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Achieving *eatwell plate* recommendations: is this a route to improving both sustainability and healthy eating?

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Summary

By using data from the National Diet and Nutrition Survey (NDNS) rolling programme, the objective was to determine the extent to which consumers meet the nutrition guidelines implicit in the *eatwell plate*; to profile those eating healthily and gain insight on how they achieved the recommendations and whether in doing so, their eating pattern was also potentially more sustainable.

Only 4% of adults simultaneously met five targets related to fat, saturated fatty acids (SFA), 5 A DAY fruit and vegetables, fibre (non-starch polysaccharide; NSP) and protein intake and, with the exception of target protein intake, the majority of people (51%) achieved *none* of the guidelines. The addition of the oil-rich fish recommendation reduces those meeting all six targets to 1%. Just 12% of the population ($n = 94$) met the three targets for fat, SFA and fruit and vegetable intake. These were designated achievers, who tended to be older by 5 years and to have a degree ($P < 0.05$), while non-achievers were more likely to smoke ($P < 0.05$). Energy intakes were slightly lower in achievers (non-significant), who had significantly lower fat and SFA intakes and higher intakes of protein. Intakes of NSP were significantly higher among achievers, who on average met the dietary reference value for NSP. The main NDNS food groups with a significantly higher intake in achievers were skimmed milks, chicken and turkey dishes, white fish (not fried) and shellfish and wholemeal breads, while non-achievers consumed more coated chicken, meat pies and pastries, cheese, whole milks and white bread. It appears that the achievers have reduced the fat content of their diet by focussing on lower fat/higher fibre alternatives within the same category of foods rather than introducing more plant foods such as legumes, nuts and seeds.

There is growing interest in the future sustainability of current dietary patterns in light of expected climate change and an expanding global population. Although only one facet of a very complex picture, plant foods are typically associated with fewer greenhouse gas (GHG) emissions than those of animal origin. On this limited basis, achievers were not necessarily eating more sustainably. It is suggested, by reference to literature values (primarily for potential GHG emissions of food production), that with some rebalancing and through the inclusion in current UK

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dietary patterns of more plant foods, particularly more plant proteins and starchy foods, the existing *eatwell plate* could not only provide the basis of a cost-effective healthy diet, but also a potentially more sustainable one too. However, in order to meet these joint objectives, improved consumer understanding and practical advice on how to use the *eatwell plate* in this way is clearly required.

Keywords: *eatwell plate*, GHG emissions, healthy eating, plant foods, sustainability

Introduction

Over the last decade, the UK population has made limited progress towards meeting key nutrition targets; data from the rolling programme of the UK's National Diet and Nutrition Survey (NDNS; Bates *et al.* 2011b) indicate that the mean intake of total fat met the dietary reference value (DRV) of no more than 35% of food energy. However, mean intake of saturated fatty acids (SFA) continues to exceed the DRV, with adults recording an intake of 12.8% food energy against a target of ≤11% food energy. In addition, nearly two-thirds of adults fail to meet the 5 A DAY recommendations for fruit and vegetable intake and average fibre (non-starch polysaccharide; NSP) intake was well below the DRV of at least 18 g NSP per day. Within the survey population, there is evidence of low iron stores and anaemia in a proportion of young adult women and low vitamin D status in adults (Bates *et al.* 2011a) as well as in children (Lanham-New *et al.* 2011). Meanwhile, average intakes of protein are in excess of requirements and have tended to increase over the last decade to 17–18% food energy for adults. By far the largest contributor to protein intake (37–38%) is meat and meat products, while most people eat well below the recommended one portion of oily-rich fish per week (Bates *et al.* 2011b). Clearly, there is still progress to be made, particularly with regard to achieving adequate fruit, vegetable and fibre intake, all of which lower the energy density of the diet, and could help combat the rising incidence of obesity (WHO 2007). In addition, SFA intake levels need to reduce, as they continue to be some 25% above target and pose a risk to cardiovascular health (DH 1994b; WHO 2003).

A detailed evaluation of micronutrient intakes was undertaken by the Scientific Advisory Committee on Nutrition (SACN) using data from the 2001 NDNS survey. SACN identified that a relatively high proportion of adults had micronutrient intakes below the lower reference nutrient intake (LRNI) or low biochemical status (SACN 2008). Furthermore, SACN reported that people in the group with the highest mean intakes or biochemical status of most nutrients ate the most fish, fruits and vegetables, nuts and seeds. The importance of achieving a nutrient-dense diet rich in fruit and vegetables was stressed by SACN, a view that many international organisations concur with (WHO 2004; WCRF/AICR 2007; USDA 2010), by emphasising plant foods in their dietary recommendations to promote good health, see Table 1.

The support for eating more plant foods goes beyond the health benefits; the recent *Foresight* report ('The Future of Food and Farming') highlighted the benefits of a moderate intake of livestock products as it considered the current and future demand for animal foods was not sustainable (Foresight 2011). There is growing interest in encouraging diets that place greater focus on plant foods and local provenance, to address concerns about food security, the environment and sustainability of the food supply (Bere & Brug 2009; Garnett 2011; Scarborough *et al.* 2012; Trichopoulou 2012).

Sustainability is defined as a system or state where the needs of the present and local population can be met without diminishing the ability of future generations or populations in other locations to meet their needs and without causing harm to the environment and natural assets (Foresight 2011). It is generally considered that sustainability comprises three 'pillars' of importance: environmental (*e.g.* global warming potential, land use, water use, biodiversity), economic (*e.g.* value of output, employment, trade) and social (*e.g.* health and welfare, ethics, social dynamics) (Foresight 2011). A sustainable diet is required to have many attributes across these pillars and there may be synergies but also the need for trade-offs between them (IFR 2012). Despite the breadth of factors that need to be considered in defining sustainability of the food supply, the main focus has to date been GHG emissions (and their impact on global warming), with less focus on other environmental factors such as water use, energy use, waste, and biodiversity and species conservation, as well as relatively little on parameters encompassed by the other two pillars (IFR 2012). In its report to the Department for Environment, Food and Agriculture (Defra), the Insti-

Table 1 Dietary recommendations that emphasize plant-based eating

World Health Organization (WHO) 2002	Keeping fit for life: • emphasise healthy traditional vegetable and legume-based dishes; • select nutrient-dense foods such as fish, lean meat, liver, eggs, soya products (*e.g.* tofu and tempeh) and low-fat dairy products, yeast-based products (*e.g.* spreads), fruits and vegetables, herbs and spices, whole-grain cereals, nuts and seeds; • consume fat from whole foods such as nuts, seeds, beans, olives and fatty fish.
WHO 2004	Recommendations in the Global Strategy on Diet, Physical Activity and Health report included: • 'increase the consumption of fruits and vegetables, and legumes, wholegrains and nuts';
World Cancer Research Fund (WCRF) 2007	• 'basing our diets on plant foods (like vegetables, fruits, wholegrains, and pulses such as beans), which contain fibre and other nutrients, can reduce our risk of cancer'; • 'to reduce your cancer risk, eat no more than 500 g (cooked weight) per week of red meats, like beef, pork and lamb, and avoid processed meats such as ham, bacon, salami, hot dogs and some sausages.'
Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans 2010	• 'several distinct dietary patterns are associated with health benefits, including lower blood pressure and a reduced risk of cardiovascular disease (CVD) and total mortality. A common feature of these diets is an emphasis on plant foods . . .'; • 'the totality of evidence documenting a beneficial impact of plant-based dietary patterns on CVD risk is remarkable and worthy of recommendation.'

tute of Food Research (IFR) notes that the current focus on GHG emissions may promote behaviour change that is environmentally beneficial but in doing this may unintentionally overlook other important aspects that may have either positive or negative consequences for sustainability, and recommends a 'consequential approach' to evaluating impact.

The agricultural sector contributes 10–12% of total GHG emissions worldwide, and deforestation (to generate land for habitation, food or feed production) and other changes in land use contribute an additional 6–17% (Friel *et al*. 2009). Production of foods from animal sources is the major contributor to emissions from the agricultural sector, and products from cows and sheep (as a source of dietary protein and other essential nutrients) have received particular attention owing to ruminants' release of methane, a particularly potent GHG, during digestion. The juxtaposition of sustainable food production and health poses challenges, although recently, it has been suggested that the concurrence of policies could have benefits to both by helping in the achievement of the targets recommended by the UK Committee on Climate Change to reduce UK emissions and concurrently reducing SFA intake (UK Committee on Climate Change 2008; Friel *et al*. 2009). From this has stemmed recommendations in several European countries that high meat intakes should be limited (Friel *et al*. 2009) (Swedish National Food Administration; Swedish Environmental Protection Agency 2009); see also the New Nordic Diet (Mithril *et al*. 2012). In the UK specifically, a reduction in consumption of SFA from all foods derived from animal products, by one-third, has been suggested as a strategy to achieve environmental objectives for 2030 (Friel *et al*. 2009).

The extent to which nutrition goals and environmental sustainability are compatible was addressed in the *Livewell Report* (Macdiarmid *et al*. 2011). It was suggested that a diet that met the current health objectives could potentially reduce GHG emissions by 25%, the target set in the UK for 2020, but more radical changes would be required to reach sustained reductions in GHG emissions. Modifications in current food intake (as reported in NDNS 2001; Henderson *et al*. 2003) would be needed to reduce GHG emissions from the UK adult diet total of 7.14 kg CO_2 equivalents /adult/year; namely a shift to more fruit, vegetables and starch-based foods and to fewer high fat and/or sugar types of food and protein-rich foods (particularly meat). A *Livewell Plate* model, developed to meet both nutrient targets and intake of the food groups illustrated in the *eatwell plate* (DH 2012), suggested that the protein sector of the *eatwell plate* model should in future include a contribution from meat and poultry of only 4%, down from the 2001 NDNS value of 16% for meat/poultry and their products/dishes (Macdiarmid *et al*. 2011). However, Riley and Buttriss pointed out that a major weakness of this estimation was that the data used in the calculation was from the 2001 NDNS survey that did not distinguish between the meat and non-meat components in meat based dishes, such as inclusion of pasta, pastry and vegetables (Riley & Buttriss 2011). Consequently, the estimation of Macdiamid *et al*. may overestimate actual meat and poultry intakes by about 30–40% compared to data from the 2008–2010 NDNS rolling programme that better reflects the contributions from individual food groups because of segregation of meat and non-meat components. Current intakes of meat and poultry: are red meat 93 g/day and 56 g/day respectively for men and

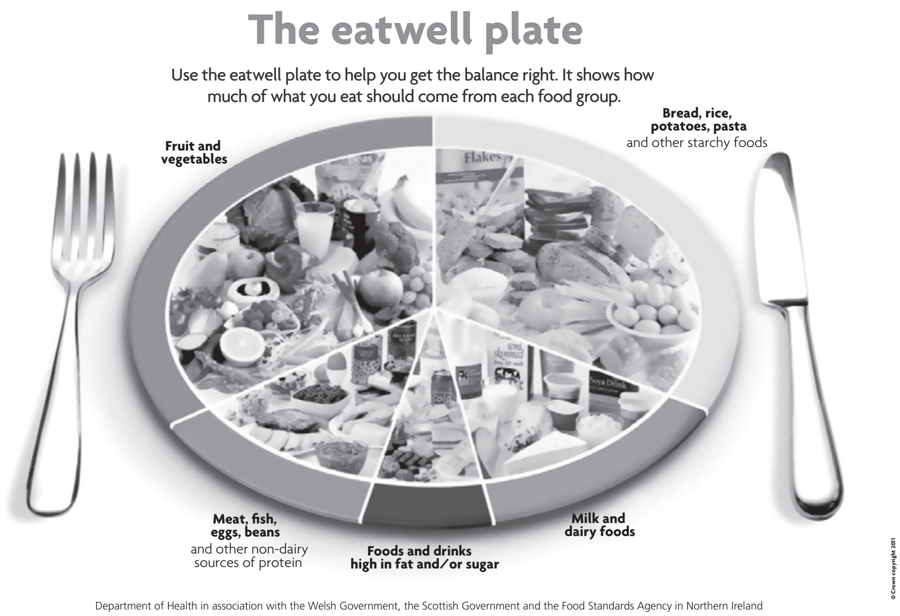

Figure 1 The *eatwell plate*.

women (average 74 g/day), and white meat (chicken and turkey) 42 g/day and 32 g/day respectively for men and women (average 37 g/day) (Bates *et al*. 2011c). While it is likely that these intakes are above the level suggested by Macdiarmid *et al*. from a sustainability perspective, red meat intakes are only marginally higher than advice from the WCRF (Table 1). Thus, in line with the recommendations from IFR about consequential analysis, before dietary advice is changed radically in an attempt to address concerns about the impact of GHG emissions on climate change, it is essential to model the likely impact of reduction in meat of different types and/or dairy products to ensure that micronutrient intakes can be maintained or enhanced (Riley & Buttriss 2011) through identification of alternate dietary patterns.

The UK government's *Food 2030* strategy committed to provide information to enable consumers to make healthy, sustainable food choices (Defra 2010). How this will be achieved in practice has yet to be resolved but the recently published conclusions of the Green Food Project recognise that consumption is an important part of any consideration of the sustainability of the food system not least because the demand for different foods influences production behaviour through price signals, and that the magnitude of the challenges facing the food system over the coming decades requires action on all fronts: production, consumption, waste and governance (Defra 2012b).

In this paper, we consider whether information about the diets of those adopting current public health messages can inform practical messaging that would facilitate wider adoption of healthy and sustainable eating. To investigate this hypothesis, using data from the 2008–2010 NDNS rolling programme, we attempted to determine the profile of those consumers who were meeting the current dietary guidelines that are implicit in the *eatwell plate* model, to look at their dietary patterns and to assess the extent to which they are sustainable and affordable.

The eatwell plate – how it was compiled

The UK's national food guide, the Balance of Good Health, now known as the *eatwell plate* (Fig. 1), was developed almost 20 years ago as a common approach to the presentation of nutrition information under the auspices of the government's Nutrition Task Force, which was established in 1992 to develop a strategy to achieve the dietary targets for 2005 outlined in the 'Health of the Nation: a Strategy for Health in England' White Paper (DH 1994a). These targets were to reduce the average percentage of food energy (E) derived by the population from SFA by at least 35% by 2005 (from 17% E to ≤11% E); to reduce the average percentage of food energy derived by the population from total fat by at least 12% by 2005 (from about 40% E to ≤35% E); and to reduce the prevalence of obesity in men and women aged 16–64 years by at least 25% and 23% respectively, by 2005 (from 8% in men and 12% in women to no more than 6% and 8%, respectively) (DH 1994a; Hunt *et al*. 1995b). Evidence at the time indicated that achievement of these targets would require a substantial change in dietary pattern, including a 50%

increase in fruit and vegetable consumption and a 50% increase in starchy foods such as bread, potatoes, pasta and rice (Bingham 1991). As indicated in the Introduction, the total fat target has been met and progress has been made with SFA reduction. But obesity prevalence has escalated and data for England shows a threefold increase since the 1980s; 25% of adults are now obese (National Obesity Observatory 2012) and the Child Measurement Programme reveals that almost 20% of children are obese by the time they leave primary school (National Obesity Observatory 2011).

Back in the 1990s, 13 different food group models were being used in the UK, varying from three to six food groups (Hunt *et al.* 1995b). Development of the resource (now *eatwell plate*) (DH 2012) was informed by qualitative research that considered a range of different formats including pyramids, plates and rainbows (Hunt *et al.* 1995a), and the 'tilted' plate emerged as the preferred format. With the input of many organisations with an interest in food and health (health professional, education, manufacturing, retail, catering, media sectors) across the UK, aims, nutritional objectives and developmental criteria were agreed. The aims were to promote overall health; provide an agreed core structure for nutrition education; increase public awareness of appropriate food choices for health; focus on the total diet (excluding alcohol); be mindful of current dietary habits; ensure maximum flexibility; be appropriate for healthy people in most age groups (but not those with special needs including infants, children under 5, pregnant and lactating women and frail elderly people) and to provide a foundation for the development of educational materials (Gatenby *et al.* 1995).

The main nutritional objectives were to help consumers understand the relative proportions of different kinds of food in a healthy diet. More specifically, to eat a high proportion of vegetables, fruit and cereal/starchy foods (and to choose those without added fat and sugar where possible); eat moderate quantities of meat, fish and alternatives (such as eggs, chicken, pulses), and of milk and dairy foods (and within these two groups to choose lower fat alternatives – non-dairy alternatives were not originally included, see below) and consume foods in the 'fatty and sugary foods' group in limited amounts. In determining the composition of each of the five groups, foods were selected on the basis of current dietary patterns including those of ethnic minority groups. The relative size of each of the segments of the plate was determined using data prepared for the Committee on Medical Aspects and Food Policy (COMA) report on 'Nutritional Aspects of Cardiovascular Disease' (DH 1994b) and were tested to ensure that an appropriate choice of foods within each group would provide nutrients in the desired proportions. The key characteristics of the foods identified for each group are shown in Table 2 and are major contributors of the nutrients in question and reflect the foods consumed by a group of individuals who on average met the dietary guidelines for fat intake (MAFF 2004). The decision was taken to place potatoes in the starchy carbohydrate group as their consumption pattern is more similar to other components of this group, *e.g.* as an alternative to rice. Pulses were placed with meat owing to their protein and iron content, recognising that unlike most other foods in this group, they do not contribute vitamin B_{12}. Nuts and eggs are also in this group because of their protein content.

The *eatwell plate* today

In 2007, the Food Standards Agency published the *eatwell plate*, as an update to the Balance of Good Health. The modifications were largely cosmetic, including renaming some food groups to make the titles more comprehensive as shown in Table 3, modernising the design and renewing the illustrations with photographs. The proportions of the *plate* devoted to specific food groups has remained the same (Table 3) and is dominated by plant-based foods, which represent two-thirds of the plate. Some national food guides, such as the one adopted in Germany (www.dge.de/modules.php?name=Content&pa=showpage&pid=40), recommend that an even greater proportion of the diet comes from plant foods (see Fig. 2).

During the development of the *eatwell plate*, the decision was taken not to incorporate specific advice on the number of servings from each food group (see Theobald 2004 for a discussion). Over time, there have been changes to the foods illustrated in the various food groups and also further clarification of which foods contribute to each group. For example, fortified soya-based drinks are now considered an alternative to milk provided they supply calcium and vitamin B_{12}. In addition, some food-based dietary guidelines have emerged, such as at least 5 A DAY from the fruit and vegetables group and advice on the inclusion of two servings of fish a week (one being an oil-rich type of fish). *Eight Tips for Healthy Eating* also exist (www.nhs.uk/Livewell/Goodfood/Pages/eight-tips-healthy-eating.aspx) and have been reworded over time. But advice of a more comprehensive nature is not currently available for the UK and some consider this, together with the absence of images of representative and commonly consumed composite foods, to be a limitation in the ease with which the *eatwell plate* can be utilised and applied.

Table 2 Summary of the key characteristics of foods within each food group in the Balance of Good Health model (adapted from Gatenby *et al.* 1995)

Food group	Nutritional characteristics
Bread, other cereals and potatoes	Major source of starchy carbohydrate and dietary fibre. Predominantly low in fat and can be consumed without the addition of fat. Commonly consumed, readily available, affordable, transcultural application. *Key nutrients*: carbohydrate, dietary fibre, B-vitamins. calcium and iron through fortification of bread and breakfast cereals. Vitamin C from potatoes.
Fruit and vegetables	Major sources of vitamins, minerals and NSP. Commonly consumed, readily available, affordable, transcultural application. *Key nutrients*: range of vitamins (*e.g.* vitamin C, carotenoids, folate), minerals (*e.g.* potassium), dietary fibre, carbohydrate.
Meat, fish and alternatives	Frequently contribute to iron intake. Major source of protein. Can be low in fat (particularly saturated fat). Commonly consumed, readily available, affordable, transcultural application. *Key nutrients*: major source of protein, iron, B-vitamins (especially B_{12}), zinc and magnesium. Also some vitamin A and D (not pulses). From pulses only, NSP. From oil-rich fish, *n*-3 polyunsaturated fatty acids.
Milk and dairy foods (excluding butter)	Frequently contribute to calcium intake. Lower fat alternatives available and encouraged. Commonly consumed, readily available, affordable, transcultural application. *Key nutrients*: major source of calcium, protein, vitamin B_{12}. Also provides vitamin A, iodine and zinc.
Fatty and sugary foods	Source of energy as fat or sugar or a combination of fat and sugar. *Key nutrients*: essential fatty acids and fat soluble vitamins (oils and spreads), fat, sugar.

NSP, non-starch polysaccharide.

Table 3 *eatwell plate*: segment size as a proportion of total area

Food group	Segment size as % of total area
Bread, rice, potatoes and other starchy foods	33%
Fruit and vegetables	33%
Milk and dairy foods	15%
Meat, fish, eggs, beans and other non-dairy sources of protein	12%
Foods and drinks high in fat and/or sugar	8%

Data taken from www.dh.gov.uk/en/publichealth/Nutrition/DH_126493.

The eatwell plate's impact on nutrition status of the nation

An analysis by Defra using the National Food Survey for 2000 reported that, at that time, 28% of food consumed was from the fruit and vegetables group; 28% from bread, other cereals and potatoes; 18% from milk and dairy foods; 16% from meat and meat alternatives and 12% from the group of foods high in fat and/or sugar (Defra 2001). So, proportionally, consumption of plant-derived foods was lower than recommended (see Table 3 for comparison).

Does this matter? Evidence from the most recent NDNS indicates that consumption of SFA, salt and non-milk extrinsic (NME) sugars remains above the UK DRVs. Furthermore, there is evidence that a significant number of individuals have intakes of some micronutrients below the LRNI (an amount that is only adequate for the 2.5% of the population with the lowest requirements) (Table 4) and the same survey provides evidence of poor status for some groups, specifically those approaching adulthood (aged 11–18 years), whose pattern of intake is different to adults' in many other respects.

The predominant sources of these nutrients are shown in Table 5, which lists the groups of foods that contribute at least 10% of current intakes, for each nutrient listed (the nutrients identified relate to the 2008–2010 NDNS but the data used for column 2 is that published for 2000/2001 as the detailed 2008–2010 data has yet to be published). This information also emphasises the risks associated with excluding whole food groups from the diet.

The *eatwell plate* from a sustainability perspective

It is noteworthy that some of these foods, *e.g.* meat, fish, dairy products, are those in the spotlight from a sustainability perspective (Buttriss 2011) and hence potential candidates for reduction in dietary terms in light of the global challenge of feeding an expanding global population of more than 9 billion by 2015 in a sustainable

Figure 2 German Society of Nutrition Circle. Deutsche Gesellschaft für Ernährung (DGE, German Nutrition Society): The new DGE- Nutrition Circle (Der neue DGE-Ernährungskreis). DGE info 4/ 2004, 54–56.

Table 4 UK vitamin and mineral intakes: % below LRNI*

	Male			Female		
Age, years	11–18	19–64	65+	11–18	19–64	65+
Vitamin A	12	9	4	13	6	1
Riboflavin	8	3	2	17	11	2
Folate	2	1	1	6	3	4
Iron	5	1	3	44	22	1
Calcium	8	3	1	15	6	3
Magnesium	27	15	17	50	9	9
Potassium	16	10	11	31	22	18
Zinc	12	8	10	19	3	0
Selenium	22	24	30	48	53	52
Iodine	7	5	0	18	8	1

Source: National Diet and Nutrition Survey, Rolling Programme years 1 and 2; 2008–2010 (Bates *et al.* 2011c).

*The LRNI (lower reference nutrient intake) is the amount of a specified nutrient that is likely to be adequate for only 2.5% of the population group to which it pertains.

manner (Riley & Buttriss 2011). If reduction is required and given the current role of such foods in Western diets as providers of a series of essential nutrients that are already present at low levels in the diets of sections of the population in Britain (Table 4), it will be important that dietary advice incorporates information about which foods to substitute so as to avoid the risk of intakes of nutrients, particularly micronutrients, falling still further. Examples include stressing alternate sources of *n*-3 fatty acids and the contribution that pulses can make to iron and protein intakes, and recognising that fortified foods, such as breakfast cereals and plant-based drinks, may need to be a more prominent part of the diet in the future.

NDNS data analysis

To establish the dietary patterns that are associated with achievement of current dietary guidelines, computerised data files from years 1 and 2 of the NDNS rolling programme were obtained from the UK Data Archive, University of Essex Colchester, UK (data.achive@essex.ac.uk) and analysed using the Statistical Package for Social Scientists (SPSS) (Version 20) software. The full dataset includes 4-day diet records of 2126 adults and children aged 19 months upwards. The present analysis was based on all adults aged 19–64 years (n = 807); data were weighted using variables in the dataset to correct for non-response and oversampling (weighted n = 813; 405

Table 5 Foods that contribute ≥10% of intake for those nutrients where there is evidence of low intake and/or status

Food types	Contribution (%) of food types to average daily intake of specific nutrients
Meat and meat products	Zinc (34%), vitamin A (28%), vitamin D (22%), iron (17%), potassium (15%), riboflavin (15%), magnesium (12%)
Fish and fish dishes	Vitamin D (25%), iodine (11%)
Milk and milk products	Calcium (43%), iodine (38%), riboflavin (33%), zinc (17%), vitamin A (14%), potassium (13%), magnesium (11%)
Cereals and cereal products	*Iron (44%), folate (33%), calcium (30%), magnesium (27%), zinc (25%), riboflavin (24%), vitamin D (21%), potassium (13%), iodine (12%)
Potatoes and savoury snacks	Potassium (18%), folate (12%), magnesium (10%)
Vegetables (excluding potatoes)	Vitamin A (27%), folate (15%), iron (10%), potassium (10%)
Fruit (excluding fruit juice) and nuts	None
Drinks (including tea, coffee, fruit juice, alcoholic drinks)	Folate (14%), riboflavin (10%)
Fat spreads	Vitamin D (17%), vitamin A (10%)

Source: Calculated from 2000–2001 NDNS by BNF (Henderson *et al.* 2003)
*A number of these nutrients are present largely through fortification as bread and many breakfast cereals are fortified in the UK.

men and 408 women). Food and nutrient consumption, and socio-demographic and lifestyle data were extracted for statistical analysis. Protein intake (per kg of bodyweight) was calculated for all subjects with valid bodyweight measurements; for 50 adults with missing data, bodyweight was imputed from the gender-specific means (71 kg for women, 84 kg for men). Differences between groups were assessed using two-tailed tests assuming equal variance with a significance level $P < 0.05$ and Bonferroni correction for multiple comparisons. Chi-square test was used for categorical variables.

As outlined previously, the *eatwell plate* sectors are heterogeneous and, with the exception of the fruit and vegetables sector, not quantified in terms of gram intake per day and hence pose a challenge to characterisation using the food groups reported in the NDNS database. In order to make the link between the NDNS data and the *eatwell plate*, six criteria were chosen, corresponding to key healthy eating recommendations implicit in the *eatwell* model and/or nutrient guidelines:

- fat intake of ≤35% food energy;
- SFA intake of ≤11% food energy;
- 5 A DAY fruit and vegetables, based on 80 g portions of fresh products or 30 g dried or 150 g pure juice/smoothie (fruit juice contributes one portion/day, maximum);
- fibre ≥18 g NSP/day;
- protein 0.66–1.32 g/kg bodyweight;[1]
- oil-rich fish ≥140 g/week.

Compliance to each one of the guidelines was assessed initially in the data from the rolling NDNS programme and, thereafter, it was the intention to assess compliance to the multiple guidelines that had been selected to represent the *eatwell plate*.

Results from NDNS database

Compliance to a single criterion

Just under half of all adults were consuming diets within the recommended target for fat content but fewer than a third had diets low in SFA. Fewer than one-third of adults ate the recommended servings of fruit and vegetables daily; see Table 6. Achieving fibre intake, which by its very nature is derived from plant foods, was even more difficult, especially for women (13% vs. 25% achieving among men). Compliance to the oil-rich fish target was also poor at 16% in men and 22% in women. The majority of adults (70%) had protein intakes within the target range; in those outside of this range, approximately 15% of adults were above and 15% below target.

Multiple criteria

Individual targets for fat and SFA were achieved simultaneously by 28% of adults ($n = 231$); see Figure 3. To select those with healthier diets, it was determined how many adults fulfilled these (fat) targets in combination

[1]Moderate protein intake was added as a marker of sustainability using the range 0.66 to 1.32 g/kg bodyweight in accordance with the recommendations of the European Food Safety Authority (EFSA) that stated that the average requirement (AR) is 0.66 g protein/kg bodyweight per day based on nitrogen balance data, consequently the range selected represents adequacy to twofold adequacy (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA) 2012). EFSA further considered taking into account the 97.5th percentile of the distribution of the requirement and assuming an efficiency of utilisation of dietary protein for maintenance of 47%. The recommended protein intake for adults of all ages was estimated to be 0.83 g protein/kg bodyweight per day and is applicable both to high-quality protein and to protein in mixed diets; consequently, within the selected range, it is anticipated that all adults have a more than adequate intake of protein.

with each of three other targets; see Table 6. Few people also met the targets associated with plant foods in combination with the fat targets; only 94 adults (12%) additionally consumed five or more portions of fruit and vegetables per day, while only 6% achieved the two fat targets combined with NSP. Overall, less than 4% of all adults ($n = 32$) met five dietary targets and only 1% of all adults met all six targets. As this number was disappointingly small ($n = 11$), individuals achieving the combined targets for fat, SFA and fruit and vegetables were designated as 'achievers' ($n = 94$) and these were compared to non-achievers (the remaining 720) within the sample; see Table 7. Equal numbers of men and women (both $n = 47$) achieved these three targets.

Energy intakes were slightly lower in achievers (not significant, NS). As expected, given the three criteria for selection, achievers had significantly lower fat and SFA intakes (g/day and as a percentage of energy) and their diets were higher in protein and carbohydrate (on a percentage energy basis). From Table 7, it can be calculated that overall the achievers consumed about 150 kcal/person/day less, comprised of 220 fewer calories from fat, 20 calories more from protein and an additional 50 calories from carbohydrate. In real terms, achievers consumed about 5 g more protein and 13 g more carbohydrate daily.

Although NSP was not one of the selected criteria, intakes were significantly higher among achievers, who on average met the DRV for NSP (DH 1991). This indicates that not only did achievers consume more fruit and vegetables, but also more starchy carbohydrates in the form of wholegrains and fibre-rich cereals.

There was no significant difference in the intake of non-milk extrinsic sugars or sodium, although these tended to be in a beneficial direction (*i.e.* slightly lower among achievers).

In terms of demographics, there was a tendency for achievers to be slightly older (by an average of 5 years) and in the case of men to be educated to degree level; see Table 8. There were few differences in economic status (household income or employment). Between achievers and non-achievers, there was no significant difference in waist circumference (WC) or the proportion within the desirable range of body mass index (BMI; 18.5 to >25 m^2/kg), or overweight or obese (≤25–30 m^2/kg and >30 m^2/kg, respectively); see Table 8. As there is a tendency to gain weight over time, the higher mean age of

Table 6 Percentage of men and women achieving each of the six dietary criteria

Dietary guideline	Male		Female		Total	
% meeting targets for:	*n*	%	*n*	%	*n*	%
Total fat ≤ 35% FE	186	46	207	51	393	48
SFA ≤ 11%FE	117	29	142	35	258	32
Fruit and vegetable ≥5 portions/day	130	32	117	29	247	30
NSP ≥ 18 g/day	101	25	51	13	152	19
Optimal protein	287	71	283	69	570	70
Oil-rich fish	66	16	91	22	156	19
Total numbers	405	100	408	100	813	100

FE, food energy; NSP, non-starch polysaccharide; SFA, saturated fatty acids.

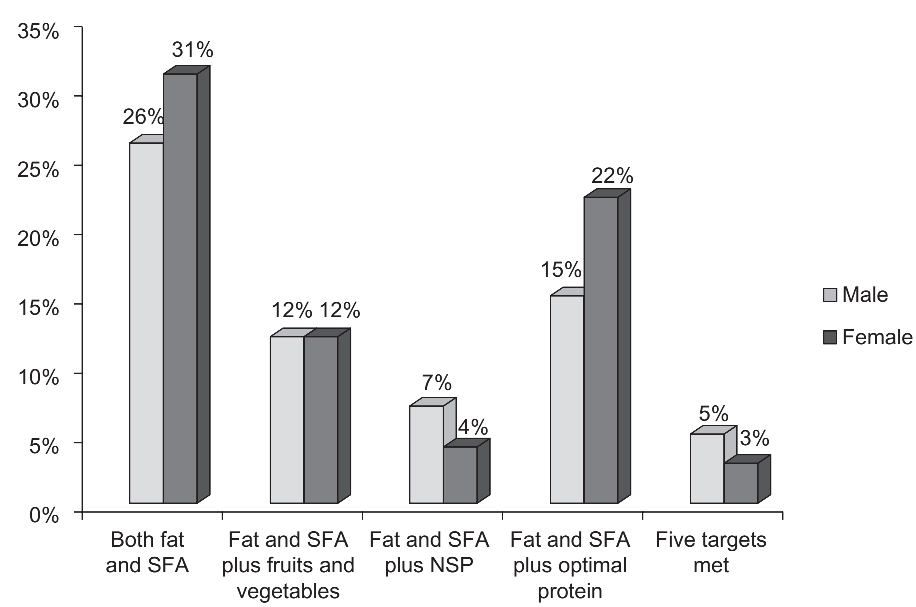

Figure 3 Percentage of men and women achieving combinations of dietary criteria. NSP, non-starch polysaccharide; SFA, saturated fatty acids.

Table 7 Energy and macronutrient intakes of achievers

	Male (M)		Female (F)		Total		Significance*
Met the targets for fat, SFA and FV?	No	Yes	No	Yes	No	Yes	
Subjects (number)	358	47	361	47	720	94	
Mean age	40	44	41	47	40	45	Yes > no (F)
Total energy (kcal)	2221	2019	1647	1551	1933	1787	NS
Total energy (kJ)	9333	8516	6926	6538	8124	7532	NS
Fat % food E	36.5	25.6	35.3	27.6	35.9	26.6	Yes < no
SFA % food E	13.5	8.0	13.1	8.8	13.3	8.4	Yes < no
Protein % food E	17.3	20.6	17.1	18.9	17.2	19.8	Yes > no
Englyst fibre (g)	14.3	19.8	12.2	17.1	13.3	18.5	Yes > no
Carbohydrate % food E	46.3	53.9	47.7	53.4	47.0	53.7	Yes > no
Non-milk extrinsic sugars % food E	12.9	12.7	12.4	10.3	12.7	11.5	NS
Sodium (mg)	2764	2491	2043	1926	2402	2210	NS

*$P < 0.05$ between achievers and non-achievers.
Food E, food energy; FV, fruit and vegetable intake; kcal, kilocalorie; kJ, kilojoule; g, gram; mg, milligram; NS, non-significant; SFA, saturated fatty acids.

Table 8 Physical and sociodemographic profile of achievers

		Male (M)		Female (F)		Total		Significance*
Met targets for fat, SFA and FV		No	Yes	No	Yes	No	Yes	
Subjects (number)		358	47	361	47	720	94	
Waist circumference	cm	97	99	87	90	92	94	NS
BMI	kg/m^2	27.4	28.2	26.9	28.5	27.2	28.3	NS
		%						
BMI	18.5 and below 25	32	23	43	42	38	31	NS
	25 and below 30	40	48	30	25	35	38	NS
	≤30	27	27	24	31	26	30	NS
Qualifications	Degree	26	42	23	32	25	37	Yes > no (M)
	Other qualification	60	42	60	51	60	46	Yes < no (M)
	No qualification	14	16	17	17	15	17	NS
Annual household income	Under £20 K	22	34	32	34	27	34	NS
	£20 K-£50 K	44	28	35	39	39	33	NS
	>£50 K	34	38	33	27	33	33	NS
Smoking status	Current cigarette smoker	30	15	24	5	27	10	Yes > no
	Ex-regular cigarette smoker	21	16	20	22	21	19	NS
	Never regular cigarette smoker	49	69	56	73	52	71	Yes < no
Economic status	School or college full-time	4	0	6	4	5	2	ND
	Full- or part-time employment	9	85	65	67	72	76	ND
	Not working	17	15	29	29	23	22	ND
Vegetarian	Vegetarian	2	0	3	4	3	2	ND
	Non-vegetarian	98	100	97	96	98	98	ND
Currently on special diet	Yes	5	10	10	20	8	15	NS
	No	95	90	90	80	92	85	NS

*$P < 0.05$ between achievers and non-achievers.
BMI, body mass index; cm, centimetre; FV, fruit and vegetable intake; kg, kilogram; m^2, meter squared; ND, not determined; NS, non-significant; SFA, saturated fatty acids.

achievers (+5 years) may have contributed to their marginally higher WC and BMI, which was unexpected in view of their healthier diet. However, it may well have been concerns about their weight that led the achievers to adopt a healthier diet. Indeed, a slightly higher proportion of achievers claimed to be on a diet, compared with non-achievers, although this difference failed to reach statistical significance.

The most marked contrast was with smoking status, smoking being much less common (although not absent) in the achievers. Smoking habit is often seen as a proxy for an unhealthy lifestyle generally.

Discussion of the NDNS/*eatwell* analysis

Overall, it can be seen that very few adults (<4%) achieve all elements of the *eatwell plate*, as interpreted using adherence to the guidelines applied in this paper. However, it should be pointed out that there are conceptual difficulties with using DRVs, which were originally intended as population targets, as maxima for individuals. Dietary guidelines framed without reference to energy intake, such as NSP, may also create anomalies (*e.g.* few women achieving guidelines for NSP yet more achieving 6 g target for salt).

However, this analysis suggests that people who eat a healthier diet, as measured by a few dietary guidelines (limiting fat and SFA, eating more vegetables and fruit), may also have intakes of NSP, sugars and salt that are closer to recommendations. There was no evidence that protein intakes were compromised. In fact, as our target range included those consuming up to twofold adequacy, it could be argued that on average intakes were more than adequate; mean intakes were 87 g (standard deviation (SD) 35.1) and 65 g (SD 18.3) respectively, for all men and women. Moreover, in the achievers mean protein intakes were non-significantly higher, at 94 g and 69 g for men and women respectively when compared to non-achievers.

With the exception of the target protein intake, the majority of people (51%) achieved *none* of the criteria and further research is required to provide insights into how to target advice to this potential group. In addition, this analysis has not explored micronutrient intakes and food choices among those achieving combinations of dietary targets and these aspects warrant further work.

An assessment of how much more plant based eating is needed to match the *eatwell plate*

Implicit within the *eatwell plate* are the target intakes for total fat, SFA, fruit and vegetables, and oil-rich fish; however, the NDNS reveals that few people achieve the weekly oil-rich fish target and while 30% of consumers meet the fruit and vegetable target and 28% meet the total fat and SFA targets, less than half of these meet the combined fat and fruit and vegetable targets (12%) (Fig. 3). In the *eatwell plate*, plant foods constitute two segments entirely in their own right and are represented in each of the other three segments. Foods are grouped slightly differently in the NDNS; plant foods are represented by three main food categories in the NDNS, specifically cereal and cereal products, vegetables and potatoes, and fruit, with small contributions made by the nuts and seeds category, and vegetable spreads.

From the rolling NDNS programme, it can be seen that the main carbohydrate source is starch, which contributes around 27% of food energy intake (Bates *et al.* 2011c); when the contribution of intrinsic and milk sugars is taken into account, this intake is still about 5% below the combined DRV for starch, intrinsic and milk sugars (DH 1991), and likely to equate to a similar shortfall in the starchy food segment of the *eatwell plate* (see Table 3). Thus, by reference to fruit and vegetable intake and the intake of starchy foods, there appears to be a shortfall in intake of plant-based foods in a significant proportion of the population. This trend is also seen in data from the annual Family Food Survey (FFS) 2010 (Defra 2011b), where an assessment of food intake relative to the *eatwell plate* proportions indicated that the starchy food shortfall was 14% (19% vs. 33%) and the fruit and vegetables shortfall was 10% (23% vs. 33%) (Defra 2011b). It should be recalled that FFS data report food purchases rather than consumption and, as such, may overestimate actual consumption.

An investigation of the intake of the major food groups revealed that while achievers and non-achievers had a similar intake of bread overall, achievers consumed significantly more wholegrain bread (see Table 9), which together with their higher fruit and vegetable intake possibly explains how this group achieved the DRV of 18 g for NSP. Although, it was not possible to identify all plant foods consumed by achievers, it seems likely that on balance they consume more plant foods than non-achievers. This data is similar to that reported in a review of 15 epidemiological studies, where those with a higher intake of whole grains had a higher intake of dietary fibre (9 g/day, $P < 0.01$), while total and SFA intakes were lower by 11 g/day and 3.9 g/day, respectively; fruit and vegetable intake, physical activity level and non-smokers were also higher in those consuming most whole grains (Harland & Garton 2008).

Nevertheless, it appears that despite over a decade of messaging to promote 5 A DAY fruit and vegetables, there are still large sectors of the population, around 70% in this sample, who do not achieve this recommendation. As the achievers tended to be older by five years, is it a case of needing to tailor messaging that is more appropriate to younger adults? Does the *eatwell plate* not appeal to this sector? Or is it that these sectors of the

Table 9 Intake of main food groups in achievers and non-achievers of fat, SFA and fruit and vegetable targets

Main significant difference in intake of food groups between achievers and non-achievers	Male (M)		Female (F)		Total (T)		Significance*
Met the three targets	No	Yes	No	Yes	No	Yes	
Subjects (number)	358	47	361	47	720	94	
Skimmed milk (g)	15	45	18	36	17	40	Yes > No (M)(T)
Whole milk (g)	39	10	18	7	28	8	No > Yes (M)(F)(T)
Other milk and cream (g)†	8	24	10	27	9	25	Yes > No (M)(T)
Cheese (g)	19	5	15	5	17	5	No > Yes (M)(F)(T)
Lamb and dishes (g)	13	15	9	20	11	17	Yes > No (F)
Meat pies and pastries (g)	14	2	8	3	11	3	No > Yes (M)(T)
Coated chicken (g)	9	1	5	5	7	3	No > Yes (M)(T)
Chicken and turkey dishes (g)	59	106	49	75	54	90	Yes > No (M)(F)(T)
Other white fish‡, shellfish and fish dishes (g)	18	30	15	18	17	24	Yes > No (M)(T)
Wholemeal bread (g)	19	35	14	23	16	29	Yes > No (M)(T)
White bread (g)	65	48	44	33	54	40	No > Yes (M)(T)
Main sources of animal-based foods that do not differ between achievers and non-achievers:							
Semi-skimmed milk (g)	98	110	89	81	94	96	NS
Beef and veal dishes (g)	59	50	46	60	53	55	NS
Pork and pork dishes (g)	15	22	8	6	11	14	NS
Bacon and ham (g)	18	18	11	10	15	14	NS
Sausages (g)	19	11	12	10	15	11	NS
Oil-rich fish (g)	9	12	11	16	10	14	NS
Approximate intakes of key animal foods (g/day):							
Red meat§					132	123	
Poultry¶					61	93	
Fish**					35	44	
Milk††					151	170	

*Results are based on two-sided tests assuming equal variances with significance level $P < 0.05$. For each significant pair, the key of the smaller category appears under the category with larger mean. Tests are adjusted for all pairwise comparisons within a row of each innermost sub-table using the Bonferroni correction. Cell counts in some sub tables are not integers. They were rounded to the nearest integers before performing pairwise comparisons.

†Includes soya milk and other non-dairy milks and creams.

‡Excludes non-fried and coated fish.

§Includes beef, lamb, pork and their products including veal and liver.

¶Includes all chicken and turkey.

**Includes all white fish, shellfish and oil-rich fish.

††Includes all milks, e.g. skimmed, 1%, semi-skimmed, whole, vegetable milks and cream.

g, gram; NS, non-significant; SFA, saturated fatty acids.

population are difficult to reach with any health messages as evidenced by the higher prevalence of cigarette smoking in non-achievers. Or even more simply, is it that concern about diet and wellbeing increases with advancing years and/or deteriorating health. Data from the FFS (2010) indicates that fruit and vegetable consumption increases with increasing age and income (Defra 2011b). It is also evident in this survey population that fruit and vegetable purchases peaked during 2006 and have decreased since this time (Defra 2011b). In real terms, the cost of fruit and vegetables has increased since 2006 and the reduction in purchases reported is markedly greater in those on a low income (–30% since 2006), emphasising the importance of cost in purchase decisions (Defra 2011b). Information on consumer attitudes and behaviours around food purchase indicates that about 80% of people have an interest in healthy eating and this manifests itself in purchase of an additional 0.7 portions of fruit and vegetables per day, on average. However, 30% of those not motivated by healthy eating cite cost as the main reason for not consuming more fruit and vegetables (Defra 2011a).

Analysis of data from the 1986–1987 and 2000–2001 NDNS series also indicated that younger participants were less likely to achieve fruit and vegetable targets (Rogers & Pryer 2012). Typically, manual social classes, younger participants and people on benefits or outside paid employment were less likely to achieve the target, as were people who were divorced, widowed or separated or in a household or a lone parent with dependent children. From the 1986–1987 survey, it was reported that 12.7% of adults in the study population were classified as achieving the 5 A DAY fruit and vegetable target; this had increased to 16.5% by the 2000–2001 survey (Rogers & Pryer 2012). However, between the 1986–1987 and 2000–2001 surveys, improvements were seen across social class groups and differences between men and women were reduced, which is broadly similar to the findings in this analysis. The inclusion of fruit and vegetables from composite dishes in the NDNS rolling programme makes it a less suitable comparison to the two earlier NDNS, as do methodological differences in the data collection (Bates *et al.* 2011b). For example, vegetables from composite dishes accounted, on average, for 50 g of total vegetable consumption (equivalent to 36% of intake in adults), while fruit contribution from composite dishes was much lower at 5–13 g/day or 6–11% (Bates *et al.* 2011b). Overall, it has been estimated that the fruit and vegetable intake from composite dishes contributes about one serving (Lennox *et al.* 2011). Nevertheless, it appears from the NDNS that achievement of the fruit and vegetable target has continued to increase marginally, although the reported compliance with 5 A DAY of 30% in the present survey overstates the improvement compared to previous surveys. There is certainly still a need to improve intake across many sectors of the population but barriers to changing consumption of fruit and vegetables will need to be overcome. Some 15 years ago, it was identified that lack of the support of family and friends, food costs, time constraints and shopping practicalities were major obstacles (Cox *et al.* 1998) and it appears that addressing some of these areas may still be relevant today, in order to encourage greater consumption. There is evidence that initiatives targeting school-age children can be effective (de Sa & Lock 2008; www.europeanfoodframework.org.uk), although it is recognised that there is a need for a more systematic and accurate evaluation of government-led interventions, as well as for a stronger focus on actual behavioural change, rather than changes in attitude or intention alone (Capacci *et al.* 2012).

Plant foods' contribution to starchy carbohydrate intake has changed little (in g/day) since 2001 (Bates *et al.* 2011c), although there have been substantial declines in intakes of bread and potatoes over the past 50 years (Defra 2011b). Some plant foods contain protein (pulses ~7–23 g/100 g, nuts ~14–27 g/100 g, seeds ~16–20 g/100 g, and grains ~2–12 g/100 g as consumed) and so can contribute to protein intake, but information from the NDNS about the extent of this (and % contribution) is limited. For example, the vegetables and vegetable dishes category in the NDNS, which includes legumes and pulses, contributes only about 5% of total protein intake (Bates *et al.* 2011c) and overall intake of baked beans and pulses is recorded as about 17 g/day, of which over 90% of intake is baked beans. Average intake of nuts and seeds is also very low (Bates *et al.* 2011c). Plant foods also contribute to other sectors of the *eatwell plate*, *e.g.* meat replacers such as mycoprotein and textured soya are found in the meat sector of the plate, while dairy replacers such as plant-derived drinks and desserts are found in the dairy sector, making it difficult to assess total intake of plant-derived foods accurately.'

How much more plant-derived food is needed to meet the balance of food categories illustrated in the *eatwell plate*? From the 2001 NDNS data, it was calculated that there was an average shortfall in both fruit and vegetables and cereals and cereal products intake of 5% (Defra 2001). The FFS (2010) data on purchases would indicate a much greater shortfall in plant foods of about 25% (Defra 2011b). However, neither of these analyses includes the role that plant proteins could make, as a relatively sustainable source of protein (from a GHG emissions perspective), in meeting overall protein requirements.

Although not directly comparable to Defra 2001, this current analysis is suggestive of at least a similar shortfall in plant foods intake compared with current recommendations and provides justification for encouraging greater consumption of plant foods in general, not just fruits and vegetables but also starchy carbohydrate sources (grains and potatoes) and plant-derived protein sources such as pulses, nuts, seeds and grains. Consequently, if the *eatwell plate* is to be achieved, then the shortfall in plant foods is at least the 5% identified in 2001, and if the *eatwell plate* is to progress to take account of sustainability as well as health, a target of, say, 10% more plant-derived foods would seem a pragmatic recommendation.

What can be learnt from those achieving fat, SFA and fruit and vegetable targets?

From a nutrient perspective, the achievers have a lower fat and SFA intake, a significantly higher intake of NSP and tend to consume a greater amount of protein, both as a percentage of food energy and in absolute terms (g/day). How has this been achieved in terms of food choice and what other aspects of achievers' intakes differ?

Total consumption of animal protein foods (g/day) in this survey differs little between achievers and non-achievers; see Table 9. However, there are differences in the main food groups that contribute to animal protein intake; while red meat intake is similar between achievers and non-achievers, the intake of chicken and turkey dishes and non-fried white fish and shellfish is significantly higher in those achieving the fat, SFA and fruit and vegetable targets. Non-achievers have a significantly higher consumption of coated chicken and meat pies and pastries. This profile of food intake tends to suggest that achievers have selected lower fat or healthier options from broadly the same categories of foods; for example, by selecting non-fried or pastry-free dishes, or perceived leaner sources of meat, such as poultry. Nevertheless, achievers have continued to eat at least as much meat protein as non-consumers. Consequently, there is little evidence that achievers are consuming a more plant-based (and potentially more sustainable) diet. Considerable potential exists for inclusion of low SFA plant protein foods (*e.g.* pulses, nuts, seeds and grains) as an alternate source of protein, in line with the balance between plant and other foods illustrated in the *eatwell plate*.

Achievers also consumed significantly less whole milk, cheese, white bread and significantly more wholemeal bread, skimmed milk, and other milks and cream (this last category is diverse and includes flavoured milks, milkshakes and non-dairy 'milks' such as soya drinks, non-dairy and dairy cream, and infant formula); see Table 9. Once again, it appears there has been uptake of messages to reduce SFA and, to a limited extent, increase wholegrain or fibre intake, but possibly also evident is the challenge of adopting multiple dietary guidelines. This difficulty has been reported previously and is in agreement with earlier findings reported in a review of three studies investigating subjects' motivation to change their diets to match nutritional goals (De Looy *et al*. 1991). All participants achieved a change in dietary intake over 1 week and met one nutritional goal but it was much easier to substitute one item in the diet for another or reduce consumption of certain foods that contributed a significant amount of fat such as swapping the type of milk consumed from whole to semi-skimmed or skimmed. Subjects in the Diet and Reinfarction Trial found it relatively easy to make one dietary alteration but, where two nutrients were involved, it became more difficult (Fehily *et al*. 1991).

An aspect that has not been addressed in this analysis is the sources from which the achievers obtained their information about diet and to what extent they have been exposed to the *eatwell plate*. Clearly, people struggle with multiple dietary recommendations but can the *eatwell plate*, which is a visual tool that considers the diet as a whole and focuses on specific food groups, be used more effectively by health professionals in communicating advice to the population at large. Further quantitative recommendations accompanying the *eatwell plate*, in addition to those for fruit and vegetables and oil-rich fish, would be helpful; for example, guidance on portion sizes for protein foods and starchy foods, (Murphy-Bokern 2010).

A driver of behaviour change is identification by individuals of benefits that motivate them to change; these will be different for each individual and may, for example, be related to wanting to eat more healthily, to manage weight, for cardiovascular health or to make a contribution to the environment (Lea *et al*. 2006a). But intent does not always translate to action. For example, while around 70% of those surveyed considered sustainably sourced fish as being important, their behaviour indicates a different priority, with only 30% actively seeking to purchase it (Defra 2011a). The key for health professionals is to capture the drivers that are important to the individual and help them to put these into practice. Whether the key drivers are related to wellbeing, health, ethical issues, convenience or cost, the use of the *eatwell plate* can be tailored to each of these, but guidance is required to help health professionals put the *eatwell plate* into practice capitalising on these different drivers.

In order to improve overall adoption of the principles implicit in the *eatwell plate*, from the low base of 4% estimated in this analysis, a significant public health effort is required to educate consumers about the foods that comprise a healthy diet. In particular, further focus is required to achieve the fruit and vegetable target to enhance consumption levels of wholegrains and other starchy foods such as potatoes, to increase the proportion of other plant-based foods to help meet NSP requirements, and also to increase oil-rich fish intake.

Environmental impact of moving towards a more sustainable diet

When considering the characteristics of a potentially more sustainable interpretation of the *eatwell plate*, the diversity of foods, which comprise each segment of the *Plate*, presents a challenge. For example, in the protein foods segment, even without taking into consideration, all three pillars of sustainability, the environmental impacts of producing meat, fish, eggs, beans and other pulses vary considerably. Although there is a commonly accepted view that red meat production has a relatively greater global warming potential than vegetable production, per kg, it is also recognised that within each type of protein production, there is a wide range of potential impact (IFR 2012). Overall, it has been concluded that the composition of the groups in the *eatwell plate* are too broad to quantify relative environmental sustainability, let alone to take into account the characteristics of the other pillars of sustainability (IFR 2012). It is for this reason that a 'consequential' approach to life cycle analysis has been suggested as the most appropriate route to evaluating the impact of dietary change (IFR 2012), although this approach has the disadvantage of not allowing nutrient content to be considered too. In addition, in its report to Defra, IFR also recognised that the data to conduct such an analysis is not currently available and recommended such an approach should be augmented by use of a 'checklist' to ensure that change between elements of the diet does not lead to unintended consequences in other attributes of sustainability, *e.g.* changes in biodiversity or societal dynamics.

Although only part of a very complex picture and recognising the substantial variation that exists in published values, life cycle analyses have generated estimates of GHG emissions. Data from many sources are collated in the IFR report, which serves to highlight the extent of the variation [kg carbon dioxide equivalents (CO_2 e)/kg product] particularly for ruminant protein and to a lesser extent fruit (IFR 2012). Overall, the calculated impact in kg CO_2 e is higher for beef and sheep meat compared to milk, grain and potatoes that are more similar. A European Parliament, Science and Technology Options Assessment (STOA) also undertook a review of studies to consider the implications of trends in eating habits for climate change. GHG emissions, water footprint and fossil fuel input data were collated for a wide range of food products and expressed in comparable units; each kg of beef production was associated with between 6.3 and 3.7 kg CO_2 e, required 15 500 l water and 15–56 MJ energy input (European Parliament STOA 2009). See Table 10 for comparable values for a range of other foodstuffs, including milk where equivalent values were 0.4–1.4 CO_2 e, 1000 l and 2.5–3.6 MJ; soya where they were 0.9 kg CO_2 e, 1800 l and 5.9 MJ; and for wheat 0.3 kg CO_2 e, 1300 l and 2.1–8.1 MJ for GHG emissions, water requirement and energy use, respectively. An analysis that compared vegetable and animal protein emissions calculated a value for cooked soya beans of 0.92 kg CO_2 e/kg product, compared to 1.0, 4.3, 9.3 and 30 kg CO_2 e/kg product for 4% milk, cooked domestic chicken, pork and beef, respectively (Carlsson-Kanyama & Gonzalez 2009). Another study calculated that on average, to produce 1 kcal of plant protein requires 2.2 kcal of fossil energy, whereas 1 kcal meat protein production requires 25 kcal of fossil fuel (Pimentel & Pimentel 2003). Using data from the UK, GHG emissions per unit of livestock product have been estimated (Friel *et al.* 2009) and these are shown in Figure 4. These values are comparable to those calculated from Swedish data, where foods based on vegetables, cereals and legumes generally had the lowest GHG emissions, with the exception of those transported by air (Carlsson-Kanyama & Gonzalez 2009). However, it is important to recognise that estimates of GHG emissions characterise just one of the many sustainability attributes within the environmental pillar and does not take account of, for example, land use issues (*e.g.* cattle and sheep, as ruminants, can graze on grass in uplands and other areas of the countryside unsuited to other food production) or water use, employment issues or societal dynamics. There is a wide variation in the sustainability characteristics between and even within production systems, even for a single food, whether it be tomatoes (grown in greenhouses vs. the open air in a warm climate with limited water) or rearing animals in different systems. Application of research is already yielding results in the UK to minimise the environmental impact of both meat and dairy production but further progress can be made (Pullar *et al.* 2011; Defra 2012a). It has been estimated that the UK's consumption of meat

Table 10 The GHG emissions, water footprint and fossil fuel input for a variety of agricultural outputs

	GHG emissions	Water footprint	Fossil fuel input
Foodstuff	Kg CO_2 equivalents	Litres/kg	MJ/kg
Milk	0.4–1.4	1 000	2.5–3.6
Beef	6.3–37	15 500	15–56
Sheep meat	7.6–17	6 100	17–19.3
Eggs	2.2–5.5	3 900	14–22.2
Poultry	1.1–4.6	2 390–4 500	12–25
Soya	0.9	1 800	5.9
Wheat	0.3	1 300	2.1–2.8
Rice	0.4	3 400	8.8
Tomatoes*	0.1–10	0.04	3.4–37.7
Apples	0.2	500	2.9

Source: Data extracted from European Parliament STOA 2009.
*Emissions from tomatoes vary greatly based on the growing method used, *i.e.* greenhouse grown and how shipped.
CO_2, carbon dioxide; GHG, greenhouse gas; kg, kilogram; MJ, megajoule.

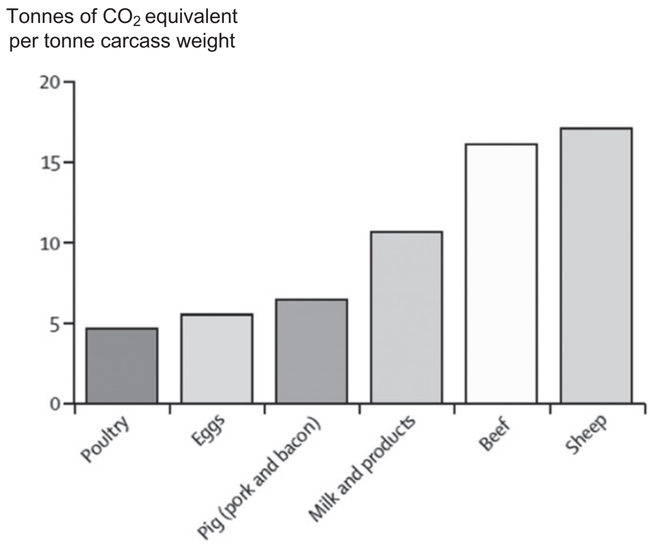

Figure 4 Estimates of total livestock emissions for livestock products produced in the UK. Extracted from Friel *et al.* 2009.

and dairy products (including imports) now accounts for some 8% of UK global warming potential associated with GHG emissions, whereas a report by the Food and Agriculture Organization puts global livestock related greenhouse gases as high as 18% (Garnett 2008).

Using UK data from the FFS (2008), three scenarios have been modelled: scenario 1 is a reduction in consumption of all meat and dairy products (50% reduction in livestock products compared to 2005 data), replaced with fruit, vegetables (including potatoes), cereals and vegetable oils (Scarborough *et al.* 2012); scenario 2 is a shift from consumption of cow and sheep meat (75% reduction) to pigs and poultry; and scenario 3 is a reduction in consumption of pigs and poultry (50% reduction), replaced with fruit, vegetables (including potatoes), cereals and vegetable oils (Scarborough *et al.* 2012). The largest environmental impact, resulting in a 19% reduction in GHG emissions and a 42% reduction in land use for foods consumed in the UK was estimated for scenario 1. Scenario 2 resulted in 9% and 39% reductions in GHG emissions and in land use respectively, compared with the 2008 baseline, and scenario 3 resulted in 3% and 4% reductions in GHG emissions and in land use, respectively (Scarborough *et al.* 2012). The health impact of these scenarios was also modelled with reduction in mortality from cardiovascular disease and cancer of 36 910, 1999 and 9297 deaths delayed/averted per year for scenarios 1, 2 and 3, respectively (Scarborough *et al.* 2012). The largest contribution (75%) to deaths averted was from increased intake of fruit and vegetables. From a nutrient perspective, scenario 1 resulted in a decreased intake of SFA, an increase in fibre and there was a marginal reduction in some micronutrients, with the exception that vitamin B_{12} was significantly reduced from a baseline value of 5.8 to 3.9 μg/day. The authors comment that uncertainty arises from the bioavailability of micronutrients in the substituted foods in all scenarios and there is a need for further work in real life settings to confirm these modelled results (Scarborough *et al.* 2012). In another in-depth analysis of meat and dairy reduction, calcium, zinc, iodine, riboflavin and vitamin B_{12} intake were identified as being at risk; however, the authors proposed that by improved public health advice on alternative dietary sources and by increasing food fortification the challenges to these nutrient intakes could be met but, as yet, this approach has not been tested in practice (Millward & Garnett 2010).

As well as the impact of GHG emissions, the production of food requires energy input, either directly or indirectly, through its use to produce and transport fertilizer and pesticides, drive machinery and irrigation. Using US data, a more integrated assessment of the environmental effect of dietary consumption patterns that represent vegetarian and non-vegetarian diets, has been attempted (Marlow *et al.* 2009). It is based on the combined differential production of 11 food items, for which consumption differs among vegetarians and non-vegetarians, and showed that the non-vegetarian diet required 2.9 times more water, 2.5 times more primary energy, 13 times more fertilizer and 1.4 times more pesticides than did the vegetarian diet. Another assessment suggests that on average, the complete life cycle environmental impact of non-vegetarian meals may be roughly a factor 1.5–2-fold higher than the effect of vegetarian meals, in which meat has been replaced by vegetable protein (Reijnders & Soret 2003).

Water and land requirements for animal and plant food production are further considerations, as are the impacts on the other two pillars (economic and social), yet to date, there are few detailed analyses that attempt to integrate even some of these demands, probably because the systems of production are too diverse and localised to provide meaningful data. The European Parliament STOA modelled the effect of current dietary trends on land use and compared these to a diet containing minimal meat for health (estimated to be 33 kg per annum) and also to a lacto-vegetarian diet (European Parliament STOA 2009); land use for each of these diets reduced with the progression to lacto-vegetarianism. More recently, Defra has funded two projects that have begun to address some of the challenges (see IFR 2012 and Defra 2012a). In addition, the UK's main public funders of food-related research are working together through an initiative, Global Food Security, to address the challenge of providing the growing population with a sustainable, secure supply of good quality food from less land and with lower inputs (www.foodsecurity.ac.uk/).

In summary, based on available data on GHG emissions derived from life cycle analyses for various foods, it is generally acknowledged that the production of plant foods is associated with a lower global warming potential (European Parliament Science and Technology Options Assessment 2008) although substantial variation exists even for particular foodstuffs. What has yet to be established is an integration of this analysis with the many other characteristics of sustainability (IFR 2012). Meanwhile, given the projected influence of GHG emissions on global warming and climate change, it has been suggested that it appears inescapable that the amount of meat and dairy products consumed in many parts of the world will need to be moderated if GHG emission targets are to be met (Garnett 2011).

Another contributor to potential GHG emission is food purchased for consumption within the home that is allowed to perish and spoil; it is estimated that this can contribute between £310–720 per household per annum. Avoidable food and drink waste by households is responsible for 20 million tonnes of CO_2 e per year: equivalent to one-third of the emissions of CO_2 with milk estimated to be the single largest contributor to avoidable waste (Defra 2011c). Overall, 15% of edible food and drink purchases are wasted per annum but there is considerable variation. Thirty two per cent of bread, 24% of vegetables and 20% of fruit are wasted, whereas meat and fish wastage is only 13% of purchases (Defra 2011c). Consequently, a change to more plant-derived foods has potentially negative implications as far as food waste is concerned necessitating focussed advice not only of food preparation and storage, but also purchase.

In the UK, the development of the *Livewell Plate* (based on analysis of the 2001 NDNS) (Macdiarmid *et al*. 2011) recommended not only focussing on eating more fruit and vegetables, but also a reduction in both red and white meat was proposed. However, it may be possible that, rather than focussing on reductions in meat protein *per se*, emphasising plant foods more generally with the view to increasing both plant proteins and wholegrains intake may be a more acceptable approach to consumers (Lea *et al*. 2006b), and may also help to achieve balance in both the starchy food and protein sectors of the plate. Thus, a greater focus on plant foods can potentially help to achieve improved health and sustainability (Harland & Garton 2011; McEvoy *et al*. 2012). However, there are barriers to overcome in order to enhance plant food consumption and one of these is perceived cost. Calculations conducted with the *Livewell Plate* (Macdiarmid *et al*. 2011) and also in an extensive review of the impact of moving to more plant-based eating (Harland & Garton 2011), demonstrate that healthy diets containing more plants foods are not more expensive; an aspect that it is essential to convey to consumers if changes to consumption patterns are to be made.

Many food combinations can be used to achieve the recommendations of the *eatwell plate* food guide but the evidence considered here suggests that consumption patterns that are commonplace in the UK are not sufficiently aligned with the proportions illustrated in the food guide. Furthermore, given the available data on GHG emissions, it is likely that increasing the proportion of plant foods consumed, in line with the food guide, will have benefits from a sustainability perspective (noting that GHG emission is just one of the characteristics of a sustainable food supply). As highlighted in IFR's analysis, a consequential analysis is important to identify any adverse sustainability consequences associated with including more plant foods in the diet; for example, more food waste within the home, higher cost of imported air freighted plant foods if locally produced foods are not available; impact on the local economy of changes in agricultural practices (the UK climate readily supports livestock production but not pulses).

In common with other analyses (*e.g.* IFR 2012), it is not possible, on the basis of this analysis, to be precise with regard to the potential environmental or more general sustainability savings from promoting use of the *eatwell plate* model, but adoption of a more plant-based interpretation of the *eatwell plate* seems to be a sound basis on which to capture the combined requirements of dietary change for health and environmental objectives.

Conclusions

This review and analysis of data from the 2008/2010 NDNS rolling programme indicates that few people (1%) within this survey meet the combination of six dietary guidelines used in this analysis as a proxy for the *eatwell plate* and, with the exception of the protein target, the majority (51%) met no guidelines at all. Those meeting the three targets for fat, SFA and fruit and vegetable intake, out of the possible six targets, were designated achievers, and comprise 12% of the population ($n = 94$). They tended to be older by 5 years and to have a degree ($P < 0.05$), while non-achievers were more likely to smoke ($P < 0.05$). Energy intakes were slightly lower in achievers (NS), who had significantly lower fat and SFA intakes and higher intakes of protein. Intakes of NSP were significantly higher among achievers, who on average met the DRV for NSP. Significantly higher intakes of skimmed milk, chicken and turkey dishes, white fish (not fried) and shellfish and wholemeal bread contributed to attaining the targets, and intake of other milks (including flavoured milks, milkshakes and non-dairy 'milks' such as soya drinks) was also increased; non-achievers consumed more coated chicken, meat pies and pastries, cheese, whole milk and white bread. It appears that the achievers have reduced the fat content of their diet by focussing on lower fat/higher fibre alternatives within the same category of foods rather than introducing more plant foods such as legumes, nuts and seeds. If, as has been suggested, eating more sustainably means eating less meat, then the achievers were not necessarily eating more sustainably.

By comparing this data to the analyses conducted with the 2001 NDNS data, it appears that there has been some progress in increasing fruit and vegetable intake but little progress in achieving an increase in foods that comprise the starchy foods section of the *eatwell plate*. Neither is there a noticeable increase in consumption of plant foods that contribute to protein intake such as pulses, legumes, nuts and seeds. Despite the lack of specific guidance in terms of number of servings and their size (weight in grams) that comprise the protein and starchy foods sectors of the *eatwell plate*, it can been seen that with some rebalancing and the inclusion of more plant foods, particularly more plant proteins and starchy foods, the *eatwell plate* provides the basis of a healthy cost-effective diet. Based on the available data for GHG emissions, it might also contribute to the achievement of at least some of the sustainability objectives. However, in order to meet these joint objectives, consideration needs to be given to how to deliver more detailed and practical advice on using the *eatwell plate* to drive healthy and sustainable dietary patterns.

One of the limitations of this analysis is the lack of data on micronutrients and further work may be warranted to explore both micronutrient intakes and their bioavailability in the food choices made by those achieving combinations of dietary targets. Another limitation is sample size; there was a relatively small number of people achieving even three dietary guidelines but as further data from the rolling programme become available, this aspect can be addressed. The imperfect match between the recommendations implicit in the *eatwell plate* and the way data is captured for the NDNS is also an aspect that could be addressed in future. A further limitation of the analysis is the lack of quantification of the potential benefit from the perspective of achieving a sustainable food supply. While the evidence from a GHG emissions perspective points to greater sustainability of dietary patterns dominated by plant foods (as depicted in the *eatwell plate*), to address the complexity of the many issues involved will require data that is not yet available.

Conflict of interest

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