

Healthy and sustainable diets in the early years

Implications of current thinking on healthy, sustainable diets for the food and nutrient intakes of children under the age of 5 in the UK

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FIRST STEPS NUTRITION TRUST



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Acronyms

AICR	Association for International Cancer Research
ALSPAC	Avon Longitudinal Study of Parents and Children
BSI	British Standards Institute
CIF	Children in Focus
DRV	Dietary reference value
EAR	Estimated average requirement
FAO	Food and Agriculture Organization
FCRN	Food Climate Research Network
GHG	Greenhouse gas
LCA	Life cycle analysis
LRNI	Lower reference nutrient intake
NDNS	National Diet and Nutrition Survey
RNDNS	Rolling National Diet and Nutrition Survey
RNI	Reference nutrient intake
SACN	Scientific Advisory Committee on Nutrition
SDC	Sustainable Development Commission
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

Summary



This report examines the progress that has been made towards defining what a healthy, sustainable diet might look like for developed countries, and in particular examines the implications of this for children under the age of 5 years in the UK.

There is no doubt that climate change will impact on food supply and that the food supply impacts on climate change, and many countries are considering the implications of this for future national dietary advice. While much of the guidance around what constitutes a healthy diet has been around for decades, there has been relatively little specific advice on how to eat to meet these guidelines. It could be suggested that applying recommendations for more sustainable consumption to existing diets might be counterproductive in terms of nutritional health. Reducing meat and dairy foods may have nutritional implications, and these may be highly variable between individuals. There is, however, considerable scope for diets to become both healthier and more sustainable with an increase in plant-based foods and a reduction in foods high in fat and sugar, and yet the latter component is often overlooked in favour of discussion about reducing consumption of livestock products.

A summary of the most recent information on the diets of children aged under 5 in the UK shows that the current diets of some children fail to achieve minimum nutrient requirements and therefore, if dietary recommendations change, the impact on those with marginal intakes needs to be considered. Children under the age of 5 years obtain a significant amount of their nutrients from milk and dairy products, and changes in the intake of these foods would require careful inclusion of substitute foods, particularly for intakes of riboflavin, zinc and iodine to remain adequate. Reducing meat and meat products is likely to be less problematic, but much is still unknown about the bioavailability of nutrients and care needs to be taken when altering the balance of foods in the diet. Current dietary reference values in the UK have been developed based on current UK intakes of foods and nutrients and therefore there may need to be some review of the adequacy of these if dietary composition is suggested to change substantially.

Dietary modelling for the purpose of delivering national food-based dietary guidelines must take into consideration factors other than meeting nutritional targets for nutrients, including national food preferences and food availability. Existing models often also attempt to deviate as little as possible from existing dietary patterns but it is likely that, if the food chain is to achieve the required reductions in greenhouse gas emissions, there will have to be a fundamental shift in food consumption patterns. There remains considerable work to be done to model diets which meet a number of health and sustainability criteria that are achievable, palatable and acceptable in developed countries with heterogeneous populations.

Introduction



There is no doubt that climate change will impact on human health over the coming decades. Extreme weather events such as floods, droughts and heat waves will have an impact on the distribution of disease, and it is likely that many of these environmental impacts will make under-nutrition, food insecurity and water stress more widespread in many areas of the world (Costello et al, 2009).

Faced with an increasing worldwide population, the agricultural sector of the future will need to adapt to a changing climate while expanding production to meet the pressure of the increasing demand for food. At the same time, strategies to mitigate the impacts of the food system on the climate and wider environment must be developed and employed.

Over the past few decades, potential solutions to the problem of feeding an increased global population have become polarised into:

- those that focus on scientific and technological innovations to boost productivity while addressing resource scarcities and environmental constraints, and
- those that place a greater emphasis on environmental constraints, question the nature of demand, and highlight the waste inherent in current food systems and the health problems associated with over-consumption.

Mitigation of demand through behavioural change, and structural changes in food systems and supply chains which allow us to live within our environmental limits, are advocated as an integral part of the transition towards more sustainable food production and consumption (Foresight, 2011; Stehfest et al, 2009; Garnett, 2008; McMichael et al, 2007; Gerbens-Leenes and Nonhebel, 2002). There is therefore considerable current thinking and debate about how recommendations about eating for optimum health might be adapted to ensure that they also reflect environmental concerns. However, meeting the nutritional needs of populations – as well as considering the cultural significance of food, traditions, production capacity, income variations, food skills and all other elements of the complex food supply chain – is unlikely to be a simple process.

Much of the debate so far has considered how to plan food systems and encourage consumers towards a more plant-based diet, generally considered by all as the most sustainable and healthy dietary option. It is generally agreed that the increasing demand globally for meat and dairy foods is unsustainable and that it is hard to imagine that this global issue can be solved through more efficient technologies in the food system alone (de Bakker and Dagevos, 2011). While there is consensus that meat and dairy foods are core products in the diet and lives of UK consumers, with long-standing associations of goodness, pleasure and health, the call for reduced intakes has generally been universally agreed as a necessary measure for reducing greenhouse gas emissions (Jackson et al, 2009). Trying to reach agreement on what a healthy and sustainable diet for adults might look like has been attempted in recent years, but is hampered by a lack of clarity about what consumers have to do to achieve current healthy eating guidance and how this might be achieved alongside changes which are sustainably beneficial. Also, there has been very little research into how reductions in meat and dairy foods in diets might impact on young children, who have greater energy and nutrient needs for growth and development. A discussion of the potential for nutritional risk of changing diets to meet sustainability criteria has been offered by Millward and Garnett (2009). They concluded that changing some elements of current diets could pose serious nutritional challenges for some key nutrients in human populations.

This report aims to review current thinking on healthy and sustainable diets and considers how current dietary modelling to achieve healthy diet goals can be linked to sustainability guidance. It considers this in particular in the context of children under the age of 5 years in the UK.

1 Food systems, climate change and greenhouse gases

This section looks at the climate changes that have occurred during the last century and predictions for future temperature changes. It examines the adverse impact that food systems have on the environment, including their contribution to greenhouse gas emissions, and looks in more detail at which food categories are the largest contributors to those emissions.

1.1 Climate change and greenhouse gas emissions

Climate change

Increases in global temperatures since the mid 20th century are largely due to greenhouse gas (GHG) emissions arising from human activity – mainly the burning of fossil fuels as a result of industrial and agricultural activity (Solomon et al, 2007). During the last century, average global temperatures rose by 0.76°C and the sea level rose by 4cm.

The best estimates from a synthesis of models predicting future temperature changes have suggested that, by 2100, temperatures could rise by between 1.8°C and 4°C, with increasingly severe implications for food and water security and the integrity of ecosystems (Solomon et al, 2007). There has been a general consensus that an increase in average global temperatures of 2°C is the threshold at which climate change becomes dangerous and it is suggested that current global GHG emissions will need to be reduced by between 50% and 85% to avert this potential crisis (Metz et al, 2007).

Targets for reductions in greenhouse gas emissions

International recognition of the scale and implications of climate change led to the implementation of the Kyoto Protocol in 2005. This agreement, linked to the United Nations Framework Convention on Climate Change (UNFCCC), committed participating countries to reducing their total GHG emissions during the period 2008-2012 by an average of 5% relative to 1990 levels. However, current emissions projections suggest that bigger cuts than those agreed in Kyoto are needed. Targets to reduce GHG emissions vary between countries. The European Union has a reduction target of 8%. Developed countries have the largest emission reduction targets, in recognition of the fact that they have made the greatest contribution to GHG-driven climate change, while it is generally agreed that many developing countries must be allowed to continue to develop and should not be obliged to reduce GHG emissions in the same way. The two largest contributors to global GHG emissions are China and the USA. However, the USA did not ratify the Kyoto Protocol and China is not obliged to. The UK has also committed itself to a self-imposed domestic target of reducing industrial emissions of CO₂ (carbon dioxide – one of the six gases included in the Kyoto Protocol) by 80% by 2050.

1.2 How do food systems impact on climate change and the environment?

Food systems undoubtedly have an adverse impact on a range of environmental concerns – including the depletion of natural resources and biodiversity, and the pollution of air, water and soil – but it is their impact on climate change induced by GHG emissions that has received the greatest attention.

The agricultural sector has been estimated to be responsible for around 10%-12% of global greenhouse gas emissions (Metz et al, 2007) with the developed world making the largest contribution as a result of industrialised food production and high consumption of GHG-intensive foods.

It has been estimated that, in the UK, GHGs associated with both food produced domestically and food imported for UK consumption represent around 19% of total GHG. Of this, around 8% is attributable to the growing of food by the agricultural sector, and the majority of the balance is accounted for by food and fertiliser manufacturing, transport, packaging, refrigeration and waste disposal (Garnett, 2008).

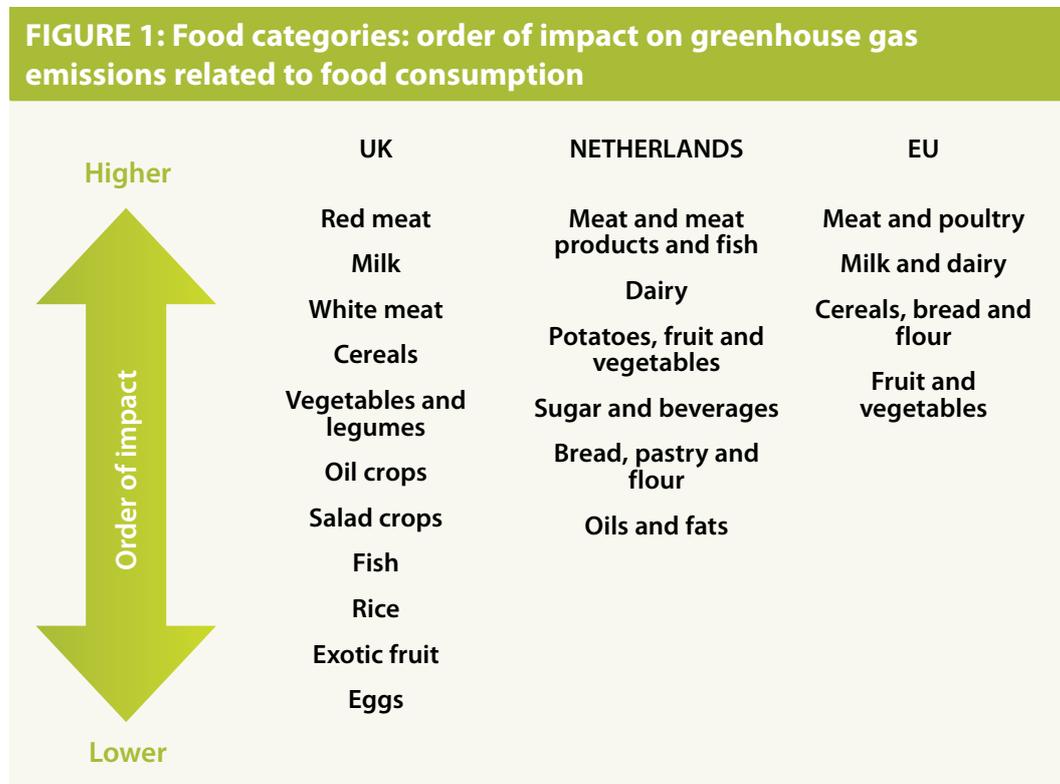
Within the agricultural sector, livestock production for meat and dairy foods is estimated to account for 80% of agricultural GHG emissions (McMichael et al, 2007). However, the scenario is not quite that straightforward because, if production switched to horticulture, the associated land-use change would alter the balance of GHG emissions. Audsley et al (2009) calculated how GHG emissions from the UK food system might be reduced by the amount needed in the UK to meet the UK Climate Change Act. They suggest that very significant changes in the food system would be required to achieve a 70% reduction across the supply

chain, but that UK diets might not have to alter substantially if agriculture became significantly more efficient.

1.3 Where and how in the food system might greenhouse gas emission cuts be made?

Which foods produce most greenhouse gases?

A number of studies have attempted to quantify the impact of specific foods on the environment (Audsley et al, 2009; Williams et al, 2006; Tukker and Jansen, 2006; Kramer et al, 1999). These studies have shown that there is considerable variation in the environmental impacts of different categories of foods, different food products and differently sourced versions of the same food product as the methods of cultivation, processing, storage and transport vary. Variations have also been found in the environmental impact of the same product from different areas, produced using the same method of cultivation (Milà i Canals et al, 2006). While the methods and boundaries for analysis have differed between studies, there is general agreement on the ranking of different food categories. Ruminant meat (beef) produces the greatest GHG emissions, followed by dairy products and non-ruminant meat (pigs and poultry). Grains and grain products, and fruits and vegetables, have a lower impact on GHG emissions. See Figure 1.



Sources: UK: Audsley et al (2009); Netherlands: Kramer et al (1999); EU: Foster et al (2006).

What are life cycle analysis (LCA) studies?

Much of the research into how and where it might be possible to make reductions in the impact something has on the environment is based on the findings of **life cycle analysis (LCA)** studies.

LCA is a methodological tool for evaluating the impact of a product, process or activity on different areas of environmental concern, or 'impact categories', throughout its life cycle. Where the subject of the analysis is an agricultural product, it may involve evaluating the impacts on global warming, use of natural resources, and water pollution, associated with the production, transport, storage, use and final disposal of the product. LCA can be used to compare the impacts of alternative products which might inform product-sourcing decisions, or it may be used to identify particularly intensive stages of production in order to determine where mitigation strategies might be most effective.

Another form of LCA is the **consequential LCA**. This approach identifies the environmental implications or consequences that changing one part of a system might have on another part.

Limitations of LCA studies

LCA studies are a useful starting point in identifying how and where reductions in the environmental impact of the food system might be made, but certain factors must be considered when interpreting the data from LCA. While the method can give a very detailed picture of embedded emissions, results may not always be conclusive. Also, confounding factors must be accounted for. For example, when comparing organic to inorganically farmed carrots, embedded CO₂ may not only fluctuate according to the production method, but may also be a consequence of the soil type or the length of the growing season. Also, the system boundaries (or production stages and inputs) included may vary between studies.

Garnett (2008) has highlighted some limitations of the method. Aside from being time-consuming and expensive, one of the most notable limitations is the LCA's inability to capture the impact of non-quantifiable environmental concerns such as biodiversity, landscape aesthetics and quality of life. Also, many LCA studies do not accurately capture the second-order impacts of land-use change. For example, clearing forest in order to grow arable crops can, over time, result in significant CO₂ emissions from soil (Garnett, 2008). Fortunately, PAS 2050 – the British Standards Institute (BSI) specification for the assessment of GHG emissions from goods and services – now includes emissions resulting from land-use change. Policy makers are urged to consider the conclusions from LCA from wider environmental perspectives and factor into their decisions the knock-on effects that mitigation strategies might have on the wider global social, economic and environmental aspects of sustainability.

Life cycle analysis can make a significant contribution towards identifying the environmental attributes of products and production methods to provide useful information for guiding consumers' shopping and eating behaviours towards products with a lower environmental burden. However, developing policy and recommendations is a complex process, as both synergies and tensions have been identified between the different social, economic and environmental aspects of sustainability. For example, fair trade products from low-income countries can often (but not always) be associated with a higher environmental burden than sourcing the product closer to home. On the other hand, the fair trade movement supports millions of poor producers and fosters socially responsible consumption (Oxfam, 2009). Defining a sustainable diet therefore requires us to make value judgements and to identify priorities in what it is we are trying to achieve. It may be more efficient in terms of the environment to increase production efficiency at the animal level, but this raises questions about the welfare consequences, and all consumption and technology change in the food supply system may impact on other policy objectives around public health, nitrate and ammonia emissions or biodiversity for example (Audsley et al, 2009).

Measuring the environmental impact of specific types of meals

Several studies have attempted to quantify the environmental impact of modifying the composition of specific meals. Using an LCA approach, Carlsson-Kanyama (1998) in Sweden compared the environmental impact of four meals containing different combinations of the following ingredients: pork, dried peas, rice, potatoes, carrots and tomatoes. (See Figure 2.) The potatoes, peas and carrots were assumed to be domestically produced in open fields, while the rice and tomatoes were considered more exotic as the tomatoes were assumed to be produced in greenhouses in Sweden or the surrounding countries and the rice was produced in distant countries on irrigated fields. Using these criteria, the meals were categorised as: domestic vegetarian meal (carrots, potatoes and dried peas); exotic vegetarian meal (rice, tomatoes and dried peas); exotic meal with animal products (rice, pork and tomatoes); and domestic meal with animal products (pork, potatoes, carrots and dried peas). Each meal contained similar amounts of protein and energy.

The results obtained suggest that the exotic meal with animal products (rice, pork and tomatoes) produced nine times more CO₂ equivalents (1,800g CO₂e) than the domestic vegetarian meal (carrots, potatoes and dried peas: 190g CO₂e). Also of interest for those concerned with making qualitative recommendations on more sustainable patterns of consumption, the exotic vegetarian meal (rice, tomatoes and dried peas) produced more CO₂ equivalents (860g CO₂e) than the domestic meal with animal products (pork, potatoes, carrots and dried peas: 380g CO₂e). It is therefore not a simple case of meat-free meals being less environmentally polluting than meals containing meat. In terms of nutritional benefit, the domestic vegetarian meal of carrots, potatoes and peas is also likely to contain more micronutrients than an exotic vegetarian meal of rice, tomatoes and dried peas, but nutritional differences between the other meals become harder to quantify as there is enormous variation in the composition of similar foods.

FIGURE 2: A comparison of the environmental impact of specific types of meals

Each meal contains similar amounts of protein and energy (calories).

Meal	Pork	Dried peas	Rice	Potatoes	Carrots	Tomatoes	CO ₂ equivalents produced
Domestic vegetarian meal		✓		✓	✓		190g CO ₂ e
Domestic meal with animal products	✓	✓		✓	✓		380g CO ₂ e
Exotic vegetarian meal		✓	✓			✓	860g CO ₂ e
Exotic meal with animal products	✓		✓			✓	1,800g CO ₂ e

Source: Carlsson-Kanyama (1998).

Would a shift from animal-based foods to plant-based foods reduce greenhouse gas emissions?

Although progress has been made in identifying more sustainable meals, there is a lack of quantitative evidence concerning how much and what sort of foods might constitute a healthy and more sustainable diet. However, there is some agreement that achieving a fundamental shift towards a diet that is lower in animal-based foods and higher in plant-based foods might contribute to the mitigation of food-related GHGs (Garnett 2009; Carlsson-Kanyama and González, 2009; Stehfest et al, 2009). Others, however, believe that changes need to be made to the whole agricultural system, not just at the individual animal level, because a simple reduction in meat consumption could result in some unwanted outcomes (Audsley et al, 2009). For example, a reduction in beef and dairy production may cause widespread abandonment of UK grazing land and an increase in imports and land-use change elsewhere. Also, switches from red meat to white meat, while reducing emissions, would increase reliance on imported soy products. A broad-based switch to plant-based products through increasing the intake of cereals and vegetables (including potatoes) is, however, generally considered a sustainable option, but tensions over food imports could still trigger unwanted consequences in land-use change elsewhere. Whether changes that aim to reduce the GHG emissions from the food supply chain should be aimed at the consumption end or through greater efficiency and production method changes within the system, remains a debate.

KEY POINTS

- **Greenhouse gases associated with both food produced domestically and food imported for UK consumption represent around 19% of total greenhouse gas emissions in the UK. Of this, around 8% is attributable to the growing of food by the agricultural sector, and the majority of the balance is accounted for by food and fertiliser manufacturing, transport, packaging, refrigeration and waste disposal.**
- **Ruminant meat (beef) produces the greatest greenhouse gas emissions, followed by dairy products, and non-ruminant meat (pigs and poultry). Grains and grain products, and fruits and vegetables, have a lower impact on greenhouse gas emissions.**
- **There is some agreement that achieving a fundamental shift towards a diet that is lower in animal-based foods and higher in plant-based foods might contribute to the mitigation of food-related greenhouse gases.**

2 What is a healthy and sustainable diet?

This section looks at the recommendations for healthy and sustainable diets that have already been developed by some European countries, and examines the effect on the environment if people moved from their current dietary patterns to the current recommendations for a healthy diet. It looks in detail at consumption of meat and dairy products, identifying what level of consumption might be sustainable and examining the implications of a reduction in consumption of meat and dairy products for individual consumers. Finally, it considers how intake of specific nutrients such as iron and zinc might be affected by reductions in red meat consumption.

Globally, current food consumption patterns are having a detrimental impact on both human health and the environment. Most countries now recognise that future food policies must aim to integrate the twin goals of better health and sustainability. The criteria that define a healthy diet are better understood and are supported by a wealth of evidence that clarifies the associations between diet and health. In recognition of the financial and social need to reduce the health burdens associated with poor diet, most developed countries have developed food-based dietary guidelines to advise consumers on how the foods commonly consumed and available in their country might be combined

to achieve a healthy diet. However, so far only a few countries have attempted to advise populations on diets that are both good for health and good for the environment.

2.1 Current recommendations for healthy and sustainable diets in Europe

Recommendations aimed at guiding consumers towards more sustainable diets in some European countries have reached different stages of development. In Sweden, Germany and France, government agencies have already issued advice, and in the Netherlands, the Health Council of the Netherlands has issued an advisory report to the government to support it in making recommendations. In Italy and the UK, non-governmental agencies have completed research projects which have the potential to support future recommendations. A summary of these recommendations is given in Table 1.

The French, German, Dutch and Swedish recommendations and those of the UK Sustainable Development Commission (SDC) are all qualitative in nature, population-based and grounded on the theory that a diet that is based mainly on plant-based foods with a much smaller contribution from animal-based foods will be both healthier and more sustainable than the prevailing national diet (see Table 2). Recommendations therefore advocate eating more, or less, from each food group and are supported by guidance on more sustainable shopping habits. In general, they tend to focus more heavily on shopping behaviours than on what and how much to eat, and do not fully address the proportions in which different types of foods should be consumed in order to achieve a healthy diet.

The report of the Health Council of the Netherlands does not issue national recommendations for healthy, more sustainable diets, but it makes recommendations for consideration by the government, based on the available evidence of the health effects and the environmental impact of different foods. Their recommendations are categorised as those that offer 'win-win' situations for both health and the environment, 'win-lose' situations where the recommendations may be beneficial to health at the expense of the environment, and 'environmental wins' that are health neutral. (See Table 2.)

TABLE 1: European reports providing guidance on healthy, sustainable diets		
France	Report title	My Shopping (Mes Achats)
	Authors/owners	Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME)
	Date	Accessed on the website, 2012
	Available at:	http://ecocitoyens.ademe.fr/mes-achats/bien-acheter/alimentation
Germany	Report title	The Sustainable Shopping Basket
	Authors/owners	German Council for Sustainable Development
	Date	2008
	Available at:	http://www.nachhaltigkeitsrat.de/uploads/media/Brochure_Sustainable_Shopping_Basket_01.pdf
Italy	Report title	2011 Double Pyramid: Healthy Food for People, Sustainable for the Planet
	Authors/owners	Barilla Center for Food and Nutrition
	Date	2011
	Available at:	http://www.barillacfn.com/uploads/file/99/en_PositionPaper-BarillaCFN_DP.pdf
Netherlands	Report title	Guidelines for a Healthy Diet: The Ecological Perspective
	Authors/owners	Health Council of the Netherlands
	Date	2011
	Available at:	http://www.gezondheidsraad.nl/en/publications/richtlijnen-goede-voeding-ecologisch-belicht
Sweden¹	Report title	Environmentally Effective Food Choices
	Authors/owners	National Food Administration and Environmental Protection Agency
	Date	2009
	Available at:	http://www.slv.se/upload/dokument/miljo/environmentally_effective_food_choices_proposal_eu_2009.pdf
UK (Sustainable Development Commission)	Report title	Setting the Table: Advice to Government on Priority Elements of Sustainable Diets
	Authors/owners	Sustainable Development Commission
	Date	2009
	Available at:	http://www.sd-commission.org.uk/data/files/publications/Setting_the_Table.pdf
UK (WWF-UK)	Report title	Livewell: A Balance of Healthy and Sustainable Food Choices
	Authors/owners	WWF-UK in collaboration with the Rowett Institute of Nutrition and Health, University of Aberdeen
	Date	2011
	Available at:	http://assets.wwf.org.uk/downloads/livewell_report_jan11.pdf

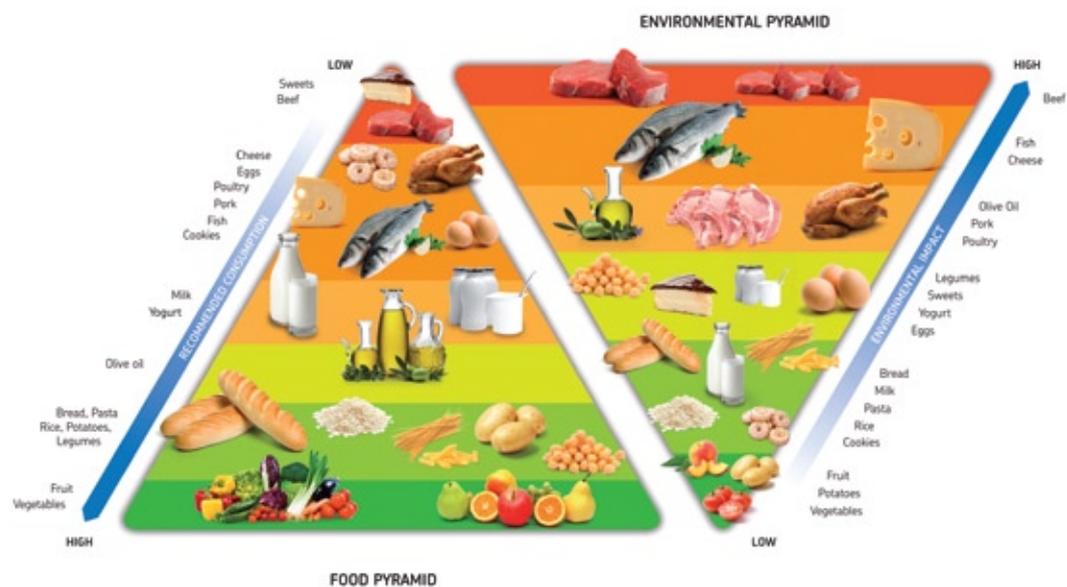
1 These recommendations were withdrawn in 2011.

TABLE 2: Key messages from qualitative guidance on sustainable food

	France	Germany	Netherlands	Sweden	UK SDC
	My Shopping (Mes Achats)	The Sustainable Shopping Basket	Guidelines for a Healthy Diet: The Ecological Perspective	Environmentally Effective Food Choices	Setting the Table: Advice to Government on Priority Elements of Sustainable Diets
Fruits, vegetables, berries and legumes	Buy varied, seasonal, local, organic. Re-discover forgotten local fruit and vegetables. Avoid fruit and vegetables sold in individual or small packages.	Aim for 5 portions of fruit and vegetables a day. Choose seasonal, local, produce (including juices).	Adopt a less animal-based and more plant-based diet: less meat and dairy products and more wholegrain cereal products, legumes, vegetables and fruit- and vegetable-based meat substitutes. (<i>Win-win.</i>)	Aim for 500g a day. Choose seasonal, local, organic produce. Prioritise fibre-rich, cruciferous (cabbage family) and other green vegetables. Eat more beans, peas and lentils.	Increase consumption of fruits and vegetables, particularly seasonal and field-grown.
Potatoes, cereals and rice				Choose local produce. Choose pesticide-free rice. Prioritise cereals and potatoes.	
Meat	Reduce consumption to a level recommended by nutritionists. Alternate meat and vegetarian menus.	Eat less.		Aim for no more than 140g a day.	Reduce consumption.
Dairy	Reduce consumption to a level recommended by nutritionists.				Reduce consumption.
Fish/ seafood	Ask for fish not from threatened stocks.	Eat less. Look for fish not from threatened stocks.	Eat 2 portions of fish a week, at least one of which should be oily fish. This recommendation may yield health benefits but may have detrimental ecological effects. Recommending even 1 portion of fish per week (as oily fish) could be detrimental as this level of consumption is higher than current consumption levels. From an ecological perspective, it is advisable to concentrate on fish species that are not under threat from overfishing or that are farmed in an environmentally friendly way. (<i>Win-lose.</i>)	2-3 servings per week at 100g-150g per serving. Try species not from endangered stocks. Look for MSC-certified.	Consume only fish from sustainable sources.
Fats and oils				Try to use rapeseed and olive oil.	
Beverages/ water	Drink tap water. If bottled water is preferred, buy in recycled packaging (PET) in 5-litre bottles.	Choose recyclable packaging.		1.5 litres of water per day. Drink tap water.	Drink tap water.
Foods high in fat and sugar			To counter excess body weight, reduce energy intake particularly by eating less non-basic foods such as sugary drinks, sweets, cakes and snacks. (<i>Win-win.</i>)		Reduce consumption of foods of low nutritional value – for example, fatty and sugary foods.
Additional generic consumer actions	Prioritise a balanced diet. Try fair trade products. Accept visually imperfect products. Buy in bulk. Reduce waste. If possible, shop without the car.	Above all, eat healthily. Try fair trade products. Eat local, seasonal, organic produce. Avoid waste.	Reduce food waste. (<i>Environmental win – health neutral.</i>)		Reduce food waste. Increase consumption of foods that are produced with respect for the environment – for example, organic food. Decrease energy input by shopping on foot or over the internet. Cook and store foods in energy-conserving ways.

In Italy, the Barilla Center for Food and Nutrition has devised the 'Double Pyramid'. This is a pictorial representation of the position different food groups occupy on a scale of their contribution to a healthy diet and their environmental impact based on GHG emissions. The Double Pyramid illustrates, in a unified model, the connection between the twin goals of health and environmental protection. It is offered as a tool to help consumers decide what to eat on a daily basis (Barilla Center for Food and Nutrition, 2011). There are two Double Pyramids: one for adults (see Figure 3), and one for children and adolescents (see Figure 4).

FIGURE 3: Double Pyramid for adults, Italy



Source: Barilla Center for Food and Nutrition (2011).

Although the pyramids do not make a combined recommendation for food choices that are healthy and sustainable, and are qualitative in nature, they are unique in that they address the nutritional needs of different population groups (adults, and children and adolescents) and show quite clearly that, in order to achieve a healthy diet, children require proportionally more meat and dairy products than adults. Furthermore, in each Double Pyramid the food pyramid comes first, underlining the importance of achieving a more sustainable diet within the parameters of what is required to achieve a healthy diet.

FIGURE 4: Double Pyramid for children and adolescents, Italy



Source: Barilla Center for Food and Nutrition (2011).

The WWF in the UK (WWF-UK) has taken the definition of a healthy, more sustainable diet one step further and has shown quantitatively how actual food products from each of the five main food groups can be combined to create a diet (the *Livewell* diet) that meets national dietary reference values (DRVs) for nutrients and is less GHG-intensive than the prevailing diet in the UK. Importantly, it provides a worked example of how consumers might replace some of the meat in their diet with less GHG-intensive plant-based foods without compromising nutritional quality.

How the recommendations compare

The detail given in the guidance varies. All the examples recommend eating local, seasonal, fruit and vegetables for example, and all but the Netherlands recommend organic, but only the Swedish recommend hardier field-grown vegetables over those that have been produced using more energy-intensive methods. The French, Dutch and UK reports mention reducing intakes of dairy products, but the Swedish and German reports do not, despite this being a key issue in much of the literature around the contribution of livestock to GHG emissions. Recommendations concerning meat all indicate reducing intakes, but this message is conveyed quite differently between models and there is no consistent distinction made between red, white and processed meat. Messages concerning fish all point out that fish should be chosen from stocks that are not threatened, but only the Dutch recommendations tackle the contentious issue of making recommendations on fish consumption that are detrimental to the environment. In the German guidance, the recommendations, based on current consumption levels, are to eat less fish, and the Swedish guidance would lead to

an increase in fish consumption compared to current intakes, while the Dutch report clearly signposts to the government that the recommendations on fish are unsustainable.

2.2 Quantifying the environmental impact of dietary change

It is generally acknowledged that the diet of many people in developed countries does not currently meet guidelines for health, with many people eating too much fat, sugar and salt and too little complex carbohydrate, fruit and vegetables. The direction of change in consumption patterns required to achieve recommendations for *healthy* diets does, however, appear to reflect the direction of change required to achieve more *sustainable* diets in terms of increased consumption of plant-based foods and reduced consumption of foods with little nutritional value and fats. However, it is not clear whether achieving the current recommendations for healthy diets necessarily requires reductions in the consumption of animal-based foods, or what impact changes in consumption patterns might have on the environment if alternative foods are eaten instead.

Tukker et al (2011) examined what would happen, across 27 European countries, if dietary changes at population level moved current dietary patterns closer to those recommended by WHO/FAO (WHO, 2003). They found that this provided no reduction in environmental impacts, despite the reductions in meat consumption that these adaptations required. However, in a further scenario where WHO/FAO recommendations were combined with a 40% substitution of the red meat content of the improved diet with chicken, seafood and cereals, and no consumption of processed meat, an 8% reduction in total impacts related to food consumption could be made. A similar reduction was reported in a scenario where prevailing diets were adapted on the basis of the 'Mediterranean-style' diet prevalent in the South-Western and South-Eastern European countries included in the analysis (Tukker et al, 2011). The authors concluded that dietary modifications to healthier diets in the absence of significant reductions in meat and dairy consumption would result in rather minor reductions of environmental impacts in Europe. The results of the analysis are relevant in that they show that adhering to a healthier diet alone might be expected to result in environmental benefits. However, this study fails to take into account all the production changes that might be required if there is a shift away from meat to other foods. Also, these results reflect the current population and do not take into account the production changes required to feed the population of the future.

In a theoretical examination of how GHG emissions resulting from the food system in the UK might be reduced by 70%, Audsley et al (2009) suggested that a 66% reduction in the consumption of livestock products might result in a 15% reduction in GHG emissions from the UK food supply chain by 2050. Of all the mitigation measures considered – in the categories of energy generation, resource conservation, production efficiencies and consumption measures – the only ones that would achieve a greater reduction were complete exclusion of meat from

the diet (15.8%), and zero use of fossil fuels (19.7%). However, these figures do not allow for the impact of associated land-use change to produce the foods that would be eaten instead of meat. The suggested 66% reduction in consumption of livestock products is explained in more detail in section 2.3.

2.3 What is a sustainable amount of meat and dairy products?

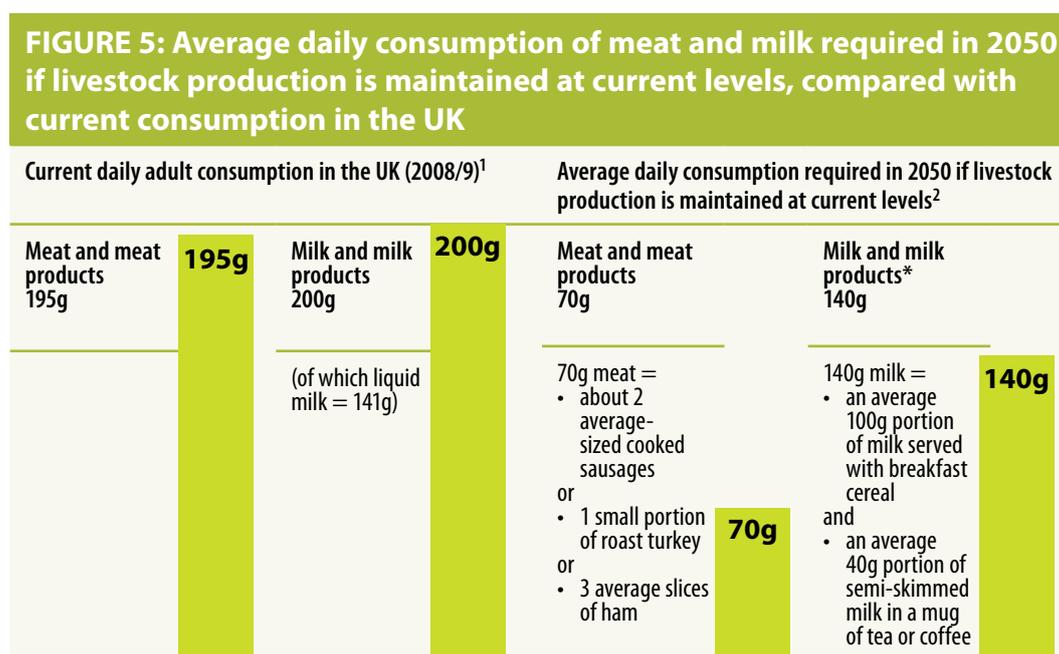
It has been predicted that global demand for meat will double by 2050 (Steinfeld et al, 2006). This is due to both the expected rise in population and the anticipated per capita rise in demand, particularly in countries in transition and in developing countries. In China alone, meat consumption, as reported from food balance-sheet data, has already increased nine-fold since 1963 (Kearney, 2010). While demand for animal-based foods is rising globally, there are huge inequalities in meat consumption between different regions, with developing countries overall consuming less than a third of the meat and less than a quarter of the milk products that are consumed in developed countries (Steinfeld et al, 2006).

Qualitative food-based dietary guidelines for health and sustainability in developed countries appear to promote a reduction in current levels of meat consumption (particularly for those who already consume a lot of meat), but it is unclear what level of meat consumption might be considered sustainable. Studies that have examined possible reductions in GHG emissions in relation to livestock have developed different scenarios to try to clarify the environmental impact of differing levels of consumption. McMichael et al (2007) suggest that, in a scenario where the population has grown by 40% by 2050 and there are no advances in GHG reduction in relation to livestock practices, average global meat consumption would need to fall from about 100g per day to 90g per day in 2050 in order to maintain the current levels of GHG emissions from livestock rearing. This proposed target emphasises global equality in the consumption of animal-based foods and would require a substantial reduction in current meat consumption in developed countries, but would allow for an increase in developing countries (McMichael et al, 2007).

With a similar emphasis on global equality, Garnett (2008) outlines a scenario where developed countries and transition countries reduce their consumption of livestock products to the levels predicted by FAO (Steinfeld et al, 2006) for developing countries in 2050. This scenario would be expected to result in lower global total meat and milk consumption than predicted by the FAO for 2050 (15% less for total meat consumption, and 22% less for milk consumption). Nevertheless, this scenario still represents a growth in consumption of 70% for meat and 45% for milk compared to 2000 levels.

To put this in perspective for UK consumers, reducing meat and milk consumption to the levels predicted for developing countries in 2050 would require per capita consumption levels of 120g per person per day for meat and 213g per person per day for milk. In order to achieve a no-growth scenario – that is, maintaining

livestock production at current levels to 2050 – meat and milk consumption would need to fall even further, to about 70g per person per day for meat and meat products and about 140g per person per day for milk and milk products (Garnett, 2008). Figure 5 illustrates what these figures mean in practice. While this level of meat consumption is lower than the 90g per person per day suggested by McMichael et al (2007) for a no-growth scenario, this estimate includes a higher predicted growth in population – 50% compared to the 40% growth in the McMichael study – and assumes no increase in consumption in developing countries, as opposed to the constrained growth factored into the estimate proposed by McMichael et al (2007).



* Excluding butter.

Sources:

1 Department of Health (2011).

2 Garnett (2008).

In a study where the focus is the effectiveness of mitigation strategies on UK emissions, Audsley et al (2009) identified that a 66% reduction in livestock products is one of the most effective measures that could be adopted in the UK to reduce GHG emissions arising from the UK food system. The levels of consumption used to determine the magnitude of savings are shown in Table 3.

TABLE 3: Reductions required to achieve a 66% reduction in consumption of livestock products in the UK

Livestock product	Required reduction in consumption as a percentage of current consumption
Ruminant meat (beef)	80%
Milk	50%
Butter	66%
Cheese	80%
Eggs	33%
Demersal fish (for example, cod, haddock, plaice, halibut, sole)	91%
Poultry	66%
Pig meat	80%
Other animal fats	80%
Offal	66%

Source: Audsley et al (2009).

2.4 What will be eaten instead?

Reducing our consumption of livestock products, if this is agreed as a necessary strategy, may necessitate an increase in consumption of other foods to meet energy and nutrient requirements. There are no data on the effects, on energy and nutrient intakes, of reducing meat and meat products in a variety of typical diets, and it is likely that there will be significant variation between individuals. For those with a diet plentiful in micronutrients but higher in energy, fat and saturated fat than currently recommended, reducing livestock product intake may be solely beneficial to health. For those for whom livestock products are an important provider of energy and nutrients, reductions may put individuals at nutritional risk. Replacement food products will themselves add to the environmental burden of the food system. However, from studies that examine the environmental burden of food products, it is clear that a diet based solely on plant foods is not necessarily more sustainable than one including small amounts of meat (Carlsson-Kanyama and González, 2009). Many of the exotic fruits and tender vegetables we currently consume carry a particularly high environmental burden. It is therefore important that, when considering the sustainability of diets, the impact of replacement products – that is, the whole diet – is considered.

In their exploration of mitigation measures that might achieve a 70% reduction in GHG emissions from the food supply in the UK, Audsley et al (2009) considered the environmental implications, including those from land-use change, of obtaining the energy (calories) lost as a result of reducing livestock product consumption by 66%, either by using soya-based analogues or by increased consumption of fruits, cereals, pulses, potatoes, vegetables and vegetable oils. The latter was considered to be the more environmentally sustainable option.

For some consumers, reducing meat and dairy consumption to the extent being discussed in theoretical modelling to reduce GHG emissions may seem daunting. Within the average consumption figures for a population there are, of course, enormous variations in intake by individuals, and in the case of meat and meat products in particular there is typically a significant difference in intake by gender. A summary of data from the last comprehensive diet and nutrition study in the UK (Scientific Advisory Committee on Nutrition, 2008) reported average intakes of meat and meat products to be 200g per day for men and 124g per day for women, with red and processed meat and meat-based dishes as 138g per day for men and 79g per day for women. New data from the most recent National Diet and Nutrition Survey attempted to disaggregate meat in meat dishes more effectively, and suggest figures of 226g for meat and meat products for men and 163g for women (Department of Health, 2011).

However, where there are more comprehensive data on intakes of food by consumers and non-consumers, such as in the last comprehensive nutrition survey of adults in the UK (Henderson et al, 2003a), there are some interesting gender differences in consumption of meat and meat products, as shown in Table 4. Men are generally both more likely to consume many meat and meat products and have greater amounts of those on average, and this is particularly true for processed foods.

Advice on consumption of meat may therefore need to take into account people's current intakes, and types of meat and meat products consumed, and may potentially need to be gender-specific.

TABLE 4: Intakes of meat and meat products, and proportion of consumers of these foods, by gender, in the National Diet and Nutrition Survey 2002

Meat group	Men aged 16-64 years		Women aged 16-64 years	
	g/day among consumers	% consumers	g/day among consumers	% consumers
Bacon and ham	25.3	77	16.9	64
Beef, veal and dishes	62.6	68	60.9	58
Lamb and dishes	36.1	24	28.1	21
Pork and dishes	33.0	34	25.4	27
Coated chicken and turkey	29.6	25	26.1	24
Chicken and turkey dishes	62.3	82	51.4	77
Liver and liver dishes	19.0	12	13.9	7
Burgers and kebabs	37.3	33	30.9	18
Sausages	24.3	55	17.7	35
Meat pies and pasties	43.1	46	28.0	33
Other meat and meat products	27.0	31	18.4	21

Source: Henderson et al (2003a).

2.5 How well aligned are recommendations for sustainable consumption of meat and dairy products with recommendations for health?

How advice is given around consumption of meat and dairy foods as part of food-based dietary guidelines varies. Guidance often includes meat in a 'protein foods' or 'meat and alternatives' category that also includes eggs and non-animal sources of protein. Qualitative guidelines often advise consumers to eat less meat and choose alternative sources of protein such as eggs and pulses more frequently, but rarely specify the amounts that should be consumed. For example, the *Eatwell plate* in the UK provides consumers with the information shown in Figure 6 below.

FIGURE 6: The *Eatwell plate*



The *Eatwell plate* shows how much of what you eat should come from each food group. This includes everything you eat during the day, including snacks. So, the advice is to try to eat:

- plenty of fruit and vegetables (33% of overall food intake)
- plenty of bread, rice, potatoes, pasta and other starchy foods – choose wholegrain varieties whenever you can (33% of overall food intake)
- some milk and dairy foods (15% of overall food intake)
- some meat, fish, eggs, beans and other non-dairy sources of protein (12% of overall food intake), and

- just a small amount of foods and drinks high in fat and/or sugar (8% of overall food intake).

Note that the *Eatwell plate* does not include references to frequency of serving or 'recommended' portion sizes, other than in relation to fruit and vegetables (at least 5 portions of about 80g of a variety of fruit and vegetables a day) and fish (eat 2 portions a week, one of which should be oily fish).

It is therefore difficult to tell how existing patterns of meat consumption compare to recommendations. Also, this type of food-based dietary guideline does not necessarily reflect the different nutritional contributions key foods play in average nutrient intakes. The Scientific Advisory Committee on Nutrition (2008) in their review of *The Nutritional Wellbeing of the British Population* reported that among adults around 20% of iron intake and 33% of zinc intake comes from meat and meat products, and that 40% of calcium, 40% of iodine and 33% of riboflavin intake comes from milk and milk products. Low status of vitamin A, potassium and magnesium was associated with lower intakes of meat and meat products, and lower status of riboflavin, vitamin A, potassium and magnesium was associated with lower intakes of milk and milk products. The contribution of these foods to intakes of these nutrients needs to be considered when substitutes for meat or dairy foods are discussed.

Meat and meat products

The most unambiguous recommendations for meat consumption come from the World Cancer Research Fund (WCRF)/Association for International Cancer Research (AICR) (2009), the Scientific Advisory Committee on Nutrition (SACN, 2010) and the German Nutrition Society (2008). The WCRF/AICR recommends no more than 300g of red meat per person per week as a population average, with no more than 500g per week for individuals. SACN recommends no more than 490g of red meat per week. The German Nutrition Society recommends that *total meat* consumption should not exceed 300g-600g per week. These levels of consumption align quite well with suggestions for more sustainable levels of meat consumption from McMichael et al (2007), who have proposed 630g of meat per week with no more than 330g from ruminants as a global target for meat consumption, and from Garnett (2008), who has estimated that, in order to achieve a no-growth scenario in global livestock emissions by 2050, consumption of meat would need to be about 500g per week. Table 5 compares these estimates with current consumption of meat in the UK.

For the UK therefore, total intakes of meat and meat products are currently above all recommended figures and the recommendation for a reduction in the intakes of these food groups is therefore likely to continue.

TABLE 5: Comparison of current health recommendations for consumption of meat, with suggestions for more sustainable levels of consumption

Current levels of meat consumption in the UK	
All meat and meat products¹	1,134g/week. Men 200g/day. Women 124g/day (cooked weights).
Red meat and red meat dishes²	582g/week. Men 101.4g/day. Women 63.7g/day (cooked weights).
Recommendations for meat consumption	
World Cancer Research Fund (WCRF)/ Association for International Cancer Research (AICR), (2009)	No more than 300g (cooked weight) of <i>red meat</i> per person per week as a population average. No more than 500g (cooked weight) of <i>red meat</i> per week for individuals.
Scientific Advisory Committee on Nutrition (2010)	Average 70g of <i>red meat</i> (cooked weight) per day (490g/week).
German Nutrition Society (2008)	<i>Total meat</i> consumption should not exceed 300g-600g per week (cooked weight).
National Food Administration and Environmental Protection Agency for Sweden	<i>Total meat</i> consumption no more than 980g per week (raw weight).
Other suggestions for more sustainable levels of meat consumption	
McMichael et al (2007)	630g of <i>total meat</i> per week, with no more than 330g from ruminants (raw weights), as a global target for meat consumption.
Garnett (2008)	About 500g of <i>red meat</i> per week (raw weight), to achieve a no-growth scenario in global livestock emissions by 2050.
Audsley et al (2009)	80% reduction in current intakes of beef and pork, and 66% reduction in poultry. (For the UK, this would reduce total meat and meat product intake to about 350g per week.)

Sources:

- 1 Scientific Advisory Committee on Nutrition (2008).
- 2 Scientific Advisory Committee on Nutrition (2010).

Milk and milk products

The changes required to achieve quantitative health-based recommendations for the consumption of dairy products appears to be uniformly in the direction of increased consumption. However, it is difficult to distinguish the direction of change required for individual dairy products such as milk and cheese, as food-based dietary guidelines tend to include these under a 'dairy foods' category. There have been far fewer estimations made of how dairy product consumption might need to change to improve sustainability. Garnett (2008) has estimated that, in order to achieve a no-growth scenario in global livestock emissions by 2050, consumption of milk would need to be about 980g per week. Audsley et al (2009) estimated that, to achieve food supply emissions reductions of around 70% by 2050, consumption of milk would need to reduce by 50%, butter by 66% and cheese by 80% (see Table 3).

Current adult intakes of milk and milk products in the UK (Department of Health, 2011) suggest an average intake of 200g a day, with 141g of this being liquid milk which is consumed by the majority of the population as a beverage, in tea and coffee and on breakfast cereal in particular. There will be considerable individual variation in intake, but there is little variation in overall consumption by gender, although women are more likely to choose lower-fat dairy products than men.

2.6 What might be the impact of reducing intakes of meat and milk?

It is difficult to determine the environmental impact of any changes to consumption patterns because this very much depends on the availability and accuracy of the data used. It is clear that reducing GHG emissions from the food system will require reductions in the consumption of GHG-intensive foods, but there remains little consensus on what exactly this might mean in terms of changes to current dietary patterns. A comparison of different estimates of sustainable meat and dairy consumption with food- and nutrient-based dietary guidelines indicates that, for adults, it is possible to reduce the amount of meat we eat and still achieve the relevant DRVs for nutrients and food-based recommendations for the prevention of chronic diseases.

In the UK, red meat is considered an important source of iron and zinc and contributes about 17% of total iron intake and 34% of total zinc intake to adults aged 19-64 years (Scientific Advisory Committee on Nutrition, 2010). The Scientific Advisory Committee on Nutrition (SACN) modelled the impact that capping red meat consumption to 180g, 120g, 100g, 90g, 80g, 70g, 60g, 50g or 0g per day would have on intakes of iron and zinc (see Table 6). This exercise was done to meet recommendations that relate to meat reduction for adults as a risk factor for colorectal cancer, not for sustainability reasons, and SACN did not consider the impact on children as no meat-related risk of colorectal cancer is known. Their results show that reducing intakes of red meat to 70g a day would have little impact on the proportion of the adult population with dietary intakes of iron

below the LRNI, but would increase the proportion of men with intakes of zinc below the LRNI from 3.7% to 5.5% (Scientific Advisory Committee on Nutrition, 2010). Currently 58% of men and 23% of women exceed the 70g a day red meat targets. When the modelling of potential decreases in micronutrient intakes was carried out, differences in nutrient status between individuals was not considered. SACN also acknowledged that in the modelling exercises it made no allowance for changing levels of bioavailability in different diets.

EAR, RNI and LRNI

The estimated average requirement (EAR) of energy or a nutrient represents average energy requirements or a level of intake of a given nutrient that would meet the needs of about half of the population. The reference nutrient intake (RNI) would be sufficient for the vast majority (97.5%) of the population, and the lower reference nutrient intake (LRNI) would be sufficient for only a very small proportion of the population (2.5%).

TABLE 6: Impact on intake of iron and zinc at different levels of red meat consumption

If daily red meat consumption is capped at:	Iron	Zinc
100g	Currently 1% of men and 25% of women in the UK have mean daily iron intakes below the LRNI. Capping at this level would have little impact on the proportion of the adult population with dietary intakes of iron below the LRNI.	Currently 4% of men and women have mean daily zinc intakes below the LRNI.
90g		Capping at this level would have little impact on the proportion of the adult population with dietary intakes of zinc below LRNI.
80g		
70g	Minimal additional effect.	Increase in the proportion of men with intakes of zinc below the LRNI, from 3.7% to 5.5%.

Source: Scientific Advisory Committee on Nutrition (2010).

KEY POINTS

- Globally, current food consumption patterns are having a detrimental impact on both human health and the environment.
- In Europe, so far six countries have issued recommendations that aim to guide consumers to diets that are both healthy and sustainable, and the status of these recommendations varies. Only one country (Sweden) recommended specific quantities of foods, but this guidance was withdrawn in 2011.
- The direction of change in consumption patterns required to achieve recommendations for *healthy* diets appears to reflect the direction of change required to achieve more *sustainable* diets in terms of increased consumption of plant-based foods and reduced consumption of foods with little nutritional value and fats. However, it is not clear whether achieving the current recommendations for healthy diets necessarily requires reductions in the consumption of animal-based foods, or what impact changes in consumption patterns might have on the environment if alternative foods are eaten instead.
- To maintain current levels of GHG emission from livestock production through to 2050, consumption of meat and meat products would need to fall from the current level of 195g per day to about 70g per person per day, and consumption of milk and milk products would need to fall from the current level of 200g to about 140g per person per day.
- Current health recommendations to reduce total consumption of meat align well with recommendations for sustainability. For adults it is possible to reduce the amount of meat eaten and still achieve the relevant DRVs for nutrients. However, it is important to look in more detail at the implications of a reduction in meat consumption for particular subgroups of the population, including young children and, potentially, older adults.

3 Recommendations for a healthy, sustainable diet based on dietary modelling

This section looks at the dietary modelling that is used in the development and testing of food-based nutritional guidelines. It also examines the direction of change required in consumption of each of the food groups to achieve better health and more sustainable consumption.

3.1 How current consumption patterns would need to change to meet current healthy eating recommendations

There is currently no *quantitative* dietary model to describe how to achieve a diet that is both healthy and more sustainable. Existing dietary recommendations have been used as a benchmark to measure the dietary changes needed to achieve better health. The differences between existing diets and recommended diets have then been examined to determine whether or not the recommended diets might result in consequential benefits for the environment.

An assessment of the impacts that adhering to WHO dietary recommendations (as expressed in its *Global Strategy on Diet, Physical Activity and Health* [WHO, 2004a]) would have on food consumption and production in 35 OECD member countries was published in 2006 (Srinivasan et al, 2006). Overall, changing existing dietary patterns to achieve the recommendations would involve reducing consumption of:

- dairy products by 28%
- vegetable oils by 30%
- animal fats by 30%

- sugars by 24%
- pork by 13.5%
- mutton and goat by 14.5%
- poultry by 1.7%.

Interestingly, along with cereals, fruits and vegetables, in this model beef consumption could actually afford to rise slightly (Srinivasan et al, 2006). Any changes in consumption patterns would be expected to be reflected in changes of equal magnitude in production of other products.

However, the pattern of adjustment to WHO recommendations differs substantially between countries. A separate paper that examines the pattern of adjustment for the UK and the USA shows that a small overall increase in consumption of dairy products (2%) is required for the USA, and an overall decrease of 10% in consumption of dairy products is required in the UK. There were also significant differences between the USA and the UK in the pattern of adjustment required for individual dairy products. Both countries would be required to increase their consumption of fruits and vegetables and cereal products quite dramatically, and reduce their consumption of red meat by a modest 16% in the UK, and 9% in the USA. One of the most notable differences between the two countries was in fish consumption, which would need to increase by 33% in the UK and by only 8% in the USA (Shankar et al, 2008).

3.2 Using dietary modelling to develop healthy eating recommendations

Modelling diets to meet food and nutritional recommendations using a global standard such as WHO dietary targets will often require simulating 'optimal diets' because specific dietary recommendations, and actual diet choices, will vary significantly from country to country. Simulated healthy diets are also likely to differ from those described by existing national food-based dietary guidelines, which take into consideration typical food choices and eating patterns. These simulated diets are achieved through 'dietary modelling' which is both iterative and mathematical, and has been used in individual countries to demonstrate how food- and nutrient-based recommendations can be achieved. These models aim to use foods that are widely available, commonly consumed and culturally acceptable to specific population groups and often attempt to deviate as little as possible from existing consumption patterns (Santika et al, 2009; Ferguson et al, 2004). Mathematical dietary modelling programmes may also be applied to the optimisation of nutritional criteria within a set of constraints – for example, optimisation of dietary energy under conditions where the food supply is very dependent on season. Modelling programmes can quickly determine whether or not these criteria may be met within the defined constraints and, where shortfalls exist, the programmes can identify which nutrients are adversely affected.

Whilst much of this work has been done in countries where there are issues around food security and dietary adequacy, this approach can also be a useful planning tool in the integration of food-based recommendations for health and sustainability. Dietary modelling has been used in the development of existing food-based dietary guidelines for health in the USA and Canada, and in the developmental stages of integrated food-based dietary guidelines for both health and sustainability in Australia and the UK. Comparing existing diets to these guidelines may provide an indication of whether or not modifying our diets in line with existing recommendations for health might in itself contribute to the mitigation of food-related environmental impacts.

The main purpose of food-based dietary guidelines is as a tool to support consumers in achieving health and wellbeing through a healthy diet. They attempt to interpret the complexities of national dietary reference values and food-based recommendations for the prevention of chronic diseases, and translate them into practical examples of how different food groups can be combined to achieve a healthy diet. They are frequently presented as a set of qualitative recommendations which support a graphic representation of how a healthy diet should look. The USA and Canadian food-based dietary guidelines are some of the most complex guidelines available, as they take the form of a quantitative description of a healthy diet that is segmented by age, gender and physical activity level, as well as having a graphic illustration and qualitative messages.

3.3 Dietary modelling methodologies

While the modelling exercises outlined in this section attempted to derive food intake patterns for specific population groups that meet nutritional requirements within a modest amount of energy, there are differences in the approach taken in each example.

Generally, country-specific dietary reference intakes/values are used to establish the nutritional adequacy of the dietary patterns proposed. However, while Canada and the USA set target reference values for almost all nutrients, the Australian model was driven by 10 nutrients for which there are established recommended daily intakes (RDI), and the remaining nutrients were included in outputs for information only. (The equivalent terms for RDI are: recommended daily amount, RDA, in the USA and Canada; and dietary reference value, DRV, in the UK.) All of the modelling exercises developed food intake patterns based on recommended amounts of food from groups of food with similar nutrient profiles and uses in the diet – for example, fruit and vegetables. The number of food groups used differed between countries. For example, the Australian model segmented vegetables into orange, green and brassica, legumes, starchy vegetables and other vegetables. This differentiation into subsets with similar nutrient profiles has the advantage of promoting the consumption of a wider variety of vegetables, thus increasing the probability of individuals achieving nutrient adequacy for a greater range of nutrients.

During the modelling process, food groups were used to develop age- and gender-specific composite foods. These composite foods represent the proportions in which the foods are commonly consumed within each food group for each age and gender group. For example, if national intake data showed that 60% of the fruit eaten by 4-8 year olds was bananas, 20% oranges and 20% apples, then 60% of the nutrient profile of the composite food fruit for 4-8 year olds would reflect the nutrient profile of 60% bananas, 20% oranges and 20% apples. The composite foods were then used to determine the number of servings of each required to supply the RDI/RDA for the target nutrients. In the USA model, adequacy was deemed to have been achieved when a pattern was found that supplied 100% of the RDI (or acceptable intake figure for those nutrients that do not have an RDI) for each age/gender group – the implication being that, if individuals follow the food intake pattern selecting individual foods in similar proportions to the composite food, there is a very high probability that their nutrient requirements will be met. Deviations from this pattern would result in a lower probability of all nutrient requirements being met.

The Canadian and Australian models have attempted to introduce greater flexibility in food choice to their models by introducing a second phase of modelling whereby 500 (Canadian model) or 100 (Australian model) diets were simulated for each age/gender group following the dietary pattern developed in the initial phase. Foods were selected by an analytical program in proportion to how often they were consumed by each age/gender group. At this stage, the target used in both models to determine nutrient adequacy was estimated average requirement (EAR). Where an unacceptable proportion of diets fell below the EAR, food patterns were manipulated in an iterative manner to identify alternative choices that would result in meeting the EAR, thereby increasing the likelihood that the diet would be nutritionally adequate.

While all of the models describe a diet that provides adequate nutrient intakes for sedentary individuals in each age and gender group, they differ in their approach to individuals in the group with higher energy requirements. The Australian model has identified how foundation diets might be built upon to cater for individuals within the group with higher energy requirements. The resulting 'total diets' are based on the foundation diets but, as energy requirements within the groups rise, additional servings are recommended in proportion to energy requirements. The total diets also allow for inclusion of 'other foods' in proportion to energy intake. The 'other foods' group includes foods higher in fats and sugar not used in the development of foundation diets. This is similar to the USA model where the foods used to drive the model are the lowest-fat, lowest-sugar alternatives. High-fat, high-sugar foods are represented in the model under the category 'discretionary calories'. The quantities of foods recommended under named food categories are expected to meet nutrient but not energy requirements and the 'discretionary calories' category allows consumers the flexibility to meet energy deficits from any foods or alcohol, including high-fat, high-sugar foods up to the calorie limit suggested under discretionary calories. The foods included in the Canadian model were lower-fat rather than the lowest fat alternatives; consequently diets

that are consistent with the recommended pattern are more likely to meet the energy requirements for sedentary individuals. Canada's food guide is, however, a recommendation for a desirable pattern of eating rather than a more prescriptive diet model. It might therefore be assumed that individuals with greater energy requirements meet their needs by eating more foods proportionally from each food group.

All of the modelled diets provide recommendations by age, gender and physical activity level. However, in order to compare recommendations, sedentary adult females were chosen for the comparison (see Table 8 on page 46), as this was the most consistent group across the modelling exercises in terms of age and gender.

3.4 Adding in sustainability criteria to healthy diet modelling

In Australia and the UK, attempts have been made to add sustainability criteria to dietary modelling, to establish diets which achieve nutritional adequacy whilst allowing for reductions in associated greenhouse gas (GHG) emissions related to food choice.

Australian modelling exercise

The Australian modelling exercise is a technical translation of nutritional targets into types and quantities of foods. The model derived is not intended for use by consumers, but is an integral stage in the process of guideline development (NHMRC, 2010). While not directly attempting to combine sustainability and health into one set of food guidelines, the executive summary to the draft report (out to consultation until February 2012) identifies one of the objectives of the modelling exercise as:

"to translate the Nutrient Reference values for Australia and New Zealand including Recommended Dietary Intakes into food consumption patterns that are culturally acceptable, socially equitable and environmentally sustainable".

Sustainability criteria in the Australian model were incorporated into the model in terms of constraints. Constraints are upper and/or lower limits imposed on the amounts of specific foods that could be included in the modelled diets. Upper limits were set for total meat and red meat, and upper and lower limits were set for fish, reflecting both concerns over sustainability and the evidence related to the health benefits associated with fish consumption. (Setting a lower limit ensures that fish is included in the modelled diet, and setting an upper limit ensures that the model selects no more than the desirable quantity.) For adults, the daily limits on total meat, red meat and fish were 150g, 65g and 40g respectively. The lower limit set for fish was 20g (NHMRC, 2010).

Livewell diet (UK)

In the UK, the WWF-UK in collaboration with the Rowett Institute of Nutrition and Health has recently combined dietary modelling and the results obtained from

life cycle analysis (LCA) of food products in a preliminary exercise to integrate both health and sustainability into a weekly meal pattern (called the *Livewell* diet) that shows how the transition to a more sustainable diet might be achieved in terms of daily meals (Macdiarmid et al, 2011). The target set, and achieved, was to reduce the greenhouse gases (GHGs) attributable to the production and consumption of food in the UK by 25% by 2020 relative to 1990 levels, while maintaining the nutritional integrity of the diet. Emissions attributable to land-use change were not included in the modelling exercise and it was assumed that 14% of the reductions would arise as a result of changes in consumption, with the remaining 11% from savings in production and processing methods of foods. However, WWF acknowledges that, while these dietary changes have the potential to reduce UK food-related GHG emissions by about 20%, achieving nutrient-based recommendations for health within a diet that involved 70% reductions in GHG emissions would significantly limit food choice and would result in a food basket that would be difficult to arrange into a 'sensible' diet, or at least one that is familiar to the UK consumer and which consumers have the skills to prepare into family meals.

Table 7 shows the total quantities of foods in the different food groups included in the modelled one-week diet for women aged 19-50 years. This group has been chosen as it is consistent across the modelling exercises so can be used to compare and contrast the different approaches. This does not reflect the full list of foods included in the modelling process, but does reflect those selected by the model in order to achieve the nutrient, food and GHG targets. As with the Australian modelled diet described above, reductions in meat products have been incorporated into the model using constraints. Unlike the dietary models driven mainly by health-based criteria, this model was driven by both nutrient DRVs and food-based recommendations for the prevention of chronic disease, and the results of LCA analysis of foods commonly consumed and available in the UK. Using LCA as co-driver in the model allows nutrient intakes to be optimised while minimising the level of GHG emissions.

TABLE 7: Food quantities included in the WWF *Livewell* diet for women aged 19-50 years

Food group	Sub-categories of food products selected in the <i>Livewell</i> diet model	Weekly weight	Average intake per day
Bread, rice, potatoes, pasta and other starchy foods	Pasta, noodles, rice, white bread, wholegrain bread, wholegrain/ high-fibre breakfast cereal, other breakfast cereal, oats, grilled or oven-baked potato products, potatoes	2,839g	406g
Fruit and vegetables	(Carrots and turnips), tomatoes, peas, (cabbages, Brussel sprouts, other brassicas), (cauliflower, broccoli, spinach), cucumber, lettuce, mushrooms, onions, raw peppers, sweetcorn, (apples, pears), bananas, (grapes, kiwi, cherries), (peaches, apricots, nectarines), (strawberries, blueberries, raspberries), fruit juice	3,724g	532g
Milk and dairy	Semi-skimmed milk, reduced-fat cheese, (full-fat yoghurt, fromage frais), (low-fat yoghurt, fromage frais)	2,256g	322g
Meat, fish, eggs, beans and other non-dairy sources of protein¹		1,279.4g	183g
Ham		21g	3g
Beef		91g	13g
Pork		91g	13g
Total red meat		203g	29g
Chicken meat		203g	29g
Total meat		406g	58g
White fish (coated, fried)		161g	23g
Shellfish		49g	7g
Oily fish		119g	17g
Total fish		329g	47g
Eggs		119g	17g
Sesame seeds		1.4g	-
Nuts		25g	4g
Beans (excluding baked beans)		70g	10g
Lentils (cooked)		56g	8g
Baked beans		273g	39g
Total for alternatives to meat and fish		544g	78g
Foods and drinks high in fat and/ or sugar	Biscuits, (buns, cakes and pastries), sponge or cereal-based puddings, ice-cream, low-fat spread, (fried, roast potatoes and fried potato products), crisps and savoury snacks, sugar, preserves, chocolate	847g	121g

¹ Sub-categories are listed separately in order to clarify the dietary changes required.

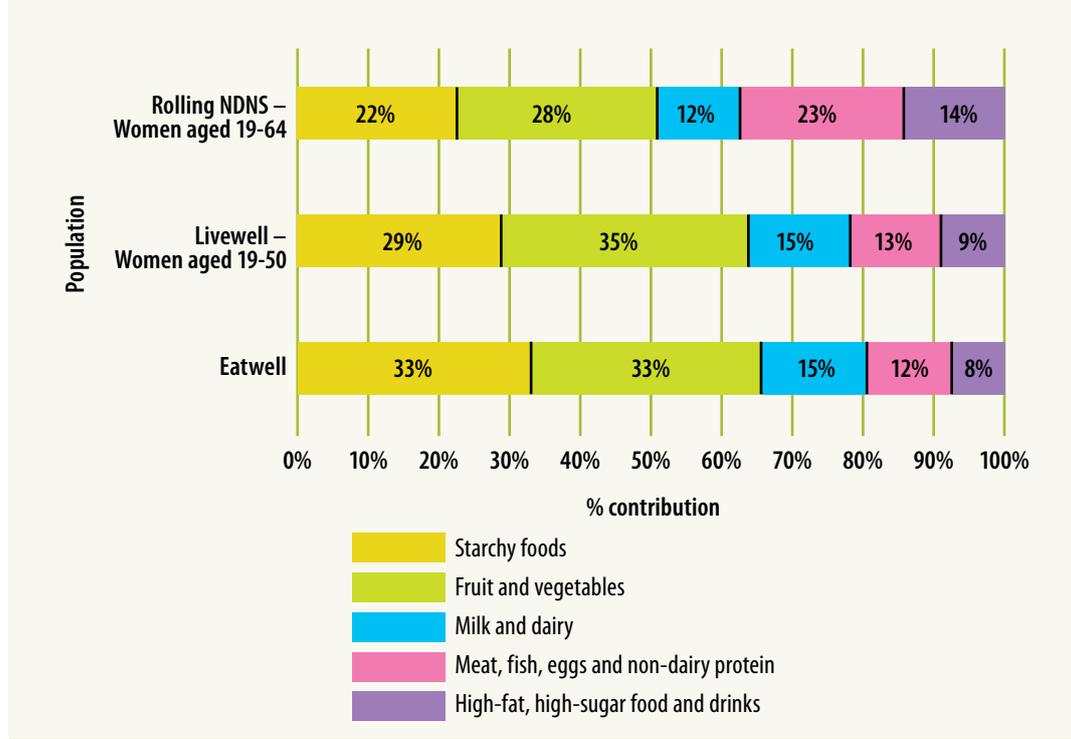
Source: Macdiarmid et al (2011).

Existing UK food-based dietary guidelines take the form of recommendations on the proportional contribution of each food category to the total diet. These are represented pictorially in the *Eatwell plate* (see Figure 6 on page 30). When comparing the *Livewell* diet with existing UK food-based dietary guidelines, significant reductions in consumption of animal-based proteins have been compensated for by much greater consumption of plant-based proteins including pulses and nuts and seeds (see Figure 7).

However, it is important to note that this is just one example of how the foods consumed in a week could be both healthy and more sustainable. For example, the actual weekly limit for red and processed meat used in the modelling exercise was up to 300g per week, which reflects the WCRF/AICR average population target of 300g per week and is within the SACN (2010) recommendation of 70g per person per day or 490g per person per week, but only 203g per week is included in the *Livewell* diet plan.

The *Livewell* diet is compared to the current diet (rolling NDNS) and the *Eatwell plate* in Figure 7.

FIGURE 7: Percentage contribution of each food category to total diet, by weight: a comparison of current consumption patterns with suggested recommendations for health and sustainability



Sources: Rolling NDNS 2008/2009: Department of Health (2011); *Livewell* diet: Macdiarmid et al (2011).

It is interesting to note that the *Livewell* weekly diet does not suggest lower intakes of dairy products than are recommended in current UK food-based dietary guidelines and that, according to the most recent national food survey, the rolling NDNS (Department of Health, 2011), women currently consume less dairy products than are recommended. However, it is worth pointing out that some high-fat dairy products such as butter and cream are included in the category 'high-fat, high-sugar foods and drinks and, as the *Livewell* meal plan suggests a slightly larger proportion of these foods than existing recommendations, a slightly higher increase in consumption of those products than is currently recommended is implied.

3.5 Differences in the recommended levels of consumption of food groups between different countries

Data are not directly comparable across countries, as different units of measurement have been used, but comparisons can be made between the different national dietary targets that have been discussed here. Table 8 compares those for Australia (NHMRC, 2010) and WWF-UK (Macdiarmid et al, 2011), both of which include sustainability criteria, with those for Canada (Katamay et al, 2007) and the USA (Britten et al, 2006) which do not. The figures for women aged 19-50 years have been used for comparison and intakes are given per week. The UK data were produced before the changes to estimated average energy intakes made by SACN in 2011 (Scientific Advisory Committee on Nutrition, 2011).

TABLE 8: Food group amounts meeting national dietary targets for energy and nutrients for women aged 19-50 years

	AUSTRALIA	CANADA	USA	WWF-UK The <i>Livewell</i> diet
Daily Average Energy Requirement (kcal/MJ)	1,750kcal (7.3MJ)	1,750-1,900kcal (7.3-7.9MJ)	1,800kcal (7.5MJ)	1,940kcal (8.1MJ) ¹
Age band in years	31-50	31-50	31-50	19-50
INTAKE PER WEEK				
	Total servings	Total servings	Total servings	Total weight
FRUIT AND VEGETABLES				
Total fruit²	14 (150g)		10.5 cup (240ml) equivalents	1,918g
Vegetables				
Starchy vegetables	5 (75g)		5 (240ml) (150g)	779g
Green and brassica vegetables	7 (75g)		1.5 (240ml) (150g)	497g
Red and orange vegetables	7 (75g)		5.5 (240ml) (150g)	133g
Legumes	2 (75g)		1.5 (240ml) (150g)	
Other vegetables	14 (75g)		4 (240ml) (150g)	
Nuts and seeds	2 (30g)			
Total vegetables	37		17.5 x 240ml (150g) equivalents	1,176g
Total fruit and vegetables	51 portions 4,785g	49 serving equivalents 1 serving = 125ml (80g) fresh, frozen or canned fruit or vegetables or juices, or cooked leafy green vegetables, or 250ml raw leafy green vegetables or 1 fruit. Approximately equivalent to 3,920g (3,884g)⁴	28 x 240ml (150g) equivalents 240ml = 240ml raw or cooked fruit or vegetables or juice or 480ml leafy green salad. (Approximately equivalent to 54 Canadian servings.) Approximately equivalent to 4,200g (4,201g)³	4,928g
Key consumer messages	N/A	Eat at least one dark green and one orange vegetable per day. Have vegetables and fruit more often than juice.	Make at least half of your plate fruits and vegetables.	N/A
CEREALS/ GRAINS				
Wholegrain cereals/ grains	28 servings	42 servings	21 x 28.3g equivalents	2,060g
Refined cereals/ grains	14 servings		21 x 28.3g equivalents	
Total cereals/ grains	42 servings 1 serving = 40g bread, or 120g cooked rice, or 30g cold breakfast cereal Approximate weight 1,680g if all expressed as bread. Approximate weight 1,260g if all expressed as cold breakfast cereal.	42 serving equivalents 1 serving = 125ml cooked pasta, rice or couscous; or 1 slice of bread (35g) or ½ bagel or pitta; or 30g cold breakfast cereal or 188ml hot cereal Approximate weight 1,470g if all expressed as bread. Approximate weight 1,260g if all expressed as cold breakfast cereal.	42 x 28.3g equivalents 28.3g = 120ml cooked pasta, rice, noodles or oatmeal; or 30g cold breakfast cereal; or 25g bread Approximate weight 1,050g if all expressed as bread. Approximate weight 1,260g if all expressed as cold breakfast cereal.	2,060g
Key consumer messages	N/A	Make at least half of your grain products wholegrain each day. Choose grain products lower in fat, sugar and salt.	Make at least half of your grain wholegrain.	N/A

1 oz = 28.3g • 1 cup Canada = 250ml • 1 cup USA = 240ml

	AUSTRALIA	CANADA	USA	WWF-UK The <i>Livewell</i> diet
MEAT AND MEAT ALTERNATIVES				
Red meat	7 servings	14 servings	35 x 28.3g equivalents	203g
White meat (poultry)	7 servings			203g
Fish and seafood				329g
Eggs				119g
Legumes				399g
Nuts and seeds				26.4g
Total meat and other sources of protein	14 servings 1 serving = 65g red meat or equivalents Approximate weight 910g if all expressed as red meat.	14 servings 1 serving = 75g meat or fish; or 187ml cooked legumes or tofu; or 2 eggs; or 2 tablespoons peanut butter; or 63ml shelled nuts or seeds Approximate weight 1,050g if all expressed as red meat.	35 x 28.3g (1oz) equivalents 28.3g = 28.3g lean meat, poultry or fish; or 1 egg; or 60ml (dried volume) of cooked beans or tofu; or 1 tablespoon peanut butter; or 14.1g nuts or seeds Approximate weight 990g if all expressed as lean red meat.	1,279.4g
Key consumer messages	N/A	Use meat alternatives such as beans, lentils and tofu more often. Select lean meats prepared without salt or fat. Eat at least 2 food guide servings of fish each week.	Choose lean meat or low-fat meat and poultry. Select some seafood that is rich in omega-3 fatty acids. Choose unsalted nuts and seeds to keep sodium intake low.	N/A
DAIRY				
Semi-skimmed milk	17 servings	14 serving equivalents	21 cups	1,603g
Cheese (reduced-fat)				203g
Full-fat yoghurt and fromage frais				156g
Low-fat yoghurt and fromage frais				294g
Total dairy foods	17 servings⁵ 1 serving = 250ml milk or milk equivalents Approximate volume 4,250ml if all expressed as liquid milk.	14 servings⁵ 1 serving = 250ml milk or soy beverage; or 175g yoghurt or kefir; or 50g hard cheese Approximate volume 3,500ml if all expressed as liquid milk.	21 cup equivalents⁵ 1 cup = 240ml milk or yoghurt; or 42g hard cheese or 57g processed cheese Approximate volume 5,040ml if all expressed as liquid milk.	2,256g (approximately 13 servings) 250ml (taking 1g as 1ml) milk equivalent to 50g cheese and 175g yoghurt Approximate volume 3,250ml if all expressed as liquid milk
Key consumer messages	N/A	Have 500ml milk every day, drink skim, 1%, or 2% (for vitamin D). Use lower-fat milk alternatives.	Switch to fat-free or low-fat (1%) milk.	N/A
FOODS HIGH IN FAT AND/OR SUGARS				
Unsaturated fats and oils	14 (10g)	210g	168g	
Other high-fat, high-sugar foods	N/A to foundation diets	Not included in the modelling process	1,120 calories	847g
Key consumer messages			Enjoy your food but eat less. Avoid oversized portions. Drink water instead of sugary drinks.	
Total foods high in fat and/or sugars	140g	210g		847g

1 The UK data were produced before the changes to estimated average energy intakes made by SACN in 2011 (Scientific Advisory Committee on Nutrition, 2011).

2 Includes fruit juice.

3 This weight is based on weights of one representative cup weight of each food category. Vegetables: corn, canned (starchy vegetables); boiled broccoli (dark green vegetables); carrot (red and orange vegetables); canned white beans (legumes); lettuce (other vegetables). Fruit: approximate weight based on average weight of a cup of each of the following fruits: raw banana, raw apple, watermelon, grapes, raw oranges, raw peaches. Data sourced from USDA National Nutrient Database for Standard Reference, Release 16 (USDA, 2004).

4 This has been calculated using the same proportion of fruits to vegetables as the USA example. However, as no breakdown is provided for vegetables, the average weight used for a cup of vegetables is based on the average weight of a cup of each of the vegetables used to calculate the total vegetable weight for the USA. An additional percentage has been added to allow for the difference in cup sizes between Canada and the USA.

5 Predominantly low-fat.

Sources: Australia: NHMRC (2010); Canada: Katamay et al (2007); USA: Britten et al (2006); WWF-UK: Macdiarmid et al (2011).

Differences in the recommended levels of consumption of food groups between different countries are a consequence of many factors, including the nutrient targets relevant to the population, existing consumption patterns, the constraints used in the modelling process and the units of measurement. Nevertheless, the data can be used to identify similarities and differences in what different administrations and organisations perceive to be a culturally appropriate, healthy diet or, in terms of sustainability, appropriate levels of consumption.

Dairy products

The most notable difference in quantities occurs in the dairy category, with the USA model recommending around 44% more dairy foods than the Canadian food intake patterns and 19% more than the Australian pattern (see Table 8). These differences do not reflect differences in DRVs for calcium – which are the same in the USA and Canada and higher in Australia (see Table 9) – but are a result of the different methodologies used in the dietary modelling processes. The target value used in the USA modelling process was RDI, while the Canadian and Australian models, which both simulated sample diets in order to accommodate greater flexibility in dietary choice, sought to achieve the EAR for each of the simulated diets. The UK EAR and RNI (reference nutrient intake) are considerably lower than those elsewhere (see Table 9). The WWF-UK *Livewell* diet models the lowest amount of dairy products at approximately 465ml equivalent per person per day, and this may reflect the lower RNI for calcium in the UK.

TABLE 9: Dietary reference values for calcium for women aged 31-50 years

	EAR	RDI (RNI)
USA and Canada	800mg/day	1,000mg/day
Australia	840mg/day	1,000mg/day
UK	525mg/day	700mg/day

Fruit and vegetables

The Australian and USA models are more prescriptive in terms of quantities of sub-types of vegetables that should be consumed in order to meet nutrient requirements, but overall the *Livewell* diet suggests the largest intake of fruit and vegetables. Table 10 translates this into approximate number of portions of fruit and vegetables a day per person (based on 80g portions). This is a crude analysis as obviously different types of fruits and vegetables are also prescribed, but illustrates how recommended intakes compare. No country population achieves the current recommendations, outlining the magnitude of the change needed to achieve these dietary recommendations.

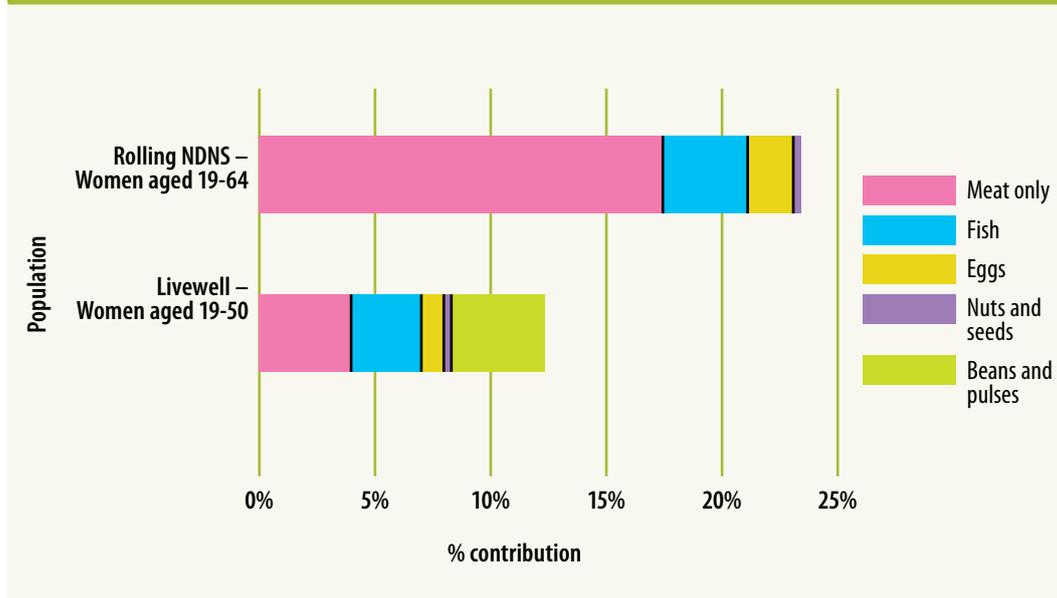
TABLE 10: Approximate number of portions of fruit and vegetables a day per person needed to meet nutrient requirements based on dietary modelling

Country	Average weekly intake recommended	Number of 80g portions of fruit and vegetables recommended per day	Current number of portions recommended in each country
UK WWF <i>Livewell</i> diet	4,928g	8.8	5 portions of at least 80g per portion
Australia	4,785g	8.5	2 fruits and 5 vegetables
USA	4,201g	7.5	Half your plate – number not specified but suggested as between 2 and 13 cups per day depending on age
Canada	3,884g	7	Women 7-8 portions, men 8-10 portions

Meat and meat alternatives

Of the examples compared, the Australian and UK models indicate the proportion of meat that should be consumed as red meat, and the UK example (the *Livewell* diet) specifies further across the category (see Table 8). The *Livewell* diet also suggests a comparatively low proportion of meat as red meat (ham, beef and pork) – 16% (203g) compared with 50% in the draft Australian recommendations. The *Livewell* diet also differs from other dietary models in that legumes and fish each make a greater contribution to the category of ‘meat and other sources of protein’ than either red or white meat. In order to achieve a diet in the proportions suggested by the *Livewell* diet, women in the UK would be required to consume cereal, fruits, vegetables, beans and pulses in larger proportions than they currently do. The meal plans generated in the *Livewell* plan show how reducing the frequency of meat consumption, using smaller portion sizes and bulking out meat dishes with beans and vegetables can provide a meal pattern that is nutritionally adequate, is less of an environmental burden, and includes enough meat and dairy products to allow meals to be planned in a way that does not deviate too far from those commonly consumed in the UK. This may mean that, when further modelling is undertaken around sustainability criteria elsewhere, more pulses and meat alternatives are required compared to current diets. Figure 8 shows the changes to this food group that would be required in the UK to achieve health and sustainability criteria.

FIGURE 8: Percentage contribution of foods to the meat and meat alternatives food group: a comparison of current consumption patterns with suggested recommendations for health and sustainability



Sources: Rolling NDNS 2008/2009: Department of Health (2011); *Livewell* diet: Macdiarmid et al (2011).

High-fat, high-sugar foods

While the *Livewell* weekly meal plan allows a much more significant amount of foods of low nutrient density and high-fat, high-sugar foods than in the food intake patterns recommended for the USA, Canada and Australia and slightly more than the existing UK recommendations (see Table 8), the quantities included are much lower than in the current diet of UK women (see Figure 7 on page 43). Furthermore, the energy target for the *Livewell* model is slightly higher than in the other models and, unlike the other models, the *Livewell* model includes fats and oils as high-fat, high-sugar foods.

3.6 So how do diets need to change to meet dietary recommendations for adults?

Comparing current diets with food-based dietary guidelines and modelled diets may provide some insight into the potential environmental impacts of widespread adoption of dietary changes. The findings from studies including comparisons of existing and modelled diets are summarised in Table 11. It is not always simple to make comparisons, as calculations have been made at different times, using different data. For Australia for example, figures in Table 11 differ from those previously presented as the data are provided on current intakes for adults only, and not broken down by specific amounts for differing age bands. For the USA, Table 11 data are based on the guidelines for fruit and vegetable consumption that were current when the figures on the magnitude of change required were derived, rather than more recent figures used elsewhere in this report. Sources of these data are given below the table.

3.7 Direction of change required to achieve better health and more sustainable consumption

Studies consistently show that, in order to comply with dietary recommendations, the direction of change for fruits, vegetables and grain products is for increased consumption. This is consistent with messages for both health and sustainability that the human diet should be based mainly on foods of plant origin (see Table 12). The direction of change for other commodities for adult diets to meet health criteria is not always consistent with general sustainability criteria.

TABLE 12: Direction of change suggested to achieve better health, compared with general guidance for more sustainable consumption					
Food product category	Health			Health and sustainability	General guidance for greater sustainability
	Australia	Canada	USA	WWF-UK	
	Adults	Women aged 19-30	Women aged 31-50	Women aged 19-50	
Fruit	↑	↑	↑	↑	↑
Vegetables	↑	↑	↑	↑	↑
Total cereals/starchy food	↑	↑	↑	↑	↑
Red meat	↓ (women) ↓↓ (men)			↓	↓
White meat, fish, seafood and eggs	↑				
Fish				↑	
All meat and alternative sources of animal protein		↓	↑	↓	↓
Total dairy	↑	↑	↑	↑	↓
High-fat, high-sugar foods	↓	↓	↓	↓	↓

Meat and meat alternatives

The direction of change for consumption of animal products is difficult to interpret as there are differences in reporting. Meat has generally been combined into a category that includes alternative sources of protein such as eggs, fish, nuts and legumes. However, the Australian model suggests that, overall, adherence would require a reduction in the consumption of red meat, mainly by men, and an increase in consumption of alternative sources of protein including white meat, fish, seafood, and eggs. The data from Canada and the USA suggest that, overall, reductions in consumption of the combined category 'meat and alternative sources of protein' would be required (although the data from Canada represent only food-secure adult females). However, it is difficult to compare the impact that the suggested changes in meat consumption will have on consumption of pulses in the Canadian and USA models, as pulses are included in either the 'fruits and vegetables' category or the 'alternative sources of protein' category. This is because their nutritional profile and use in the diet has similarities with both categories. However, in both examples the qualitative messages suggest that consumers should choose pulses including beans and lentils as an alternative to meat more often. The WWF-UK model specifies an increase in 'beans and pulses' and 'nuts and seeds', but figures for current consumption of these are not available for comparison.

Fish

Interestingly, the USA and Canadian models do not quantify recommendations for fish but, in the qualitative messages, suggest that consumers consider eating fish as an alternative source of protein to meat, which would suggest an increase in consumption. The Canadian food-based dietary guidelines recommend 2 portions of fish per week. Canada does not say how many portions need to be oily but encourage choosing oil-rich species such as salmon, mackerel, herring, sardines and trout. Existing food-based dietary guidelines in many European countries including the UK also recommend 2 portions of fish per week, one of which should be oily fish. The Australian modelled diet does not separate fish consumption from other sources of protein. However, in the National Health and Medical Research Council's draft report, it is suggested that the target level of consumption should be 1 portion per week (NHMRC, 2010). This differs from the existing Australian food-based dietary guidelines which, like those of many other countries, suggest 2 portions of fish per week. It is again important to note that the anticipated new food guidance system for Australia is still in the consultation phase and has not yet been issued. However, this might indicate willingness to compromise on recommendations concerning the consumption of fish. Where existing levels of fish consumption are below recommended levels, the impact of making recommendations for increased consumption of fish can only be detrimental to marine ecology. The potential health benefits of consuming 2 portions of fish a week must be reconsidered in terms of the current low nutritional contribution that fish make to the national diet, the strength of the evidence concerning reductions in the incidence of cardiovascular disease, and the threat to marine ecology.

Dairy products

The direction of change required to meet recommendations for dairy foods is quite uniformly in the direction of increased consumption in order to meet dietary goals, but this is not generally reflected in sustainability guidance. Overall increases of between 33% and 114% are suggested (see Table 11 on page 51). This is likely to be due to the difficulties inherent in finding alternative sources of nutrients such as calcium, riboflavin and iodine without radically changing existing dietary patterns. Recommendations to increase cereal foods are also likely to impact on this as cereals and milk are often consumed together, and in order for foods to make sense in consumption terms some products will be linked.

Foods high in fat and sugar

Each of the modelling exercises has taken a different approach to foods high in fat and sugar. As has previously been mentioned in the overview of methodologies in section 3.3, the named food groups in the USA model are expected to supply nutrient adequacy and not necessarily meet energy requirements. Any energy deficit may be made up from foods not included in the modelling process – for example, alcohol, higher-fat versions of foods included in the model, solid fats or high-fat, high-sugar foods. The foods included in the Canadian model are lower-fat and lower-sugar rather than the lowest fat and sugar alternatives and it may therefore be assumed that energy requirements are more likely to be met within the recommended intake of named foods. The Australian model takes a different approach to people with higher energy requirements and suggests two different scenarios for increasing energy intake. The first suggests increasing consumption of foods from each food category. The second is more in keeping with the aims of the sustainability agenda and suggests that additional energy requirements are met by increased consumption of foods from all categories with the exception of meat and dairy products. Overall the modelling exercises all suggest minimal intakes of foods of low nutritional value and attempt to provide food intake patterns that promote eating within our energy requirements, thus reflecting goals for both health and sustainability. The WWF-UK model specifies amounts for foods higher in fat and sugar and the amount consumed needs to be approximately halved from current intakes.

KEY POINTS

- Dietary modelling has been used in the development of existing food-based dietary guidelines for health in various countries, and in the developmental stages of integrated food-based dietary guidelines for both health and sustainability in Australia and the UK.
- In the UK, the resulting *Livewell* diet integrates both health and sustainability goals into a weekly meal pattern that shows how the transition to a more sustainable diet might be achieved in terms of daily meals. The target set, and achieved, in the *Livewell* diet was to reduce the greenhouse gases attributable to the production and consumption of food in the UK by 25% by 2020 relative to 1990 levels, while maintaining the nutritional integrity of the diet. When comparing the *Livewell* diet with existing UK food-based dietary guidelines, the significant reductions in consumption of animal-based proteins are compensated for by much greater consumption of plant-based proteins including pulses and nuts and seeds.
- Overall, the direction of change required to achieve both better health and more sustainable consumption is that adults' diets should be based mainly on foods of plant origin, with an increased intake of fruits, vegetables and grain products.
- The direction of change required for other food groups to meet health criteria is not always consistent with general sustainability criteria:
 - It is difficult to interpret the direction of change for consumption of animal products as there are differences in reporting. However, it is suggested that consumers should choose pulses – including beans and lentils – as an alternative to meat more often.
 - For dairy products, the direction of change required to meet recommendations for health is quite uniformly in the direction of increased consumption, but this is not generally reflected in sustainability guidance.

4 How might current thinking on healthy, sustainable diets impact on the diets of young children in the UK?

This section looks at current food-based recommendations for children and how these differ from their existing dietary patterns. It examines what we know about the nutritional health and food habits of young children in the UK and the significance of meat and dairy products in their diet. It also looks at where reductions in the consumption of meat and dairy products might create new areas of concern for public health, or might exacerbate or ameliorate existing problems.

4.1 What are pre-school children in the UK currently eating?

The results of three surveys of the diets of pre-school children are shown in Table 13: the National Diet and Nutrition Survey (NDNS) 1995 (Gregory et al, 1995); the Avon Longitudinal Study of Parents and Children (the ALSPAC study) (Emmett et al, 2002); and the rolling National Diet and Nutrition Survey 2008/2009 (Department of Health, 2011).

The rolling NDNS 2011 survey and the previous NDNS 1995 survey of children aged 1½-4½ years provide a snapshot of the dietary habits of children in the UK. However, both these reports have limitations: the sample size in the rolling NDNS is small (only 65 boys and 56 girls are included in this sample), and the data from the previous NDNS were collected in 1992/93 and it is likely that dietary habits

have changed since this time. Despite this, the surveys provide the most reliable national information available and can give some indication of the importance of meat and dairy foods in the diets of young children in the UK.

At the regional level, the ALSPAC study provides information on the dietary habits of a large sample of children aged 1½-3 years living in Avon in 1994. Some of the data was collected on a smaller sample known as the Children in Focus (CIF) study. This age range falls within that included in the NDNS programme and has the advantage of using food categories almost identical to those in the NDNS 1995. The results from the ALSPAC survey have been included here as a useful corroboration of the data from the national surveys.

The difference in age ranges among these studies does pose some problems, as the figures are not always directly comparable. It is therefore important to see these as guide figures rather than as definitive amounts. For more on the limitations of these surveys, see the box below.

The difficulties of comparing data across the three studies of children's diets

It is difficult to compare the data across the three studies mentioned above, as the demographics and social characteristics of the participants, as well as the study methodologies, differ. The data collection method used in the NDNS 1995 was the 4-day weighed diary method, where all food consumed must be weighed. In contrast, the ALSPAC study and the rolling NDNS studies used estimated food diaries, where the quantity of food consumed is estimated using standard household measures. The Children in Focus (CIF) study and the rolling NDNS 2011 differed in that the recording period was three days for CIF and four days for the rolling NDNS. While there is evidence to suggest that the requirement to weigh all foods consumed may lead to a degree of under-reporting, the NDNS 1995 and the rolling NDNS are, respectively, the most comprehensive and contemporary datasets available on the dietary habits of children across the UK. A more detailed account of the methodological differences between the NDNS studies and their implications has been given by Riley (2010).

In general, the recorded food and nutrient intakes for the ALSPAC study cohorts were higher than both the NDNS 1995 and rolling NDNS 2011. It is difficult to establish whether these differences represent real differences in intake or are directly attributable to methodological differences. The preliminary results of the second wave of the rolling NDNS 2011 suggest that, over time, there have been some small but important changes in the dietary habits of pre-school children. Some, but not all, of the changes recorded are positive in that they appear to reflect changes in eating patterns that align more closely with qualitative recommendations for healthy eating for young children made by the Department of Health and regional recommendations aimed at supporting those responsible for providing meals in childcare settings.

TABLE 13: Mean weight of foods consumed per day by children aged 1½-4½ years in the UK during three sampling periods¹

Age of sample	NDNS 1992/3		NDNS ² 1992/3		NDNS ² 1992/3		NDNS ² 1992/3		Rolling NDNS 2008/9/10/11		ALSPAC 1994		ALSPAC 1996	
	All n = 1,675	Mean g/day (% consumers where data available)	1½-2½ years n = 576	Mean g/day (% consumers where data available)	2½-3½ years n = 606	Mean g/day (% consumers where data available)	3½-4½ years n = 493	Mean g/day (% consumers where data available)	1½-3 years n = 219	Mean g/day (% consumers where data available)	18 months n = 1,026	Mean g/day (% consumers where data available)	43 months n = 863	Mean g/day (% consumers where data available)
CEREALS AND CEREAL PRODUCTS														
Pasta, rice, other cereals	25.7		24.6		25.2		27.8		53.0		28		35.8	
White bread	27.7 (86)		21.5 (83)		28.2 (87)		34.3 (88)		25 (78)		20.4 (74)		35.7 (84)	
Wholemeal bread	6.3 (27)		6.3 (29)		5.7 (27)		7.1 (26)		8 (31)		7.9 (34)		10.6 (32)	
High-fibre white/ softgrain	1.4 (7)		1.1 (7)		1.4 (6)		1.9 (7)				0.9 (5)		1.3 (6)	
Other bread	4.7 (30)		4.2 (30)		9.9 (32)		4.3 (26)		11		3.7 (17)		3.5 (13)	
Wholegrain/ high-fibre breakfast cereal	11.0 (61)		10.9 (64)		11.9 (62)		10.0 (58)		18 (61)		13.6 (73)		13.2 (59)	
Other breakfast cereal	8.7 (66)		6.9 (62)		8.9 (65)		10.6 (72)		5 (49)		4.5 (46)		9.8 (66)	
Biscuits	15 (88)		12.4 (86)		16 (91)		16.7 (88)		11 (75)		12.2 (87)		17.2 (88)	
Buns, cakes, pastries	9.4 (55)		6.7 (50)		10.3 (55)		11.8 (61)		8 (48)		8 (47)		16 (55)	
Fruit pies	0.9 (6)		0.6 (5)		0.8 (6)		1.0 (6)							
Ice-cream	8.4 (43)		6.3 (35)		9.1 (47)		10.2 (48)		6 (29)		24.9 (58)		35.8 (69)	
Other desserts	17.7		15.8		18.3		19.5		13					
MILK AND MILK PRODUCTS														
Whole milk	221.6 (83)		274.3 (86)		207.6 (82)		176.3 (80)		193 (65)		391 (90)		260.4 (84)	
Semi-skimmed milk	55.7 (32)		42.6 (23)		63.1 (35)		59.9 (38)		77 (42)		30.5 (15)		77.7 (33)	
Skimmed milk	4.3 (4)		2.4 (3)		4.9 (4)		6.7 (7)		9 (3)		1.6 (1)		1.5 (2)	
Infant formula	6.7 (2)		13.3 (4)		3.8 (1)									
Other milk and cream	4.9 (13)		6.8 (12)		3.8 (12)		4.3 (17)		45 (23)					
Cheese	5.7 (59)		5.6 (60)		5.6 (58)		6.2 (57)		8 (67)		6.9 (57)		9.1 (58)	
Fromage frais	8.0 (26)		9.2 (26)		7.6 (27)		6.9 (23)		44 (81)		40.9 (69.8)		39.3 (63.9)	
Yoghurt	20.1 (40)		22.7 (43)		20.5 (42)		16.6 (33)							
Eggs and egg dishes	8.3 (46)		7.4 (45)		8.5 (45)		9.1 (47)		9 (39)		6.4 (29)		7.4 (30)	
MEAT AND MEAT PRODUCTS														
Beef and veal	12.3 (47)		12.6 (48)		12.2 (46)		12.2 (46)		14 (40)		9.4 (37)		9.3 (24.9)	
Lamb	2.0 (15)		1.4 (14)		2.5 (16)		2.0 (15)		4 (12)		6.9 (19)		6.1 (16.2)	
Pork	1.9 (18)		1.5 (17)		2.0 (19)		1.9 (19)		3 (11)		2.4 (15)		3.9 (15.3)	
Liver and products	0.4 (4)		0.6 (4)		0.4 (4)		0.2 (4)		0 (1)		1.5 (8)		0.9 (4)	
Total red meat	16.6		16.1		17.1		16.3		21		20.2		20.2	
Chicken and turkey	6.6 (52)		6.0 (52)		6.6 (51)		7.1 (52)		13 (55)		8 (45)		12.7 (45)	
Coated chicken	3.0 (18)		2.1 (16)		2.8 (16)		4.3 (24)		5 (26)		1.6 (10)		5 (24)	
Total white meat	9.6		8.1		9.4		11.4		18		9.6		17.7	
Sausages	9.0 (53)		8.1 (51)		8.6 (54)		10.5 (54)		11 (44)		4.6 (33)		6.6 (35)	
Bacon and ham	3.3 (40)		2.2 (34)		3.2 (41)		4.4 (46)		4 (45)		2.8 (33)		5.3 (45)	
Burgers and kebabs	3.4 (24)		2.8 (22)		3.3 (24)		4.3 (26)		2 (8)		0.8 (6)		1.3 (6)	
Meat pies and pastries	6.0 (28)		5.3 (28)		6.1 (29)		6.4 (27)		5 (23)		3.2 (15)		3.6 (13)	
Other meat products	3.9 (27)		2.7 (23)		3.9 (28)		5.1 (30)		2 (11)		0.6 (8)		0.9 (10)	
Total processed meat	25.6		21.1		25.1		30.7		24		12		17.7	

	NDNS 1992/3	NDNS ² 1992/3	NDNS ² 1992/3	NDNS ² 1992/3	NDNS ² 1992/3	Rolling NDNS 2008/9/10/11	ALSPAC 1994	ALSPAC 1996
Age of sample	All n = 1,675	1½-2½ years n = 576	2½-3½ years n = 606	3½-4½ years n = 493	1½-3 years n = 219	18 months n = 1,026	43 months n = 863	
Type of food	Mean g/day (% consumers where data available)							
FISH								
Coated and fried white fish	6.3 (38)	5.6 (39)	6.5 (38)	6.9 (38)	7 (41)	5.6 (33)	8.4 (36)	
Other white fish dishes	1.7 (10)	2.2 (13)	1.3 (8)	1.4 (9)	5 (24)	3.1 (14)	3.1 (11)	
Oily fish	1.6 (16)	1.3 (15)	1.9 (17)	1.6 (15)	3 (10)	1.4 (11)	2.5 (14)	
Total fish	9.6	9.1	9.7	9.9	15	10.1	14	
VEGETABLES								
Total vegetables	26.8	24.1	26.6	29.8	54 ³	39.2 (92)	40.1 (83)	
of which raw and salad vegetables	5.3	3.7	5.2	7.3	9	3.5	8.9	
Baked beans	12.0 (49)	12.4 (52)	12.4 (50)	11.3 (45)	16.1 (46)	16.1 (46)	15 (40)	
Chips, fried and roast potatoes	24.3	19.7	24.4	29.3	20	17.6	32.1	
Potato products	1.6 (12)	1.5 (12)	1.6 (11)	1.8 (12)				
Other potatoes	22.4 (77)	22.1 (80)	21.4 (75)	24.2 (77)	22 (68)	29.2 (78)	25 (63)	
FRUIT								
Total fruit	50.4	48.6	51.1	50.7	102 (92)	63.9 (84)	69 (83)	
HIGH-FAT AND HIGH-SUGAR FOODS								
Savoury snacks	9.4 (78)	7.6 (73)	10.3 (80)	10.4 (81)	6 (64)	6.2 (66)	11.7 (75)	
Sugar, preserves, sweet spreads, fillings, icings	4.5	3.9	4.4	5.3	4		6.8	
Sugar confectionery	9.6 (58)	6.2 (46)	10.4 (62)	12.4 (67)	3 (27)	3.8 (18)	5.2 (42)	
Chocolate confectionery	10.7 (74)	8.6 (70)	11.4 (76)	12.3 (76)	5 (53)	6.9 (63)	11.6 (68)	
DRINKS								
Fruit juice	36.9 (36)	37.0 (34)	40.2 (37)	32.7 (36)	58 (52)	(38)	64.2 (44)	
Diet soft drinks	115.7 (49)	100.6 (41)	118.2 (52)	127.0 (52)	202 (62)		321.5 (75)	
Other soft drinks	256.1 (86)	228.3 (80)	262.1 (88)	282.5 (90)	58 (42)		128.5 (59)	
Coffee	6.1 (7)	4.3 (6)	7.7 (8)	6.8 (8)				
Tea	37.0 (37)	41.0 (38)	34.2 (36)	34.8 (38)	196 (83)		23.1 (25)	
Tap water	302.9 (92)	331.9 (92)	290.1 (90)	280.9 (94)				
Commercial infant foods	1.9 (4)	2.0 (4)	1.1 (3)	0.3 (2)				
Commercial infant drinks	3.6 (2)	12.2 (8)	3.9 (2)					

1 These data are for the whole sample and therefore represent average intakes for all children of this age, but do not reflect how much consumers might have. These data were used as they were consistent across the three data sets.

2 These data have been calculated from data for consumers only and percentage of consumers as presented in the report of the NDNS of children aged 1½-4½ years.

3 Includes baked beans.

Sources: NDNS: Gregory et al (1995); rolling NDNS: Department of Health (2011); ALSPAC: Emmett et al (2002).

Cereals and cereal products

The majority of children consume some form of bread and breakfast cereal. Data from the rolling NDNS 2011 suggest that the average consumption of cereals has risen, largely as a result of a greater proportion of children consuming pasta, rice and other cereals.

The Department of Health does not provide any specific guidance on the amount of cereals children should consume, but it is recommended that a mixture of wholegrain and non-wholegrain foods are provided, as too much fibre may reduce the amount of minerals such as iron and calcium absorbed from meals.

Across all the surveys, the vast majority of children consumed white bread during the survey periods, with less than one-third of children typically having wholemeal bread. About two-thirds of children ate wholegrain or high-fibre breakfast cereals.

Cereal and grain products in the form of high-fat, high-sugar products – such as biscuits, buns, cakes and pastries – are also widely consumed by young children, with approximately 85% of children across all surveys having consumed biscuits during the survey periods. However, results from the rolling NDNS 2011 suggest that a smaller proportion of children are eating these products and in smaller quantities than during the NDNS 1995 survey periods.

Milk and milk products and eggs

While the majority of children across all surveys drank whole milk during the study periods, the rolling NDNS 2011 suggests that both the percentage of children drinking whole milk and the average amount consumed has diminished since the NDNS 1995. This has coincided with an increase in both the number of children drinking semi-skimmed and other types of milk and the average amount consumed. The 'other types of milk' category includes evaporated milk, canned milk and milk shakes, and also soya milk, goat's milk and sheep's milk.

The Departments of Health in the UK consistently recommend that children under 2 years of age should continue to drink whole milk, but that after the age of 2 children can move to semi-skimmed milk if they are eating well. Skimmed milk is not recommended for under-5s, to ensure they get sufficient energy and nutrients. In keeping with this recommendation, results from the NDNS 1995 suggest that, as children move up the age bands, both the number of children drinking full-fat milk and the average amount consumed diminish, while the proportion of children drinking semi-skimmed milk and the amount consumed increase. However, results from all surveys indicate that a small proportion of children aged less than 2 years of age may be drinking semi-skimmed and skimmed milk.

The most notable increases in dairy consumption between 1995 and 2011 are in the amounts and proportion of children consuming other types of milk, and yoghurt and fromage frais. Average consumption of eggs across surveys was less

than 10g per day, equivalent to about 1 egg per week on average, and across all surveys less than half of the children reported having eaten eggs in the study period. Cheese consumption recorded as a discrete item also remains low (less than 10g per day) with only 57%-67% having eaten cheese during the study periods. However, it is likely that cheese is more frequently consumed as part of dishes such as pizza.

Meat and meat products

Children in all of the surveys, with the exception of ALSPAC participants aged 43 months, consumed more processed meat than either red or white meat during the study period. The most commonly consumed products from each meat category were beef and veal and dishes, chicken and turkey and dishes, and sausages.

The rolling NDNS 2011 suggests that overall since 1995 there has been an increase in the total amount of meat consumed, largely as a result of increased consumption of chicken and turkey dishes and coated chicken products, but that those eating beef and veal and dishes may have slightly decreased. The rolling NDNS 2011 survey results suggest that fewer children are consuming burgers and kebabs and other processed meat than in previous years. About one-quarter of children participating in the NDNS 1995 ate burgers and kebabs, while the rolling NDNS 2011 survey results suggest that this has dropped to less than 10% and is more consistent with the results from the ALSPAC survey. However, the rolling NDNS sample is small, and caution needs to be taken when reviewing potential dietary shifts when comparing data from studies.

Fish

Approximately 40% of children consumed coated and fried white fish throughout the period 1995-2011. Significantly smaller proportions of children consumed other white fish dishes and oily fish. The average amount of all fish consumed increased from about 10g per day in 1995 to 15g per day in 2011. This is mainly due to more children eating greater quantities of other white fish which includes fish pie, fish curry, poached fish and kedgeree, than to increases in coated white fish (fish fingers, etc).

While the average amount of oily fish consumed does appear to have increased, there has been a reduction in the proportion of children consuming oily fish, from around 16% in the NDNS 1995 to 10% in the rolling NDNS 2011. However, this result must be viewed with caution because between the NDNS 1995 and the rolling NDNS 2011, canned tuna was re-classified from 'oily fish' to 'other white fish and canned tuna'.

Fruit and vegetables

The health benefits of increasing fruit and vegetable consumption have been widely publicised. For most of the period 1995-2011 covered by the surveys, the Departments of Health in the UK did not specify how much fruit and vegetables children under 5 should consume per day, but it is generally recommended in new guidance for this age group that 200g a day or more is appropriate (School Food Trust, 2011).

While fruit and vegetable consumption appears to have increased between the NDNS 1995 and rolling NDNS 2011, this change may well be for the most part a result of methodology changes to how the amount is counted, and most children have not yet achieved intakes of 200g a day even with this change.

Reported fruit and vegetable consumption in the NDNS 1995 was very low, with mean total intakes of 50g of fruit and 27g of vegetables. More than half the children in the survey did not eat any individual fruit or vegetables in the survey period and where fruit and vegetables were consumed, peas, baked beans, carrots, bananas, apples and pears were those most likely to be consumed. Conversely, the majority of children (over 70%) in the surveys consumed potatoes, particularly chips, potato products and other potatoes. The rolling NDNS 2011 suggests the number of children consuming chips and savoury snacks, as well as the average amount consumed, have reduced, while more children are now eating more fruit and vegetables. This survey measures both individual fruit and vegetables and those contained in other dishes (eg. meat dishes, pizza, and pasta dishes) and this automatically increases the number of consumers and amounts consumed, and comparison between surveys is therefore more difficult. Average consumption has risen to 102g of fruit and 54g of vegetables per day, with 92% of children consuming some fruit.

Sugar, preserves and confectionery

Results from the rolling NDNS 2011 suggest that both the number of children consuming sweets and chocolate and the amount consumed are diminishing. The amount and the number of consumers both appear to have decreased in the more recent study, but in all studies intake increases with age.

Beverages

There is no consistency between surveys concerning the most commonly consumed drinks. However, it is clear that most children consume soft drinks. The average amount of soft drinks consumed is similar to the average amount of milk consumed.

The rolling NDNS 2011 suggests that the proportion of children drinking fruit juice and the amount they drink have risen, while the balance between diet soft drinks and other soft drinks is shifting in favour of diet soft drinks. While it seems that the vast majority of children drink some tap water, results from the NDNS 1995 and rolling NDNS 2011 are not comparable because in the rolling NDNS 2011 coffee, tea and tap water are combined into the same category.

4.2 Do the diets of children under 5 meet current energy and nutrient recommendations?

In the UK, the nutritional adequacy of children's diets can be assessed by comparing them with national dietary reference values (Department of Health, 1991) and guidance on other nutrients subsequently published by the Scientific Advisory Committee on Nutrition (SACN, 2011).

EAR, RNI and LRNI

The estimated average requirement (EAR) of energy or a nutrient represents average energy requirements or a level of intake of a given nutrient that would meet the needs of about half of the population. The reference nutrient intake (RNI) would be sufficient for the vast majority (97.5%) of the population, and the lower reference nutrient intake (LRNI) would be sufficient for only a very small proportion of the population (2.5%).

Energy

Children require energy (calories) for growth and development as well as to function normally and be active. Individual energy requirements differ according to body size and levels of physical activity. Regular intakes of energy higher than that required each day for growth and activity are likely to lead to fat deposition and obesity, while low energy intakes may lead to poor growth and development and other health problems. While energy needs differ between individuals, population average requirements for different age groups have recently been reassessed for children under the age of 5 years in the UK, and new values were published by SACN in 2011 based on more relevant data on heights, weights and basal metabolic rate, which are thought to be a better reflection of the needs of this age group (Scientific Advisory Committee on Nutrition, 2011). The new average energy requirement values represent a reduction in average energy requirement compared to previous values used when the studies discussed here were published.

Previously, it was typically found that energy intakes reported in dietary surveys for children were significantly lower than those recommended, despite rising rates of obesity among children at all ages (School Food Trust, 2011). However, the newly derived energy requirement figures for children under the age of 5 years given in Table 14 show that typical average energy intakes are actually slightly higher than the new requirement figures, with children aged 18 months in the ALSPAC survey typically having 129% of current energy requirements. The new, most up-to-date data from the rolling NDNS data for boys and girls aged 1½-3 years show that average energy intakes are slightly above current recommendations, but that there is considerable variation, with those in the bottom 2.5 percentile having 65% of energy requirements and those in the top 2.5 percentile having almost 170% of energy requirements. New energy requirement figures therefore appear a better fit to current behaviour. However, it is difficult to compare energy intakes over time as the age and gender mixes of population groups measured varies, but it could be suggested that there is some reduction in observed energy intakes between 1995 and the rolling NDNS data published in 2011.

TABLE 14: Energy intake among 1½-4½ year olds, compared with SACN recommendations for energy

Survey/cohort	Energy requirement ¹	Energy intake					
		Mean intake		Lower 2.5 percentile		Upper 2.5 percentile	
	MJ/day	MJ/day	as % of EAR	MJ/day	as % of EAR	MJ/day	as % of EAR
NDNS / 1½-2½ years	3.975	4.393	111%	2.634	60%	6.596	166%
NDNS / 2½-3½ years	4.765	4.882	103%	2.596	55%	6.991	147%
NDNS / 3½-4½ years – boys	5.675	5.356	95%	3.349	59%	8.085	142%
NDNS / 3½-4½ years – girls	5.25	4.976	95%	3.207	61%	7.372	140%
Rolling NDNS / 1½-3 years ²	4.17	4.710	113%	2.710	65%	7.020	168%
ALSPAC / 18 months – boys	3.7	4.765	129%	-	-	-	-
ALSPAC / 18 months – girls	3.45	4.441	129%	-	-	-	-
ALSPAC / 43 months – boys	5.35	5.809	109%	-	-	-	-
ALSPAC / 43 months – girls	4.95	5.492	111%	-	-	-	-

NDNS National Diet and Nutrition Survey 1995

Rolling NDNS Rolling National Diet and Nutrition Survey, 2008-2011

ALSPAC Avon Longitudinal Study of Parents and Children: 18 months data 1994; 43 months data 1996

1 The data have been adapted where necessary to be an average by age and gender and are taken from average population data.

2 Based on average intake of boys and girls at 1½, 2 and 3 years.

Sources:

Energy requirement figures: Adapted from Scientific Advisory Committee on Nutrition (2011).

Energy intake data: NDNS: Gregory et al (1995); rolling NDNS: Department of Health (2011); ALSPAC: Emmett et al (2002).

Regardless of the accuracy of energy intake data and energy requirement calculations however, the proportion of energy provided from different food sources can be reviewed across studies and over time.

Food sources of energy

Across both the NDNS 1995 and the rolling NDNS 2011, children derived around 30% of their energy from cereals and cereal products (see Table 16 on page 68). However, it is important to note that around one-third of this comes from foods such as biscuits and cakes rather than complex carbohydrate and starchy foods.

The proportion of milk and milk products as a source of energy appears to have increased from 23% in the NDNS 1995 to 25% in the rolling NDNS 2011. This change appears to be as a result of increases in the intake of milk products rather than from liquid milk intakes. Where data are available, it suggests that the energy contribution made by milk diminishes with age.

Vegetables, potatoes and savoury snacks contributed a further 12% and 10% to total energy in the NDNS 1995 and rolling NDNS 2011 respectively, with high-fat products such as chips and savoury snacks making a significant contribution to this category. However, the importance of savoury snacks, sugar, preserves and confectionery and non-low-calorie soft drinks to total energy diminished between 1995 and 2011, reflecting lower intakes of these foods.

Meat and meat products contributed around 10% to total energy intake across the two studies.

Macronutrients

Dietary reference values for carbohydrates and fats are often expressed as the proportion of energy that should be derived from each. In the UK, the current advice for adults and children over 5 years is to consume a diet in which about 35% of their daily energy needs are provided by fat. It has generally been suggested that the fat intake of children aged under 2 years should not be restricted, as the under-2s need foods which are energy-dense and nutrient-dense. However, evidence from a large longitudinal study of children at 18 months suggests that there is no evidence that children who get 30%-35% of their energy from fat experience delayed growth, and there is in fact evidence that diets higher in fat may be lower in some micronutrients (Rogers et al, 2002). The Caroline Walker Trust in their recommendations for diets for under-5s recommends that about 35% of energy from fat and about 50% of energy from carbohydrate are reasonable average targets for children under 5, but makes no recommendation for saturated fat since under-5s still have and need a relatively high milk consumption (Crawley, 2006).

TABLE 15: Dietary reference values for carbohydrates and fat for children under 5 years as a percentage of food energy, compared to intakes from food survey data

% energy derived from nutrients	Dietary reference values ¹	NDNS 1½-2½ years	NDNS 2½-3½ years	NDNS 3½-4½ years BOYS	NDNS 3½-4½ years GIRLS	Rolling NDNS 1½-3 years	ALSPAC 18 months	ALSPAC 43 months
Carbohydrate % energy	About 50% energy	49.9%	51.5%	52.3%	51.7%	50.6%	46.7%	49.2%
NMES % energy	Less than 11% energy	17.3%	19.3%	20.3%	19.2%	11.4%	12.3%	16.4%
Intrinsic and milk sugars % energy ²		11.5%	9.4%	8.6%	8.9%	13.4%	13.6%	9.4%
Starch % energy ²		21.2%	22.7%	23.3%	23.6%	25.8%	20.8%	23.4%
Fat % energy	About 35% energy	36.4%	35.8%	35.3%	35.5%	34.1%	38.3%	37.1%
Saturated fat % energy	(Adult recommendation) Less than 11% energy	16.9%	16%	15.4%	15.5%	14.8%	18%	16.5%
MUFA % energy	(Adult recommendation) 13% energy	11.2%	11.1%	11.1%	11.1%	11.3%	12.0%	12.1%
PUFA % energy	(Adult recommendation) 6.5% energy	4.4%	4.7%	4.8%	4.9%	4.7%	4.3%	5.2%

ALSPAC Avon Longitudinal Study of Parents and Children

MUFA Monounsaturated fatty acids

NDNS National Diet and Nutrition Survey

NMES Non-milk extrinsic sugars

PUFA Polyunsaturated fatty acids

1 Taken from *Eating Well for Under 5s in Child Care*, published by The Caroline Walker Trust (Crawley, 2006). Figures in that report were derived from the Department of Health report *Dietary Reference Values for Food Energy and Nutrients for the UK* (Department of Health, 1991) and the adult figures shown in the Table above are taken from this report.

2 For the NDNS, these figures have been calculated from total intakes in grams.

Sources: NDNS: Gregory et al (1995); rolling NDNS: Department of Health (2011); ALSPAC: Emmett et al (2002).

Carbohydrates

Children in all three studies derived around 50% of their total energy from carbohydrates (see Table 15). However, changing patterns of food consumption between 1995 and 2011 have resulted in a shift in the proportions of energy derived from different types of carbohydrates.

The main difference between the studies was in the proportions of energy derived from sugars, particularly non-milk extrinsic sugars (NMES). In the NDNS 1995, more energy was derived from sugars than from starch and, of these sugars, NMES made a greater contribution to total energy than intrinsic and milk sugars. However, while there has been little change in the total amount of carbohydrates consumed, the rolling NDNS 2011 reports that starch makes a greater contribution to energy than sugars, and that intrinsic and milk sugars make a greater contribution to total energy than NMES.

Fat

Children across all surveys derived approximately 35% of their energy from fat, with those in the younger age bands deriving slightly more energy from fat than those in older age bands (see Table 15). Across all surveys, saturated fat intakes contribute approximately 17% of total energy, which is higher than the recommended level of 11% for the general adult population, and reflects the higher milk consumption in this age group. Intakes of unsaturated fats are therefore likely to be lower than current recommendations for adults, but are in similar proportions to the recommendations.

Protein

Children require proportionally more protein in their diets than adults in order to meet the demands of growth and development, as well as for maintenance and repair of body tissues and the synthesis of enzymes. Protein intakes in children in the UK generally exceed the RNI by a considerable margin (see Figure 9 on page 70).

Food sources of macronutrients

Fat

There have been few changes in the sources of fats in children's diets over the period 1995-2011, with milk and milk products, cereals and cereal products and meat and meat products making the greatest contribution to total fat intake (see Table 16). Within these categories, liquid milk, biscuits and sausages make a significant contribution to saturated fat intakes. Vegetables, potatoes and savoury snacks also make a significant contribution to total fat intakes, with high-fat vegetable products such as chips and savoury snacks making the greatest contribution within the category to both total and saturated fat intakes.

Carbohydrates

Cereals and cereal products, particularly biscuits, are the major source of NMES across both surveys. However, the significance of milk and milk products as a source of NMES has increased substantially from 6% in the NDNS 1995 to 17% in the rolling NDNS 2011 (see Table 16). This is due to increasing consumption of sweetened yoghurt and fromage frais products: the contribution from these foods has increased the amount of energy derived from milk-product NMES from 4% to 13%. The contributions made by confectionery and non-diet soft drinks have declined as a result of diminished levels of consumption of these products, but the contribution to energy made by fruit juices has increased.

Protein

There has been little change in the proportions of protein derived from different food categories over the study periods. Milk and milk products provide about one-third of children's protein intake, with cereals and cereal products and meat and meat products each contributing just under one-quarter of protein intake.

TABLE 16: Food sources of macronutrients among children aged 1½-3½ years (data published in 1995), and 1½-3 years (data published in 2011)

Figures represent the percentage contribution of individual food product categories to macronutrients.

Food product category	Energy		Protein		Total carbohydrates		NMES		Total fat		Saturated fat	
	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011
Cereals and cereal products	29	30	23	23	38	41	23	24	19	18	18	17
Milk and milk products	23	25	35	35	14	16	6	17	31	34	41	46
Egg and egg dishes	1	1	3	2	0	0	0	0	3	3	2	2
Fat spreads and oil	3	3	0	0	0	0	-	0	9	10	7	8
Fish	2	2	4	5	1	1	0	0	2	3	1	2
Meat and meat products	10	10	21	21	3	4	0	0	16	15	13	12
Vegetables, potatoes and savoury snacks	12	10	8	8	13	12	1	3	13	11	9	5
Fruit and nuts	3	6	1	2	5	10	1	3	1	2	1	0
Sugar, preserves and confectionery	8	4	2	1	10	5	26	19	6	4	7	5
Beverages	8	4	1	1	14	7	40	28	1	0	0	0

Sources: Gregory et al (1995); Department of Health (2011).

Micronutrients

Micronutrient intakes calculated from dietary surveys are at best estimates since there is likely to be significant variation in the composition of foodstuffs as well as in how foods are stored and cooked, to add to the other estimation errors inherent in dietary survey work. The surveys do, however, allow variations across populations to be observed and consideration of the food sources of various essential nutrients.

Comparison of micronutrient intakes are made against dietary reference values for the UK (Department of Health, 1991) which are presented for children aged 1-3 years and 4-6 years. However, derived values can be calculated for the age groups 1-2 years and 3-4 years which are more appropriate for comparison with data from diary surveys. Table 17 shows the derived RNIs and LRNIs for 1-2 year olds and 3-4 year olds. The derived values for RNI for vitamin A, vitamin C, iron, zinc, calcium and sodium are taken from Crawley (2006); other derived values and all those for LRNI are made here following the same methodology as outlined in Crawley (2006). The figures for children aged 1-2 years and 1-3 years are similar and can be compared with the NDNS data for children aged 1½-2½ years and the rolling NDNS data for 1½-3 year olds.

TABLE 17: Derived RNIs and LRNIs for micronutrients for 1-4 year olds¹

Micronutrient	RNI		LRNI	
	1-2 years	3-4 years	1-2 years	3-4 years
Vitamin A µg/d	400	450	200	200
Riboflavin mg/day	0.6	0.7	0.3	0.35
Vitamin B₆ mg/d	0.7	0.8	0.5	0.6
Folate µg/d	70	85	35	43
Vitamin C mg/d	30	30	8	8
Vitamin D µg/d	7	-	-	-
Calcium mg/day	350	400	200	240
Iodine µg/day	70	85	40	45
Iron mg/day	6.9	6.5	3.7	3.5
Magnesium mg/day	85	105	50	60
Potassium mg/day	800	950	450	525
Zinc mg/day	5.0	5.8	3	3.5
Sodium mg/day ²	800	1000		

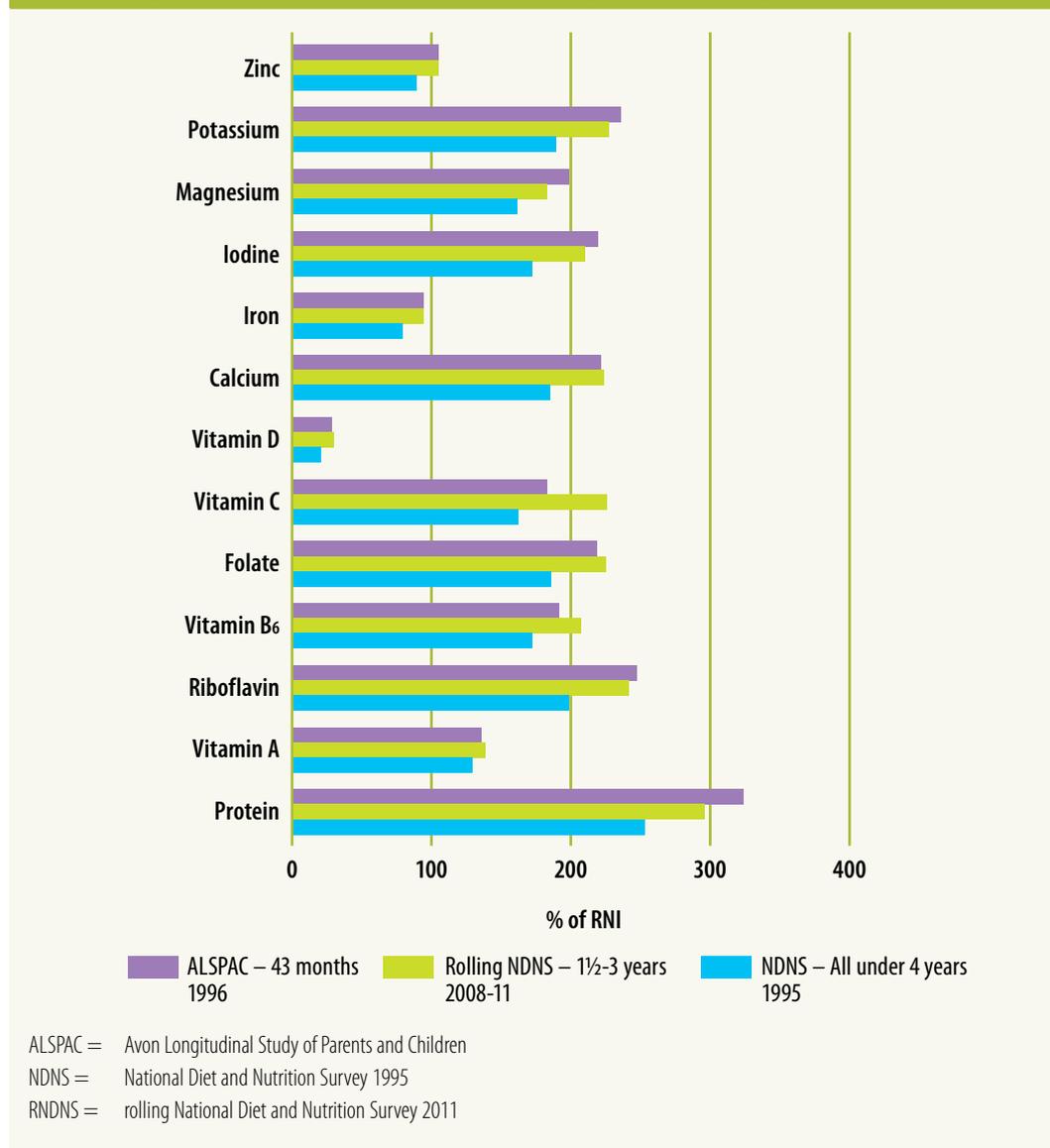
Sources:

1 Based on data from Department of Health (1991).

2 Based on data from Scientific Advisory Committee on Nutrition (2003).

Data from the NDNS and ALSPAC surveys (Cowin et al, 2000, Emmett et al, 2002) suggest that current dietary patterns provide sufficient micronutrients for the majority of young children, with average intakes of most essential nutrients in excess of the RNI (see Figure 9). The exceptions are iron and vitamin D where average intakes fall below the RNI in all studies, and zinc where average intakes fall significantly below the RNI in the 1995 NDNS study. This indicates that the diets of children aged between 1½ and 4½ years may not provide adequate amounts of these nutrients. In the case of vitamin D, dietary sources alone are not expected to provide sufficient intake, with additional vitamin D being provided through the action of summer sunlight on the skin and through vitamin supplements which remain recommended for all children aged 1-4 years in the UK.

FIGURE 9: Mean nutrient intakes for 1½-4 year olds in the UK as a percentage of RNI, from national and regional surveys



Sources: ALSPAC: Emmett et al (2002); NDNS: Gregory et al (1995); rolling NDNS: Department of Health (2011).

Average figures may, however, mask quite large differences in intakes between individuals. For example, data from the NDNS survey (Gregory et al, 1995) show that intakes of vitamin A in the highest 2.5 percentile of the population are around 10 times greater than those in the lowest 2.5 percentile, and for vitamin D they are more than 20 times greater in the highest 2.5 percentile.

The surveys show that some children have intakes of micronutrients below the LRNI, but it is difficult to directly compare cohorts of children as the age range differences will have a significant impact on average intakes.

TABLE 18: Mean intake of micronutrients and the proportion of children with food intakes of micronutrients below the RNI and LRNI									
Micronutrient	NDNS 1995					Rolling NDNS 2011		ALSPAC 2000 and 2002	
	All aged 1½-2½ years		All aged 2½-3½ years			All aged 1½-3 years		All aged 18 months	All aged 43 months
	Mean daily intake 1½-3½ years	% below RNI	% below LRNI	% below RNI	% below LRNI	Mean daily intake 1½-3 years	% below LRNI	Mean daily intake	Mean daily intake
Vitamin A µg	524	46	7	52	9	545	9	618	535
Riboflavin mg	1.2	6	0	7	0	1.44	1	1.5	1.47
Vitamin B ₆ mg	1.2	11	2	8	1	1.4	0	1.1	1.3
Folate µg	127	8	0	6	0	156	1	132	152
Vitamin C mg	48.7	40	1	38	2	67.3	1	51.3	54.4
Vitamin D µg	1.2	100	*	100	*	1.9	*	1.55	1.8
Calcium mg	649	11	1	11	1	773	1	803	768
Iron mg	5.15	90	25	86	12	6.3	8	5.4	6.3
Iodine µg	120	24	3	24	3	146	1	179	152
Magnesium mg	135	10	1	6	0	154	1	153	168
Potassium mg	1495	3	0	3	0	1807	1	1727	1877
Zinc mg	4.4	76	15	72	14	5.2	6	5.0	5.14

* No LRNI for comparison.

ALSPAC = Avon Longitudinal Study of Parents and Children

NDNS = National Diet and Nutrition Survey

Sources: NDNS 1995: Gregory et al (1995); rolling NDNS 2011: Department of Health (2011); ALSPAC: 18 month data Cowin et al (2000) and 43 month data Emmett et al (2002).

The percentage of children with intakes of nutrients below the LRNI and RNI needs to be interpreted with caution however, since the new rolling NDNS data are based on very small numbers, the age ranges vary, and there are no data available at the present time on food sources of nutrients from the rolling NDNS. It is difficult to explain why, for example, zinc intakes are now significantly higher among small children in the UK. This could be due to an increase in milk-based products such as yoghurt and fromage frais which are a source of zinc, or could potentially be due to updated analysis figures in the composition database used in this new study. The data do suggest an increase in the intakes of all micronutrients between the NDNS and the rolling NDNS and this might also be the result of increased intakes of fortified food and drink products.

A summary of the key sources of micronutrients of interest in the diets of young children in the UK is outlined in Table 19.

TABLE 19: Food sources of micronutrients for children aged 1½-4½ years

All figures are percentages.

Food group	Vitamin A	Vitamin B ₆	Riboflavin	Folate	Vitamin C	Vitamin D	Iron	Calcium	Magnesium	Potassium	Zinc	Iodine	Sodium
Cereals and cereal products	8	23	24	36	2	29	48	19	29	14	23	12	34
Milk and milk products	34	25	51	17	8	14	6	64	27	31	33	58	18
Eggs and egg dishes	3	1	2	2	0	11	3	1	1	1	2	3	2
Fat spreads and oil	9	-	0	-	-	26	0	0	0	0	0	2	3
Fish	1	2	1	1	0	10	2	1	2	2	-	8	3
Meat and meat products	20	9	8	5	2	4	14	3	7	8	25	4	19
Vegetables, potatoes and savoury snacks	17	23	3	21	19	2	14	3	15	23	9	3	12
Fruit and nuts	0	7	2	4	15	0	3	1	6	8	2	1	1
Sugar, preserves and confectionery	1	0	4	1	0	0	3	3	4	3	2	2	1
Beverages	4	9	2	8	50	0	2	2	7	8	1	4	1

Source: Gregory et al (1995).

Milk and milk products are the major provider of vitamin A, riboflavin, vitamin B₆, calcium, iodine, zinc, potassium and magnesium to the diet of children aged 1½-4½ years in the UK. Meat and meat products are an important source of zinc, iron and vitamin A.

Vitamin A

Both milk and milk products and meat and meat products are important contributors to total retinol equivalent intake in the diets of young children, and of the 20% of vitamin A from meat and meat products, 23% of this is from liver, despite the fact that only 4% of under-5s eat liver and liver products. Milk provides about a third of intakes.

Riboflavin

Milk and milk products provide over half of riboflavin intakes, the majority from liquid milk, the only other significant provider being fortified breakfast cereals.

Vitamin B₆

Milk and milk products also provide about a quarter of vitamin B₆ intakes in the diets of under-5s.

Iron

In the UK, children derive the majority of their iron (62%) from cereals and cereal products (particularly fortified breakfast cereals – 20%) and vegetables, potatoes and savoury snacks and this is mostly non-haem iron which is absorbed less effectively. Meat and meat products contribute a further 14% to iron intakes, but the 1995 NDNS reported that intakes of haem iron were on average only 0.2mg per day for children aged 1½-3½ years, about 4% of total iron intakes.

Zinc

In the UK, the 1995 NDNS reported that young children derive the majority of their zinc from milk and milk products (33%), particularly liquid milk (25%). Twenty-five per cent of zinc is obtained from meat and meat products, 23% from cereals and cereal products, and 9% from vegetables, potatoes and savoury snacks. The increased consumption of meat in the new rolling NDNS is likely to contribute to the higher average zinc intakes observed in this cohort.

Iodine

Children in the UK obtain over half of their iodine from milk and milk products. Cereals and cereal products contribute 12% to iodine intakes, and fish a further 8%. The NDNS 1995 shows that iodine intakes decreased with age, suggesting that the diets of younger children are richer in iodine than those of older children, due to their higher consumption of milk. It follows, therefore, that any reduction in consumption of milk might further compromise iodine intakes in this group and this is one of the key areas of concern around population reductions in milk intakes in the UK where there is a greater reliance on dairy products as the major source of dietary iodine.

Potassium

Milk and milk products contribute about a third of potassium intakes to the diets of 1½-3½ year olds, with the majority coming from liquid milk. Meat and meat products contribute about 8%.

Magnesium

Milk and milk products are also one of the main contributors of magnesium to the diet of under-5s, contributing just over a quarter.

4.3 Nutrient status of children in the UK

The national dietary surveys also provide data on the nutrient status of population groups, with measurements made from blood samples or urine samples taken while dietary data are collected. A smaller proportion of subjects take part in the assessments of nutrient status, and therefore figures must be viewed with some caution as they may not represent an average population. The data available for nutrient status of relevance to this report are outlined in Table 20.

TABLE 20: Proportion of children with nutritional status below commonly accepted cut-off points								
Nutrient	Marker measured	Cut-off points	NDNS 1995				Rolling NDNS 2011	ALSPAC (Data collected in 1994)
			1½-2½ years	2½-3½ years	3½-4½ years boys	3½-4½ years girls	All aged 1½-3 years	18 months
Riboflavin	EGRAC	1.0-1.3	14%	21%	29%	38%	23%	
Vitamin C	Plasma ascorbate	below 10µmol/l	5%	3%	1%	1%	3%	
Vitamin D	Plasma 25-hydroxyvitamin D	below 25nmol/l	1%	1%	-	-	1%	
Iron	Serum haemoglobin concentration	below 11g/dl	12%	6%	4%	8%	8%	17.3%
Zinc	Plasma zinc concentration	below 10µmol/l	5%	5%	5%	5%	5%	

Sources: NDNS 1995: Gregory et al (1995); rolling NDNS: Department of Health (2011); ALSPAC: Sherriff et al (1999).

Riboflavin

Although dietary intakes suggest few under-5s have intakes below the LRNI or even RNI for riboflavin, a significant number have EGRAC scores which suggest low status and this correlates to dietary intake. Under-5s who do not have milk and milk products are likely to have low intakes of riboflavin.

Vitamin D

The RNI for vitamin D is applicable only to children aged less than 4 years. Across all study groups, mean intakes of vitamin D fell far short of the RNI (see Figure 9 on page 70). Vitamin D is only found naturally in a very narrow range of foods, particularly oily fish, consumption of which is very low in the diets of pre-school children. As could be expected where food sources are very limited, the pattern of intakes of vitamin D in the NDNS 1995 and in the rolling NDNS 2011 were very skewed, with children in the upper 2.5 percentile consuming up to 50 times that of children in the lower percentile. The NDNS 1995 reported that, when variations in energy intake are taken into account, children aged 1½-2½ years have significantly higher intakes of vitamin D per 100kcal than those aged 2½-4½ years. This reflects the dietary change from infant formula and weaning foods – which are fortified with vitamin D – to a more mixed diet. Children in the UK derive the majority of their dietary vitamin D from fortified products such as breakfast cereals and fat spreads rather than from foods that naturally contain vitamin D such as such as oily fish and eggs (see Table 19 on page 72).

Very low intakes of dietary vitamin D do not necessarily imply a wide prevalence of low vitamin D status, as the majority of vitamin D is derived by the action of sunlight on the skin. In the NDNS 1995 sample, 1% of children had a plasma 25-hydroxyvitamin D concentration below 25nmol/l (see Table 20), a value that is considered to indicate deficiency (Arnaud et al, 1976). While 1% may seem low, vitamin D deficiency has been identified as being concentrated in specific population subgroups. Grindulis et al (1986) reported that, in a sample of Asian children aged 22 months born in a Birmingham maternity hospital, 40% had concentrations of plasma 25-hydroxyvitamin D concentration below 25nmol/l, indicating deficiency. Similarly, in a national survey commissioned by the Department of Health, Lawson and Thomas (1999) reported that between 20% and 34% of 2 year old Asian children were deficient in vitamin D. The most comparable value for children aged between 1½ and 2½ years in the NDNS 1995 survey was 1%.

Vitamin D is of particular importance for the calcification of bone. Children aged between 6 months and 3 years old are particularly vulnerable to vitamin D depletion due to the rate at which calcium is being sequestered for bone formation, and due to the limited access to sunlight for many children (Department of Health, 1991). The deficiency disease associated with vitamin D is rickets. Rickets among Asian children was thought to be declining in the late 1980s due to public health efforts to improve vitamin D status, but it is now considered to be re-emerging as a problem for public health (Shaw and Pal, 2002). Of 160

cases of children identified with symptomatic vitamin D deficiency at a Glasgow hospital between 2002 and 2008, three of the children were of white European origin and the remainder were from South Asian, Middle Eastern and sub-Saharan backgrounds. Furthermore, there were twice as many cases recorded in 2008 than in the previous five years (Ahmed et al, 2011). The median age of children included in that study was 24 months and the ages ranged from 2 weeks to 14 years. Ladhani et al (2004) also recorded a majority of black and Asian children among 48 children presenting at a London hospital with radiological evidence of rickets.

The Department of Health recommends that vitamin D supplements be given to all children up to the age of 3 years, and up to 5 years in those at high risk of developing vitamin D deficiency (Department of Health, 1998). However, uptake appears to be low, with some studies reporting that 25% or less of participants regularly take supplements (Gregory et al, 1995; Lawson and Thomas, 1999).

Iron

Iron deficiency anaemia is a common deficiency disease in developed countries, particularly among young children and the recent SACN report *Iron and Health* (Scientific Advisory Committee on Nutrition, 2010) stated that children aged 1½-2½ years in the UK are one of the population groups most vulnerable to iron deficiency anaemia. The most commonly used measure of iron status is serum haemoglobin. The serum haemoglobin levels of children in the NDNS and ALSPAC study groups suggest that between 4% and 18% of children could be considered anaemic using the cut-off point of less than 11g/dl recommended by the World Health Organization for the identification of anaemia (see Table 20 on page 74). The prevalence of anaemia recorded in the NDNS 1995 was highest in the youngest study groups and decreased with age. An inverse association between prevalence of anaemia and age has also been recorded in other studies (Duggan et al, 1991; Taylor et al, 2004).

It can be difficult to compare studies that have examined the prevalence of iron deficiency anaemia, because different cut-offs have been used and the characteristics of the samples differed. However, it is apparent that some population groups are at greater risk of anaemia than others. Irrespective of the cut-off points used, studies examining serum haemoglobin levels in pre-school children, both before and since the NDNS, have found that greater proportions of children of Asian origin than children of either white European or other racial origins have serum haemoglobin levels below the cut-off point, implying that Asian children are at greater risk of anaemia (Ehrhardt, 1986; Warrington and Storey, 1989; Mills, 1990; Childs et al, 1997). Early infant feeding practices such as the use of formula milks, the age of introducing complementary foods, and the type and quantity of foods given influence nutritional status in young children. Thane et al (2000) suggest that overdependence on milk, where this displaces iron-rich or iron-enhancing foods, is significantly related to low iron status in pre-school children.

Iron bioavailability

The current absorption of iron from mixed UK diets is estimated as 15%, but this relates to a diet that includes meat and fish products. The FAO/WHO make recommendations for diets with a variety of bioavailabilities, and suggest a variation from 5% to 15% bioavailability and iron requirements of 11.6mg per day to 3.9mg per day for children aged 1-3 years as the amount needed to meet differing requirements (equivalent to the UK LRNI) (WHO, 2004b). This suggests that, should the bioavailability of the diet be reduced, higher amounts of iron might be needed to ensure sufficient is absorbed. It is not yet known how this might work in practice in a UK population since much is still unknown about iron metabolism (Scientific Advisory Committee on Nutrition, 2010). It could be estimated that diets with reduced meat and fish content might be less bioavailable and, following FAO/WHO estimates, if this were reduced to 12% or 10%, then 23% and 49% more iron might be needed from non-haem sources to compensate. Currently the UK RNI figures for iron contain a significant safety margin and the EAR figure of 5.3mg of iron per day for children aged 1-3 years may be adequate for more than 50% of the population. However, if iron became less bioavailable in diets, it is likely that intakes below the LRNI figure would be insufficient for the majority of children.

Zinc

Zinc is an essential component of over 300 enzymes, some of which are involved in maintaining cell and organ integrity and in gene transcription. It therefore plays an essential role in growth and development (WHO, 2004b). The clinical signs of severe zinc deficiency are well known and include stunting and hypogonadism and impaired immune function. However, the clinical signs of mild deficiency are less well understood and specific measures of zinc status have yet to be discovered (WHO, 2004b). It may be that children with low zinc status have compromised immune systems, for example, but this can be difficult to establish in developed countries where illnesses are swiftly treated.

The most commonly used measurement of zinc status is plasma zinc, but this is not ideal as it only fluctuates in response to severe zinc deficiency and does not appear to be correlated with dietary intake (Sharp, 2005).

There is a lack of available reference data for comparison of zinc status among UK pre-school children. However, within the few studies that compared plasma zinc in this age group, results were not dissimilar. In a group of 77 apparently healthy Canadian children aged between 1 and 5 years, the lower and upper 2.5 percentiles of plasma zinc concentration were 10.3 μ mol/l and 18.1 μ mol/l respectively (Lockitch et al, 1988). Mean plasma zinc concentration in the NDNS 1995 was 13 μ mol/l and the lower and upper 2.5 percentiles were 9.4 μ mol/l and 18.1 μ mol/l respectively. In a more recent study of a group of 13 British children aged 2 years, the mean plasma zinc concentration was 14.1 μ mol/l and ranged from 9.9 to 19.0 μ mol/l (Taylor et al, 2004). There are no clear cut-off points to determine deficiency or marginal status. However, using 11 μ mol/l as a guide to

low status, Taylor et al (2004) found that 7% of the 2 year old children in their study had low zinc status. Using the slightly lower value of 10µmol/l, the NDNS survey found that 5% of the total sample had low zinc status (see Table 20). While there remains a poor correlation between zinc status and observed dietary zinc intakes, and the effects of marginal zinc status are poorly understood and difficult to define, a degree of caution is required when determining whether or not intakes are sufficient or of public health concern. The increased intake of zinc observed in the rolling NDNS has not led to any observed change in zinc status.

Zinc bioavailability

The current absorption of zinc from mixed UK diets is estimated as about 30%, but this relates to a diet that includes animal products. The FAO/WHO make recommendations for diets with a variety of bioavailabilities from 2.4mg/day to 8.3mg/day for children aged 1-3 years (WHO, 2004b). This suggests that, should the bioavailability of the diet be reduced, higher amounts of zinc might be needed to ensure sufficient is absorbed.

Iodine

It is well known that, globally, iodine deficiency is the major cause of preventable mental impairment. The main function of iodine is in the synthesis of thyroid hormone that is required for the growth and development of organs, particularly the brain. Even mild maternal hypothyroidism can lead to intellectual and neuropsychomotor deficits (Nawoor et al, 2006). Pregnant and breastfeeding women and young infants are most susceptible to the detrimental effects of iodine deficiency. However, it has also been shown that iodine intake can influence IQ in schoolchildren (Santiago-Fernandez et al, 2004). Until quite recently, iodine status in the UK was thought to be adequate. However, evidence from recent studies has shown that, within some populations, iodine intakes are too low and that, according to WHO benchmarks, mild and moderate iodine deficiency exists at levels that are of major importance for public health (Vanderpump et al, 2011; Rayman et al, 2008). These studies are limited to girls and women of childbearing age and there are no recent data available on the iodine status of young children and other population groups in the UK. However, the NDNS 1995 reports that 24% of children aged 1½-4 years, and 46% of children aged 4-4½ years, have iodine intakes below the RNI, and 3% of children aged 1½-4 years, and 5% of children aged 4-4½ years have iodine intakes below the LRNI. More recent data from the rolling NDNS 2011 suggest that 1% of children aged 1½-3 years have iodine intakes below the LRNI but the small sample size on which these data are based should be noted.

4.4 Which foods make up a healthy diet for children?

The main principles of a healthy diet are the same for children as for adults. However, food-based dietary guidelines for children cannot simply be extrapolated from those for adults, as the nutritional demands of growth and development mean that, in proportion to their body size, children need different proportions of certain nutrients.

The national food-based dietary guidelines for Australia (NHMRC, 2010), Canada (Katamay et al, 2007) and the USA (Britten et al, 2006) are based on the results of dietary modelling exercises that address the nutritional needs of all age groups. The results provide examples of how different food groups might be combined to provide a diet for children that achieves DRVs and food-based recommendations for the prevention of chronic diseases. The amounts of different food categories recommended for children aged from 1 to 8 years of age in those countries are summarised in Table 21 on page 81.

Table 21 also includes the German dietary modelling exercise (the Optimix diet) (Kersting et al, 2005). The purpose of this exercise was to develop an optimised total diet for German children based on the concept of qualitative food-based dietary guidelines. Initially 7-day menus were developed to achieve German nutrient RNIs and paediatric preventative recommendations, while reflecting typical German family meal patterns and the food preferences of children and adolescents. Commonly available and consumed nutrient-dense, non-fortified foods were used in the modelling exercise rather than food composites. The nutrient adequacy of the derived menus was calculated and the menus adjusted iteratively until nutrient adequacy and paediatric preventative recommendations were achieved. The individual foods from the menus which met recommendations were then categorised into 11 food groups, based on their specific nutrient properties or their use in different meals. The proportions of the 11 food groups in the menus were calculated for each age group, and each food group was further sub-divided into 10 groups of recommended foods with high nutrient densities that were essential for nutrient adequacy, and an 11th group of high-fat, high-sugar foods that could also be fitted into the menus, but which are acknowledged as not essential. The 10 recommended food groups provide nutrient adequacy and 90% of energy requirements, with the remaining 10% being derived from other foods which could be described as those offering sweetness and greater variety to the diet. The food intake pattern derived therefore includes high-fat, high-sugar foods as a means by which the balance of energy might be achieved. The German mixed diet was based on a moderate level of physical activity, so diets consistent with the recommended pattern may result in energy consumption in excess of requirements for those with a sedentary level of activity. This however remains the case in all dietary modelling exercises where an average consumer has to be chosen as the basis of the model.

Within age bands, recommended amounts of foods from different food groups in the dietary models from the USA, Canada and Australia are remarkably similar, but the German Optimix diet differs. However, adjusting for differences in the presentation of the data can help to identify where there are similarities and differences between countries. Despite aiming for a slightly higher total food energy target, the Optimix diet recommends the lowest amount of meat. The quantities for fruit and vegetables initially appear to be lower than the other models. However, potatoes (starchy vegetable) and legumes are included in a separate category with pasta, and not in the fruits and vegetables category as in the other models. Adjusting for this difference diminishes the differences between quantities.

It is worth noting that there are differences between countries in how they accommodate increasing energy requirements between the ages of 3 and 4 years. The Australian model suggests that consumption of fruits, vegetables, meat and dairy foods should increase with age, whereas the Canadian model suggests that additional food energy and nutrients should come from increased consumption of fruits, vegetables and grains alone, with milk and dairy product consumption unchanged. The USA model suggests that additional nutritional requirements should be met by increased consumption of vegetables, grains and meat.

TABLE 21: Food group amounts meeting national dietary targets for energy and nutrients for children, per week: modelling exercises in four countries for children aged between 1 and 8 years

	Australia	Australia	Canada Food-based dietary guidelines	USA Food-based dietary guidelines	Australia	Canada Food-based dietary guidelines	USA Food-based dietary guidelines	Germany Optimix diet
Age	13-23 months	2-3 years	2-3 years	2-3 years	4-8 years	4-8 years	4-8 years	4-6 years
Activity level relative to Basal Metabolic Rate for estimating energy requirements	1.4	1.4	1.4	Not known	1.4	1.4	Not known	1.65-1.82
Average energy intake MJ and kcal per day	3.5MJ 837kcal	4.2MJ 1,003kcal	4.2-5.0MJ 1,050-1,200kcal	4.2MJ 1,000kcal	4.8-5.2MJ 1,146-1,242kcal	4.2-6.3MJ 1,100-1,500kcal	5.0-5.9 MJ 1,200-1,400kcal	6.1MJ 1,450kcal
	Servings Number (amount)	Servings Number (amount)	Servings Number (amount)	Servings Number (amount)	Servings Number (amount)	Servings Number (amount)	Servings Number (amount)	Servings Amount
FRUIT AND VEGETABLES								
Fruit	3½ (150g)	7 (150g)		7 x 150g equivalents	10½ (150g)		7-10½ (150g)	1,400g
Starchy vegetables	2½ (75g)	2½ (75g)		2 (160g)	3½ (75g)		3½ (160g)	
Green and brassica vegetables	3½ (75g)	3½ (75g)		½ (150g)	7 (75g)		1 (150g)	
Red and orange vegetables	3½ (75g)	3½ (75g)		2½ (150g)	7 (75g)		3 (150g)	
Legumes	1 (75g)	2 (75g)		½ (150g)	2 (75g)		½ (150g)	
Other vegetables	7 (75g)	7 (75g)		1½ (150g)	10½ (75g)		2½ (150g)	
Total vegetables	17½ servings	18½ servings		7 x 150g equivalents	30 servings		10½ x 150g equivalents	1,400g ¹
Total fruit and vegetables per week (Some guidelines give cups and amounts in ml rather than weights in g, but equivalent amounts have been shown for comparison, taking 240ml cups of fruit and vegetables as approximately equivalent to 150g.)	21 servings where 1 serving of vegetables = 75g and 1 serving of fruit = 150g Approximate weight 1,838g	25½ servings where 1 serving of vegetables = 75g and 1 serving of fruit = 150g Approximate weight 2,437g	28 serving equivalents 1 serving = 125ml fresh, frozen or canned fruit or vegetables or juices, or cooked leafy green vegetables, or 250ml raw leafy green vegetables or 1 fruit. Approximate weight 2,200g ³	14 x 150g equivalents Approximately equivalent to 26 Canadian servings of 80g portions of fresh or cooked fruit or vegetables or juice, or leafy green salad. Approximate weight 2,100g ²	40½ servings where 1 serving of fruit = 150g and 1 serving of vegetables = 75g 3,825g	35 serving equivalents 1 serving = 125ml fresh, frozen or canned fruit, vegetables, juices, cooked leafy green vegetables or 250ml raw leafy green vegetables or 1 fruit. Approximate weight 2,800g ³	17½-21 x 150g equivalents Approximately equivalent to 33-39 Canadian servings of 80g portions of fresh or cooked fruit or vegetables or leafy green salad Approximate weight 2,625-3,150g ²	2,800g

Per week	Australia	Australia	Canada Food-based dietary guidelines	USA Food-based dietary guidelines	Australia	Canada Food-based dietary guidelines	USA Food-based dietary guidelines	Germany Optimix diet
Age	13-23 months	2-3 years	2-3 years	2-3 years	4-8 years	4-8 years	4-8 years	4-6 years

CEREALS AND CEREAL PRODUCTS

Wholegrain cereals/ grains	16	19	21 serving equivalents	10½ x 28.3g equivalents	19	28 serving equivalents	17½ x 28.3g equivalents	1,190g ¹
Refined cereals/ grains	8½	9		10½ x 28.3g equivalents	9		17½ x 28.3g	
Total	24½ servings 1 serving = 40g bread or equivalents.	28 servings 1 serving = 40g bread or equivalents.	21 serving equivalents 1 serving = 125ml cooked pasta, rice or couscous, or 1 x 35g slice bread, or ½ bagel or pitta.	21 x 28.3g equivalents 28.3g equivalent = 120ml cooked pasta, rice, noodles or oatmeal; or 30g cold breakfast cereal; or ½ muffin.	28 servings 1 serving = 40g bread or equivalents.	28 serving equivalents 1 serving = 125ml cooked pasta, rice or couscous, 1 x 35g slice bread, or ½ bagel or pitta.	35 x 28.3g equivalents 28.3g equivalent = 120ml cooked pasta, rice, noodles or oatmeal; 30g cold breakfast cereal; or ½ muffin.	1,190g ¹
	Approximate weight 980g if all expressed as bread, or 735g if all expressed as cold breakfast cereal.	Approximate weight 1,120g if all expressed as bread, or 840g if all expressed as cold breakfast cereal	Approximate weight 735g if all expressed as bread, or 630g if all expressed as cold breakfast cereal.	Approximate weight 525g if all expressed as bread, or 630g if all expressed as cold breakfast cereal.	Approximate weight 1,120g if all expressed as bread, or 840g if all expressed as cold breakfast cereal.	Approximate weight 980g if all expressed as bread, or 840g if all expressed as cold breakfast cereal.	Approximate weight 875g if all expressed as bread, or 1,050g if all expressed as cold breakfast cereal.	

MEAT AND MEAT ALTERNATIVES

Red meat	3½	3½	7 serving equivalents	14 x 28.3g equivalents	5	7 serving equivalents	28 x 28.3g equivalents	280g
White meat (poultry)	3½	3½			5½			105g
Fish and seafood								105g (2-3 eggs per week)
Eggs								
Legumes								
Nuts and seeds								
Total intake per week	7 servings 1 serving = 65g red meat or equivalents.	7 servings 1 serving = 65g red meat or equivalents.	7 serving equivalents 1 serving = 75g red meat or fish; 175ml cooked legumes or tofu; 2 eggs; 30ml peanut butter; 63ml shelled nuts and seeds	14 28.3g (1 oz) equivalents 28.3g = 28.3g lean meat, poultry or fish; or 1 egg; or 60ml (dried volume) beans or tofu; or 1 tablespoon peanut butter; or 14.1g nuts or seeds.	10½ servings 1 serving = 65g red meat or equivalents.	7 serving equivalents 1 serving = 75g red meat or fish; or 175ml cooked legumes or tofu; or 2 eggs; or 30ml peanut butter; or 63ml shelled nuts and seeds	28 x 28.3g (1oz) equivalents 28.3g = 28.3g lean meat, poultry or fish; or 60ml (dried volume) beans or tofu; or 1 egg; or 1 tablespoon peanut butter; or 14.1g nuts or seeds.	490g
	Approximate weight 455g if all expressed as lean red meat	Approximate weight 455g if all expressed as lean red meat	Approximate weight 525g if all expressed as lean red meat	Approximate weight 396g if all expressed as lean red meat	Approximate weight 683g if all expressed as lean red meat	Approximate weight 525g if all expressed as lean red meat	Approximate weight 792g if all expressed as lean red meat	

Per week	Australia	Australia	Canada Food-based dietary guidelines	USA Food-based dietary guidelines	Australia	Canada Food-based dietary guidelines	USA Food-based dietary guidelines	Germany Optimix diet
Age	13-23 months	2-3 years	2-3 years	2-3 years	4-8 years	4-8 years	4-8 years	4-6 years

POTATOES AND PASTA

Potatoes/ pasta	N/A	910g ⁴						
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MILK AND MILK PRODUCTS

Total milk and milk products	8 servings 1 serving = 250ml milk or milk equivalents.	10½ servings 1 serving = 250ml milk or milk equivalents.	14 servings 1 serving = 250ml milk or soy beverage; or 175g yoghurt or kefir; or 50g hard cheese.	14 cup equivalents 1 cup = 240ml milk or yoghurt; or 42g hard cheese or 57g processed cheese.	Boys: 14 servings Girls: 11½ servings 1 serving = 250ml milk or milk equivalents.	14 servings 1 serving = 250ml milk or soy beverage, 175g yoghurt or kefir, 50g hard cheese.	17½ cup equivalents 1 cup = 240ml milk or yoghurt, 42g hard cheese or 57g processed cheese.	2,450g Where 250ml milk corresponds to 37.5g hard cheese, 75g soft cheese
	Approximate volume 2,000ml if all expressed as liquid milk	Approximate volume 2,625ml if all expressed as liquid milk	Approximate volume 3,500ml if all expressed as liquid milk	Approximate volume 3,360ml if all expressed as liquid milk	Approximate volume 3,500ml (boys), 2,875ml (girls), if all expressed as liquid milk	Approximate volume 3,500ml if all expressed as liquid milk	Approximate volume 4,200ml if all expressed as liquid milk	Approximate volume 2,525ml if all expressed as liquid milk

FATS AND HIGH-FAT, HIGH-SUGAR FOODS

Unsaturated fats and oils	3½ (10g)	3½ (10g)	210g	97g	5 (10g)	210g	129g	175g
Other high-fat, high-sugar foods				945kcal ⁵			840kcal ⁵	350g
Total fats and high-fat, high-sugar foods	35g	35g	210g		50g	210g		525g

- 1 Potatoes and legumes are included in the 'potatoes/pasta' category.
- 2 This weight is based on weights of one representative cup weight of each food category. Vegetables: corn, canned (starchy vegetables); boiled broccoli (dark green vegetables); carrot (red and orange vegetables); canned white beans (legumes); lettuce (other vegetables). Fruit: approximate weight based on average weight of a cup of each of the following fruits: raw banana, raw apple, watermelon, grapes, raw oranges, raw peaches. Data sourced from USDA National Nutrient Database for Standard Reference, Release 16 (USDA, 2004).
- 3 This has been calculated using the same proportion of fruits to vegetables as the USA example. However, as no breakdown is provided for vegetables, the average weight used for a cup of vegetables is based on the average weight of a cup of each of the vegetables used to calculate the total vegetable weight for the USA. An additional percentage has been added to allow for the difference in cup sizes between Canada and the USA.
- 4 Rice, pasta, millet and wheat are included in the 'potatoes/pasta' category.
- 5 Other discretionary foods are allowed, to bring the total calories up to the calorie limit.

The Australian and German models include comparisons of existing diets with those recommended for health (see Table 22). The comparisons indicate that children are still not consuming the recommended level of fruit, vegetables and wholegrain cereals, with the exception of younger Australian children aged 2-3 years who are consuming more than the recommended level of fruit. Levels of meat consumption are also lower than current recommendations. Milk and dairy consumption – particularly consumption of full-fat dairy products – is above recommended levels in younger Australian children and German children aged 4-6 years, and below recommended levels in older Australian children aged 4-8 years. The Australian modelled diet does not accommodate high-fat, high-sugar foods within the foundation diet for the smallest and youngest members of any age group, so it is not possible to determine how far existing consumption levels of high-fat, high-sugar foods deviate from recommended levels. The German example does, however, suggest that consumption of high-fat, high-sugar foods is far in excess of recommended levels.

TABLE 22: A comparison of children's current diets with modelled diets recommended for health

	Australia			Australia			Germany
Age	2-3 years			4-8 years			4-6 years
	Current diet (g/day)	Modelled diet (g/day)	Change (%)	Current diet (g/day)	Modelled diet (g/day)	Change (%)	Recommended change (%)
FRUIT AND VEGETABLES							
Fruit	167	150	-10%	167	225	+35%	+25%
Starchy vegetables	41	27	-34%	57	38	-34%	
Green and brassica vegetables	15	38	+153%	17	75	+341%	
Orange vegetables	14.5	38	+162%	16	75	+369%	
Legumes	5	21	+320%	5	21	+320%	
Other vegetables	29.5	75	+154%	30	94	+213%	
Total vegetables	105	199	+90%	124	303	+144%	+67%
CEREALS AND GRAINS							
Wholegrain cereals/grains	57	148	+159%	54	141	+161%	+29%
Refined cereals/grains	112	108	-4%	143	103	-28%	
Total cereals/grains	169	256	+51%	197	244	+24%	
MEAT AND OTHER SOURCES OF PROTEIN							
Red meat	25	33	+32%	27	46	+70%	
White meat (poultry)							
Fish and seafood	32	48	+50%	43	79	+84%	
Eggs							
All meat							-50%
MILK AND DAIRY PRODUCTS							
Total dairy	487	366	-25%	383	457	+19%	-10%
High/medium-fat	401	44	-89%	301	69	-77%	
Low-fat	86	322	+274%	82	388	+373%	

Source: Australia: NMHRC, 2010; Germany: Kersbergen et al, 2009

TABLE 23: Suggested direction of change required to achieve healthier diets for children, compared with recommendations for more sustainable diets for adults

Target population/criteria	Children/health			Adults/general guidance for sustainability
	Australia	Australia	Germany	
	2-3 years	4-8 years	4-6 years	
Fruit	↓	↑	↑	↑
Vegetables	↑	↑	↑	↑
Total cereals	↑	↑	↑	↑
All meat			↓	↓
Red meat	↑	↑		↓
White meat, fish, seafood and eggs	↑	↑		
Milk and milk products	↓	↑	↓	↓

These data suggest that modifying children’s diets to be more consistent with the recommended healthy eating patterns could benefit the environment in respect of reduced consumption of high-fat, high-sugar foods. However, as has previously been described for adults, it is difficult to determine what the required direction of change in meat consumption might be, due to the inclusion of eggs, nuts and seeds and seafood in combined ‘meat and other sources of protein’ categories. The Australian data suggest that children’s consumption of red meat should increase to meet recommendations, while it is suggested that, for German children, total meat consumption needs to be reduced, but it should be borne in mind that total meat consumption is currently twice the level recommended by German national food-based dietary guidelines. See Table 22.

4.5 So what is a healthy and sustainable diet for children under the age of 5?

On the basis of existing models of healthy diets for children and adults for Australia, Canada, the USA and Germany, the changes in consumption patterns suggested for achieving healthier diets do not fully align with those suggested as necessary for achieving more sustainable consumption for adults (see Table 23).

There is little doubt that consuming more plant-based foods is beneficial for health and aligns well with the general messages surrounding achieving more sustainable consumption. However, the implications of reducing intakes of animal-based foods at the population level are less clear. For children, a reduction in intakes of meat would clearly be at odds with the dietary changes required to meet existing models of healthy diets for Australian children, but reductions in current levels among German children are compatible. Some children's diets might still achieve nutritional targets while accommodating reductions in the amount of dairy products they consume, but this is not consistent across countries and age groups.

The German model is unique in that it suggests that children's diets could accommodate all of the dietary changes suggested for more sustainable consumption. The changes required to meet suggestions for a healthier diet are relative to existing diets.

Direction of change required in the UK

In the UK, it is difficult to determine the direction of change in consumption of food products that would be required to achieve recommendations on healthy eating, as food-based dietary guidelines do not explicitly prescribe what and how much of different foods children should eat. However, we do have quite comprehensive data on the contribution that different foods make to nutrient intakes and which nutrients are causes for concern in children's diets. It is therefore possible to identify where nutrient intakes may be compromised by reductions in the consumption of meat and dairy products. (See Table 24.)

TABLE 24: Contribution of milk and milk products and meat and meat products to nutrient intakes of children aged 1½-4½ years, and comparable data for adults

Nutrient	% contribution by milk and milk products					% contribution by meat and meat products				
	1½-2½ years	2½-3½ years	3½-4½ years boys	3½-4½ years girls	Adults	1½-2½ years	2½-3½ years	3½-4½ years boys	3½-4½ years girls	Adults
Total energy	26	19	16	16	10	10	10	11	11	15
Protein	38	32	28	28	16	20	22	25	24	36
Carbohydrate	16	12	9	10	6	3	3	3	3	5
Fat	35	26	22	22	14	15	16	17	17	23
Saturated fat	46	36	31	32	24	12	13	15	15	22
Vitamin A	39	32	31	30	14	23	21	12	16	28
Riboflavin	56	49	44	45	33	7	8	8	9	15
Vitamin B ₆	31	24	20	19	9	8	9	10	9	21
Folate	21	16	13	13	8	5	5	5	4	7
Vitamin D	24	10	9	7	3	3	3	4	4	22
Calcium	70	63	59	59	43	2	3	3	3	6
Iodine	64	57	53	53	38	3	4	4	4	7
Iron	9	6	5	5	1	14	14	14	15	17
Magnesium	32	26	23	23	11	6	7	8	8	12
Potassium	37	30	26	26	13	7	8	9	9	15
Zinc	38	32	28	28	17	23	25	28	27	34

Sources:
 Data for 1½-4½ year olds: Gregory et al (1995).
 Data for adults: Henderson et al (2003b).

Children derive proportionally more of their nutrients from milk and milk products and proportionally less of their nutrients from meat and meat products than adults. When considering the impact of reductions in meat and dairy products, it is therefore essential that children’s diets are considered separately from those of adults. Any reduction in consumption of meat and dairy products may compromise the dietary intakes of those nutrients that meat and dairy products supply in relatively large proportions. However, the risk is greatest where those nutrients are already in short supply or where there is evidence of low status. For children in the UK this includes vitamin A, riboflavin, vitamin B₆, folate, vitamin D, calcium, iodine, iron, magnesium, potassium and zinc.

What would a healthy and sustainable diet for children in the UK look like?

It is possible to achieve energy and nutrient intakes that meet current guidelines for health for children aged 1-4 years and which attempt to increase the number of meals based on non-meat dishes, as demonstrated by the work of The Caroline Walker Trust's CHEW project (Caroline Walker Trust, 2011). Menu plans over a period of a week were created, for diets that included meat and meat products and for diets that excluded them, to show how energy and nutrient intakes could be achieved, and the dishes were created and photographed to give a visual account of what a healthy diet looks like for children of this age group.

The amounts of meat and dairy foods in the example menu plans for children eating a mixed diet and a vegetarian diet from the CHEW project are shown in Table 25 and are compared with the German Optimix diet recommendations. From the NDNS study data it is not easy to calculate average total intakes of 'milk and milk products' or of 'meat and meat products' and so it is difficult to make comparisons with current diets. The CHEW diets were not put together to meet minimum standards for all nutrients and on average provide significantly more of most micronutrients than the dietary reference values. In order to achieve the balance of nutrients across a menu and ensure sufficient energy and nutrients without having high levels of sugar and fat, it is necessary to over-supply some micronutrients. Modelling diets to reduce milk and dairy foods and meat and meat products is currently underway to see which nutrients become compromised and where substitutions are needed to ensure dietary adequacy. Diets which meet all current food and nutrient guidance made up of foods and drinks acceptable in the UK diet for under 5s appear to require greater amounts of milk and milk products than diets calculated including sustainability criteria might suggest.

TABLE 25: A comparison of modelled diets that achieve energy and nutrient requirements for children under the age of 5 years

Food group	CHEW mixed diets/day	CHEW vegetarian diet/day	Optimix diet/day
Liquid milk	370ml	372ml	
Cheese	5.5g	12.6g	
Yoghurt/fromage frais	44g	54.6g	
Approximate milk equivalents	447g	502g	350g
Meat	31.6g-43.2g		40g
Fish	14.5g		15g

Sources:

CHEW diets: Based on two different five-day menus that offered a range of meat, fish and vegetarian options (Caroline Walker Trust, 2011).

Optimix diet: Kersting et al (2005).

KEY POINTS

- The main principles of a healthy diet are the same for children as for adults. However, food-based dietary guidelines for children cannot simply be extrapolated from those for adults, as the nutritional demands of growth and development mean that, in proportion to their body size, children need different proportions of certain nutrients.
- Current dietary patterns provide sufficient micronutrients for the majority of young children. Average intakes of most essential nutrients are in excess of the RNI, except for iron, vitamin D and zinc. Also, a proportion of children have intakes of vitamin A, iron and zinc below the LRNI.
- Milk and milk products are the major provider of vitamin A, riboflavin, vitamin B₆, calcium, iodine, zinc, potassium and magnesium to the diet of children aged 1½-4½ years in the UK. Meat and meat products are an important source of zinc, iron and vitamin A.
- Any reduction in consumption of meat and dairy products may compromise the dietary intakes of those nutrients that meat and dairy products supply in relatively large proportions. The risk is greatest where those nutrients are already in short supply or where there is evidence of low status. For children in the UK this includes vitamin A, riboflavin, vitamin B₆, folate, vitamin D, calcium, iodine, iron, magnesium, potassium and zinc.
- The iron in meat and oily fish (haem iron) is more bioavailable than the iron in other foods such as cereals and vegetables (non-haem iron). If the amount of meat and meat products in the diet is reduced, more iron would need to be consumed from non-meat sources, to allow for the lower bioavailability of non-haem iron.
- When considering the impact of reductions in meat and dairy products, it is essential that children's diets are considered separately from those of adults.

5 Conclusion



There is much debate currently about healthy and sustainable diets and this report summarises the current position and makes some observations about how this might impact on the diets of children under the age of 5.

The importance of dairy foods in the diets of children in the UK means that care needs to be taken when criteria for sustainability are applied. However, it appears that there would be less difficulty if the amount of meat and meat products in the diet were reduced, providing that sufficient iron was consumed from non-meat sources.

Further work is currently underway to look at the practical application of sustainability criteria to the diets of children to see how this can be achieved in practice. Other important areas to consider are the amount of waste in the diets of children, the acceptability of diets that are higher in meat alternatives such as beans and pulses, and the potential impact on bioavailability of nutrients among those with high needs for growth and development.

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