Lasagne	137	575	11.8	1.4	6.1	3.0
Morrisons NuMe Lasagne	101	423	11.1	2.8	2.9	1.4
Difference (g/100g)				(+1.4)	(-3.2)	
Beef Lasagne Waitrose	130	543	10.6	2.6	6.1	2.9
You Count Beef Lasagne Waitrose Love Life	89	347	9.9	2.3	2.1	0.8
Difference (g/100g)				(-0.3)	(-4)	

Summary	Total (n)
Standard products	4
Reduced fat products	4
Total comparisons made	4
Higher sugar in lower fat product	1
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	3

Table 15: Ready meals cottage pie	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Sainsbury's British Classic Cottage Pie	90	377	6.9	0.9	4.1	2.2
Sainsbury's Cottage Pie, Be Good To Yourself	89	374	10.9	1.7	2.4	1.2
Difference (g/100g)				**(+0.8)**	**(-1.7)**	
ASDA Chosen By You Cottage Pie	111	467	11.4	0.6	4.5	1.8
ASDA Reduced Calorie Cottage Pie	72	302	12.3	2	0.7	0.3
Difference (g/100g)				**(+1.4)**	**(-3.8)**	
Morrisons Kitchen Cottage Pie	108	454	9.7	1.1	4.8	2.5
Morrisons NuMe Cumberland Pie	77	325	9.7	1.3	1.6	0.8
Difference (g/100g)				**(+0.2)**	**(-3.2)**	
Tesco Cottage Pie	107	449	11.4	1.3	3.6	2.0
Tesco Healthy Living Cottage Pie	88	373	12.0	0.5	1.8	0.8
Difference (g/100g)				**(-0.8)**	**(-1.8)**	
Cottage Pie Waitrose	117	491	10.4	0.8	5.0	2.5
You Count Cottage Pie Waitrose Love Life	82	343	10.9	0.9	2.0	0.9
Difference (g/100g)				**(+0.1)**	**(-3)**	

Summary	Total (n)
Standard products	5
Reduced fat products	5
Total comparisons made	5
Higher sugar in lower fat product	1
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	4

Table 16: Ready meals chilli	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Sainsbury's Beef Chilli & Rice	146	615	16.9	2.9	4.9	1.9
Sainsbury's Chilli Con Carne, Be Good To Yourself	94	395	13.4	2.7	1.8	0.8
Difference (g/100g)				**(-0.2)**	**(-3.1)**	
ASDA Mexican Chilli & Rice	136	573	18.2	1.7	3.9	1.8
ASDA Chosen by You Reduced Calorie Chilli Con Carne & Rice	95	398	14	2.8	1.6	0.7
Difference (g/100g)				**(+1.1)**	**(-2.3)**	
Morrisons Kitchen Tex Mex Chilli Con Carne & Rice	98	414	14.4	1.6	1.6	0.6
Morrisons NuMe Chilli Con Carne with Rice	112	471	17.9	2.5	2.1	0.9
Difference (g/100g)				**(+0.9)**	**(+1.5)**	
Tesco Chilli Con Carne & Rice	116	490	15.4	1.4	2.4	0.5
Tesco Healthy Living Chilli Chilli & Rice	99	419	14.9	1.8	1.7	0.6
Difference (g/100g)				**(+0.4)**	**(-0.7)**	

Summary	Total (n)
Standard products	4
Reduced fat products	4
Total comparisons made	4
Higher sugar in lower fat product	1
Lower sugar content in lower fat product	0
Same sugar content (differ by less than 1g/100g)	3

Table 17: Ready meals chicken dinner	Energy (kcal/100g)	Energy (kJ/100g)	Carbohydrate (g/100g)	Total sugars (g/100g)	Fat (g/100g)	Saturated Fat (g/100g)
Sainsbury's Roast Chicken Dinner	111	466	10.1	2.2	3.0	0.8
Sainsbury's My Goodness! Classic Roast Chicken Dinner	81	342	7.7	2.2	1.5	0.3
Difference (g/100g)				**0**	**(-1.5)**	
Morrisons Kitchen Chicken Dinner	103	434	10.9	2.3	3.4	0.3
Morrisons NuMe Chicken Dinner	78	327	7.1	0.8	1.8	0.5
Difference (g/100g)				**(-1.5)**	**(-1.6)**	
Tesco Chicken Roast Dinner	93	392	9.2	1.1	2.9	0.6
Tesco Healthy Living Chicken Potatoes & Vegetables	69	293	8.1	2.1	0.8	0.3
Difference (g/100g)				**(+1)**	**(-2.1)**	

Summary	Total (n)
Standard products	3
Reduced fat products	3
Total comparisons made	3
Higher sugar in lower fat product	1
Lower sugar content in lower fat product	1
Same sugar content (differ by less than 1g/100g)	1

Table 18: Ready meals sweet & sour chicken	**Energy (kcal/100g)**	**Energy (kJ/100g)**	**Carbohydrate (g/100g)**	**Total sugars (g/100g)**	**Fat (g/100g)**	**Saturated Fat (g/100g)**
Sainsbury's Sweet & Sour Chicken With Rice	159	669	23.6	11.8	3.2	0.3
Sainsbury's My Goodness! Katsu Chicken Curry & Lemongrass Rice	121	512	16.7	2.0	2.7	0.9
Difference (g/100g)				**(-9.8)**	**(-0.5)**	
Tesco Big Night Time In Sweet & Sour Chicken & Egg Fried Rice	143	604	22.2	6.1	2.3	0.4
Tesco My Fit Lifestyle Sweet & Sour Chicken	105	443	15.3	3.3	2.0	0.3
Difference (g/100g)				**(-2.8)**	**(-0.3)**	

Summary	**Total (n)**	
Standard products	2	
Reduced fat products	2	
Total comparisons made	2	
Higher sugar in lower fat product	0	
Lower sugar content in lower fat product	2	
Same sugar content (differ by less than 1g/100g)	0	
Summary across all categories	**Total (n)**	**Total (%)**
Standard products	94	
Reduced fat products	98	
Total comparisons made	107	
Higher sugar in lower fat product	27	25.2%
Lower sugar content in lower fat product	39	36.4%
Same sugar content (differ by less than 1g/100g)	41	38.3%

Annexe 5e. Development of new example menus to meet food and nutrient based standards

The meal plans in this section show how dietary recommendations, including SACN's new recommendations for free sugars and fibre, as well as all other macronutrients, could be met. They provide illustrative examples of a combination of foods and drinks that, if consumed over a day, would meet these requirements. It is recognised that there are many other ways to do this and many other foods that could be included. The meal plans are based on an average daily energy requirement for a woman of 8.4MJ (2000kcal). Healthier options have been used to help meet dietary recommendations including use of lower or no added sugar foods and drinks, lower fat dairy products, reduced fat spreads and healthier recipes (modified to reduce the fat and sugar content, and increase the fibre content for example).

Daily meal plan 1

Breakfast:
A bowl of porridge with blueberries
A poached egg on a slice of wholemeal toast with reduced fat spread and tomato
Water/tea or coffee (no sugar added)

Lunch:
Chicken, soft cheese and spinach wholemeal wrap served with a large mixed salad
A bowl of stewed dried fruit with low fat natural yogurt
1 semi-sweet biscuit
Water/sugar-free soft drinks/ tea or coffee (no sugar added)

Evening meal:
Fish and vegetable potato-topped pie with broccoli, green beans and a wholemeal roll
Fruit crumble with zero-fat Greek style yogurt
Water/sugar-free soft drinks/ tea or coffee (no sugar added)

Drinks:
2 cups of tea/coffee with semi-skimmed milk (no sugar added)
Low calorie fruit juice drink or sugar-free soft drink

Snacks:
Wholemeal fruit scone and reduced fat spread
2 large plums
2 rice cakes with peanut butter

Daily meal plan 2 – vegetarian

Breakfast:
A bowl of no added sugar muesli with low fat natural yogurt and prunes (stewed in water)
A slice of wholemeal toast with reduced fat spread and reduced sugar jam
Water/tea or coffee (no sugar added)

Lunch:
Jacket potato with vegetable chilli and cheese
Apple
Chocolate-coated biscuit
Water/sugar-free soft drinks/ tea or coffee (no sugar added)

Evening meal:
Tofu, vegetable and cashew nut stir-fry with noodles and mini pitta bread
Summer pudding with fat-free fromage frais
Water/sugar-free soft drinks/ tea or coffee (no sugar added)

Drinks:
2 cups tea/coffee with semi-skimmed milk (no sugar added)
Low calorie fruit juice drink or sugar-free soft drink

Snacks:
3 oatcakes with low-fat soft cheese and grapes
Large satsuma
Slice of malt loaf

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