An overview of the role of bread in the UK diet

A. O'Connor
British Nutrition Foundation, London, UK

Summary
Despite being a staple food in the UK for centuries, bread consumption has fallen steadily over the last few decades. Average consumption now equates to only around 2–3 slices of bread a day. As well as providing energy, mainly in the form of starch, bread contains dietary fibre and a range of vitamins and minerals. The National Diet and Nutrition Survey (NDNS) of adults suggests that it still contributes more than 10% of our daily intake of protein, thiamine, niacin, folic acid, iron, zinc, copper and magnesium; one-fifth of our fibre and calcium intakes; and more than one-quarter of our manganese intake. Therefore, eating bread can help consumers to meet their daily requirements for many nutrients, including micronutrients for which there is evidence of low intake in some groups in the UK, such as zinc and calcium. This paper gives an overview of the role of bread in the UK diet, its contribution to nutrient intakes and current consumption patterns in different population groups.

Keywords: bread, consumption patterns, national diet and nutrition survey, NDNS, nutrients, UK diet

Introduction
Bread has been a staple food of the UK population for centuries, but over the past few decades, consumption has fallen. Prior to the discovery of fermentation attributed to the Egyptians (about 2600 BC), ground cereal was most likely used for making unleavened cakes (i.e. contain no leavening agents such as yeast or baking powder, which put air into the dough mixture, thereby increasing the volume of bread and cakes). Bread was a significant constituent of the diet of Greeks and Romans, and over time, wheat became established as the main cereal crop of Southern Europe (DHSS 1981). In the UK, oats, rye and barley were traditionally grown in the north and wheat in the south and east of the country (because of the temperate climate in these regions of England). Individuals from higher social classes and those living in the south and east of the country consumed wheaten bread. White bread is made from white flour that usually contains 70–72% of the whole wheat grain, but the majority of the bran and wheat germ have been removed. White bread was more expensive than the darker breads such as wholemeal bread, made from 100% of the whole wheat grain, and consumed only by those who could afford it until the mid-18th century. During the Second World War, food policy was put in place to ensure an adequate supply of bread, and to do so, without rationing. One way this was achieved was by raising the minimum extraction rate (i.e. the yield of flour obtained from a grain in the milling process). The sale of white bread was banned and ‘high extraction’ or brown bread (contains 85% of the whole wheat grain) became the staple bread. Since 1942, all UK wheat flour except wholemeal flour has been fortified with calcium carbonate (to provide...
Bread consumption in the UK

To assess food consumption, nutrient intakes and nutritional status among the UK population, nutrition surveys, specifically the National Diet and Nutrition Surveys (NDNS) are carried out. The most recent data from the NDNS, which is a continuous cross-sectional survey of the general population aged 18 months upwards in the UK, come from the second annual report of a rolling programme. This combines data from two 1-year periods 2008/2009 and 2009/2010 (Bates et al. 2011a) to achieve a larger sample size. However, the relatively small sample size even after 2 years limits the range of analyses compared with the previous NDNS surveys (e.g. contribution of foods to vitamin and mineral intake).

The most recent NDNS data show that the average intake of bread (all types) among UK adults was approximately 87 g/day (Bates et al. 2011a). This corresponds to about 2.5 medium slices (average weight of 90 g) of a large loaf of white bread. White bread is the most commonly consumed bread (around 60%) in the UK population, although the average amount consumed was lower as a proportion of total bread intake than levels reported 10 years ago in the 2000/2001 NDNS. Women tend to consume slightly less bread, particularly white bread, compared with men (see Table 1a for intake of white and wholemeal bread in UK adults and Table 1b for intake of white and wholemeal bread in UK children).

White bread is also most popular with children (Table 1b), although intake has fallen among 4–18 year olds compared with that of 1997. For example, boys in this age group consumed about half a slice less of white bread per day, compared with that of 13 years ago, which equates to around 3–4 slices less of white bread per week. In contrast, wholemeal bread intake has risen very slightly in those aged 4–10 years.

While the rolling programme separates intakes of brown, granary and wheat germ bread from other breads (i.e. bread made from non-wheat flour), the previous survey in adults (2000/2001) and children (1997) grouped brown, granary, wheat germ and other breads together; thus, a direct comparison cannot be made to determine changes in consumption of these specific types. The findings of both studies are therefore presented separately in Table 2a and 2b. The average intake of brown, granary and wheat germ bread was higher in men and boys compared with women and girls in the recent NDNS survey.

Market research data has also found white bread to be most popular among UK consumers (see Fig. 1). For example, Kantar data reported white bread to make up around 50% of total bread intake, although differences were reported by age (Fig. 1). White bread is consumed more often by young males and females aged 16–24 years. In contrast, brown bread is eaten more often than white bread in older adults (45–65 years of age and over). White bread, particularly ‘white plus’ (i.e. bread made from half brown and half white flour or white bread plus

1At the time of writing this paper data from year 3 (2010/2011 period) was not available. Hence, the combined data from years 1 and 2 were used in this review paper.
added germ), is consumed more frequently by children (Fig. 1) (Kantar WorldPanel 2011). These market research data categorise bread in a different manner to the NDNS data (e.g. the Kantar data have a total seeded category that includes seeded/granary breads, whereas the NDNS data group granary bread with brown bread and wheat germ bread), therefore comparison of the findings are difficult. Different methods of data collection are also likely to have impacted on the different findings of these surveys and probably explain the minor discrepancy in the proportion of white bread consumed.

**Bread consumption among low-income earners in the UK**

The Low Income Diet and Nutrition Survey (LIDNS) is used to assess the dietary habits and nutritional status of low-income/materially deprived consumers in the UK (Nelson et al. 2007). This survey, of the 15% most deprived households in the population, found average bread consumption to be 82 g/day for adults (Table 3a) and 67 g/day for children (Table 3b), corresponding to about 2 and 1.5 medium slices of a large loaf of white bread, respectively. Thus, total bread intake is lower than reported for the general UK population who consumed more bread (82 g/day vs. 87 g/day) (see the section on Bread consumption in the UK). However, as observed for the general population, white bread is the most popular type with both children (90%) and adults (83%) in low-income families (Nelson et al. 2007) and women and girls tend to have a lower bread intake than men and boys (Table 3a,b).

Comparison of results from the NDNS (2000/2001) with the LIDNS show that low-income groups tend to consume less wholemeal bread (Nelson et al. 2007). This has also been supported by findings from Kantar WorldPanel (2011) market research. Recent data collected in households over a 4-year period have shown that those in the lowest social classes (D and E) eat a higher proportion of white bread (Fig. 2). Furthermore, these groups had the highest frequency of bread consumption (11 bread eating occasions, on average, in a 2-week period compared with an average of 9 in the higher social groups) (Fig. 3) (Kantar WorldPanel 2011).

### Table 1a Intake of white and wholemeal bread (g/day) in UK adults (19–64 years) in 2000/2001* compared with years 1 and 2 combined (2008/2009–2009/2010), by gender (Bates et al. 2011a)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>White bread</td>
<td>82 ± 69</td>
<td>51 ± 47</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>19 ± 41</td>
<td>14 ± 26</td>
</tr>
</tbody>
</table>

*Data from the NDNS 2000/01 were reanalysed by Bates et al. (2011a) based on 4 days instead of the original 7 days in order to make it comparable with the new NDNS data.

NDNS, National Diet and Nutrition Survey.

### Table 1b Intake of white and wholemeal bread (g/day) in UK children in 1997* compared with years 1 and 2 combined (2008/2009–2009/2010), by gender and age (Bates et al. 2011a)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>4–10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>59 ± 43</td>
<td>49 ± 34</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>7 ± 18</td>
<td>7 ± 18</td>
</tr>
<tr>
<td>11–18 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>79 ± 59</td>
<td>60 ± 43</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>7 ± 22</td>
<td>6 ± 17</td>
</tr>
</tbody>
</table>

*Data from the NDNS 2000/01 were reanalysed by Bates et al. (2011a) based on 4 days instead of the original 7 days in order to make it comparable with the new NDNS data.

NDNS, National Diet and Nutrition Survey.
Trends in bread consumption over time

Data from the Expenditure and Food Survey by the Department for Environment, Food and Rural Affairs (DEFRA) between the years 2000 and 2010 show that purchases of white bread per week have decreased during this time, on average, by 39% per person, while brown and wholemeal bread purchases have increased slightly, on average, by 1.2% (DEFRA 2010). Weekly purchases of other breads (including continental and speciality breads) increased, on average, by 17% per person during this period (DEFRA 2010). Consumption of bread and sandwiches eaten outside of the home fell by 19%, on average, per person between the years 2000 and 2010 (DEFRA 2011). Older data from the National Food Survey database suggest that the purchase of bread in households in Great Britain has continuously decreased over the past few decades, with purchases in 1996 [27 ounces (765g)/person/week] being more than half of the level recorded in 1942 [61 ounces (1729g)/person/week] (see Fig. 4) (DEFRA 2000). Possible reasons why bread consumption has fallen (e.g. lifestyle

Table 2a Intake of brown, granary, wheat germ bread and other breads (g/day) in UK adults in the NDNS (years 1 and 2 combined, 2008/2009 and 2009/2010) and intake of brown, granary, wheat germ bread and other bread combined (g/day) in UK adults (19–64 years) in 2000/2001 (Bates et al. 2011b)*

<table>
<thead>
<tr>
<th>NDNS rolling programme year 1 (2008/09–2009/10)</th>
<th>Men</th>
<th>Women</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown bread, granary and wheat germ bread</td>
<td>14 ± 29</td>
<td>12 ± 22</td>
<td>13 ± 25</td>
</tr>
<tr>
<td>Other breads†</td>
<td>3 ± 13</td>
<td>4 ± 11</td>
<td>4 ± 12</td>
</tr>
<tr>
<td>2000/2001 NDNS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown bread, granary and wheat germ bread, other breads†</td>
<td>22 ± 40</td>
<td>16 ± 28</td>
<td>19 ± 34</td>
</tr>
</tbody>
</table>

*Data from the NDNS 2000/01 were reanalysed by Bates et al. (2011a) based on 4 days instead of the original 7 days in order to make it comparable with the new NDNS data.
†Breads made with non-wheat flour: sliced, unsliced, toasted and fried. Includes rye bread, gluten free, oatmeal bread, besan flour chappatis, soya and linseed bread. NDNS, National Diet and Nutrition Survey.

Table 2b Intake of brown, granary, wheat germ bread and other breads (g/day) in UK children in the NDNS (years 1 and 2 combined, 2008/09 and 2009/10) and intake of brown, granary, wheat germ bread and other bread combined (g/day) in UK children in 1997*

<table>
<thead>
<tr>
<th>NDNS rolling programme year 1 (2008/09–2009/10)</th>
<th>Boys</th>
<th>Girls</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>4–10 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown bread, granary and wheat germ bread</td>
<td>17 ± 30</td>
<td>10 ± 21</td>
<td>13 ± 25</td>
</tr>
<tr>
<td>Other breads†</td>
<td>3 ± 13</td>
<td>3 ± 9</td>
<td>3 ± 11</td>
</tr>
<tr>
<td>11–18 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown bread, granary and wheat germ bread</td>
<td>12 ± 26</td>
<td>11 ± 21</td>
<td>11 ± 23</td>
</tr>
<tr>
<td>Other breads†</td>
<td>3 ± 13</td>
<td>3 ± 10</td>
<td>3 ± 11</td>
</tr>
<tr>
<td>1997 NDNS young people</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4–10 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown bread, granary and wheat germ bread, other breads</td>
<td>6 ± 16</td>
<td>6 ± 14</td>
<td>6 ± 15</td>
</tr>
<tr>
<td>11–18 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown bread, granary and wheat germ bread, other breads</td>
<td>11 ± 25</td>
<td>10 ± 20</td>
<td>11 ± 22</td>
</tr>
</tbody>
</table>

*Data from the NDNS 2000/01 were reanalysed by Bates et al. (2011a) based on 4 days instead of the original 7 days in order to make it comparable with the new NDNS data.
†Breads made with non-wheat flour: sliced, unsliced, toasted and fried. Includes rye bread, gluten free, oatmeal bread, besan flour chappatis, soya and linseed bread. NDNS, National Diet and Nutrition Survey.
changes and consumer perceptions about bread) will be discussed in a paper to be published in Nutrition Bulletin in due course.

Nutrient content of bread

Cereals are the edible seeds or grains of the grass family, Gramineae, and some common types include wheat, rye, oats, barley and rice. Products derived from cereals include breads, breakfast cereals, biscuits, cakes and pastries, and dried products such as pasta. Although the structure of cereal grains differs, there are some typical features – the germ, the endosperm and the bran layer, which vary in nutrient content. The ‘endosperm’ (the largest component of the grain kernel) is composed of starchy carbohydrate (the main component), protein, vitamins and minerals; the ‘bran’ is composed of fibre (the main component) and phenolic compounds such as ferulic acid, vitamins and minerals; and the ‘germ’ is composed of vitamins, minerals, fats and some protein (Okarter & Liu 2010). Bread makes a valuable contribution to micronutrient and fibre intake and also contributes some protein. Many factors affect the nutrient

Table 3a Intake of white bread, wholemeal bread and other breads (g/day) in UK adults in the LIDNS in 2007 (Nelson et al. 2007)

<table>
<thead>
<tr>
<th>LIDNS (2007)</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>19–34 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>67 ± 53</td>
<td>47 ± 36</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>9 ± 25</td>
<td>9 ± 22</td>
</tr>
<tr>
<td>Other breads</td>
<td>24 ± 48</td>
<td>10 ± 23</td>
</tr>
<tr>
<td>35–49 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>82 ± 70</td>
<td>48 ± 39</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>20 ± 39</td>
<td>10 ± 26</td>
</tr>
<tr>
<td>Other breads</td>
<td>13 ± 28</td>
<td>13 ± 24</td>
</tr>
<tr>
<td>50–64 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>84 ± 75</td>
<td>47 ± 43</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>17 ± 42</td>
<td>19 ± 35</td>
</tr>
<tr>
<td>Other breads</td>
<td>9 ± 26</td>
<td>11 ± 23</td>
</tr>
</tbody>
</table>

*LIDNS, Low Income Diet and Nutrition Survey.

Table 3b Intake of white bread, wholemeal bread and other breads (g/day) in UK children in the LIDNS in 2007 (Nelson et al. 2007)

<table>
<thead>
<tr>
<th>LIDNS (2007)</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>2–10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>49 ± 38</td>
<td>45 ± 34</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>7 ± 21</td>
<td>3 ± 10</td>
</tr>
<tr>
<td>Other breads</td>
<td>7 ± 16</td>
<td>8 ± 17</td>
</tr>
<tr>
<td>11–18 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bread</td>
<td>71 ± 55</td>
<td>56 ± 38</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>8 ± 27</td>
<td>5 ± 15</td>
</tr>
<tr>
<td>Other breads</td>
<td>8 ± 19</td>
<td>9 ± 16</td>
</tr>
</tbody>
</table>

*LIDNS, Low Income Diet and Nutrition Survey.
content of bread such as milling, the bread-making process and the cooking method.

**Restoration of nutrients lost during milling**

Nutrients can be lost during the milling process (*e.g.* in the production of white flour), the amount being dependent on the quantity of bran and germ removed. However, the food industry in the UK is required by law, under the *UK Bread and Flour Regulations* (FLR) 1998, to restore nutrients lost through milling. The FLR stipulates the amount of iron (\(\geq 1.65 \text{ mg/100 g of flour}\)), calcium (235–390 mg/100 g of flour, except self-raising flour that contains \(\leq 200 \text{ mg of calcium/100 g of flour}\)), thiamine (\(\geq 1.24 \text{ mg/100 g of flour}\)) and niacin (\(\geq 1.60 \text{ mg/100 g of flour}\)) that must be added to all white and brown flour (the requirement does not apply to wholemeal flour). These requirements were introduced in order to restore the nutrients lost during the milling process to the levels present in unrefined (wholemeal) flours. This ensures that white flour (where the outer bran and inner germ layers are removed) and brown flour contain similar levels of these nutrients to wholegrain flour (*i.e.* contains endosperm, germ and bran). The addition of thiamine, niacin and iron is also mandatory in a number of other developed countries (*e.g.* in the USA). In some countries, calcium and folic acid are also added (*e.g.* in the UK).
USA, the Food and Drug Administration mandated folic acid fortification of grain products in 1998 and many other countries, except European countries have followed this course of action).

In the 1980s, a review of the nutritional aspects of bread and flour was carried out by government advisory committees in the UK (DHSS 1981). The report recommended that the addition of vitamins and minerals should no longer be mandatory, on the basis that dietary intake of these nutrients was adequate (and in the case of iron, the fortificant was poorly absorbed) as shown by dietary survey evidence available at that time. This recommendation has not however been implemented. In 1998, the COMA Nutrition and Bone Health Report recommended that calcium fortification of bread should be retained (DH 1998). A further report was published in June 2012 using the most recent NDNS data to model the impact of removal of these nutrients from flour on nutrient intakes in the UK population (SACN 2012a). The Scientific Advisory Committee on Nutrition (SACN) report found that repealing the UK Bread and Flour Regulations would decrease intakes of thiamine, niacin, calcium and iron, and subsequently lead to an increase in the proportion of the population with intakes below the Lower Reference Nutrient Intake (LRNI)* (especially low socio-economic groups). The report noted that the evidence for maintaining the current regulation is strongest for calcium followed by iron, and weakest for the mandatory addition of the aforementioned B-vitamins (see the section on Nutrient content of bread and possible health effects of the nutrients bread provides). DEFRA is currently reviewing the need for these regulations and will be producing a report for public consultation later this year.

Energy and macronutrients

With an energy content of around 2.2 kcal (9.2 kJ)/g, bread is considered a ‘medium’ calorie food from an energy density perspective (Rolls 2005). Most of the energy in bread comes from starch; therefore, bread is generally classified as a ‘starchy food’. A medium slice of white bread typically provides 86 kcal (361 kJ). This can increase with the addition of spreads high in fat and/or sugar [e.g. a medium slice of white bread with butter provides 160 kcal (672 kJ)], while a medium slice of white bread with marmalade provides 123 kcal (516 kJ)] or fillings with a high fat content, such as mayonnaise [e.g. a medium slice of white bread with mayonnaise provides 189 kcal (794 kJ)]. Continental breads (such as focaccia) contain oils (usually olive oil; rich in monounsaturated fatty acids) that increase the calorie content, with a 50 g serving of focaccia containing, on average, 180 kcal (756 kJ). An average slice of ciabatta (around 45 g) contains, on average, 116 kcal (487 KJ).

The wheat grain contains a relatively small amount of fat, the greatest concentration of which is located in the embryonic grain (the part of the grain that becomes a new plant when fertilised by pollen). Wholemeal (2.2 g/100 g) and brown flours (2 g/100 g) therefore contain slightly more fat than white flour (1.2 g/100 g). Although white and brown flour provide a similar profile of saturated (e.g. palmitic acid), monounsaturated (e.g. oleic acid) and polyunsaturated fatty acids (e.g. linoleic acid), the specific flours differ in their fatty acid concentration, with wholemeal flour providing the greatest proportion of fatty acids. Wholemeal flour provides 0.25 g of palmitic acid, 0.01 g of stearic acid, 0.01 g of arachidic acid, 0.21 g of oleic acid, and 0.83 g and 0.06 g of the essential fatty acids linoleic and α-linolenic acid, respectively, per 100 g. The amount of fat/100 g bread is small (Table 4). However, the addition of fat during the bread-making process or in meal preparation can increase the fat content. Bread also contains considerable amounts of protein and carbohydrate (Table 4).

Dietary fibre

Dietary fibre in wheat is mainly derived from the cell wall polymer, with around 75% located in the bran and around 25% in the endosperm (Shewry 2009). The amount of fibre in the bread depends on the flour used to make it. For example, wholemeal bread provides more fibre than white, brown, granary and wheat germ bread as it is made with the whole wheat grain (see Table 4). Although all types of bread provide fibre, the inclusion of wholegrain/wholemeal or granary varieties in the diet will increase dietary fibre intakes, as well as eating other sources of dietary fibre, such as cereal products, vegetables and potatoes. The fibre content of various types of bread provided in Table 4 is based on the Englyst method, which measures non-starch polysaccharide (NSP) only. Two slices of wholemeal bread (72 g) provides 3.6 g of NSP, which is around one-fifth of the dietary reference value (DRV) for adults (18 g/day) (DH 1991). In the UK, the Englyst method has traditionally been used to derive food table values, but these published values may not equate with those that appear on food labels (including labels found on sliced bread), calculated using the Association of Offi-

*The LRNI is only adequate for 2.5% of the population with the lowest requirement.
cial Analytical Chemists (AOAC) method. The AOAC method (a wider definition of dietary fibre) is used globally and was advocated by the European Commission (EC) to ensure consistent labelling of food products. The AOAC-derived value for bread can be considerably greater than the NSP value because the AOAC method quantifies a variety of different types of dietary fibre (see the section on Possible health effects of the nutrients bread provides). For example, a medium slice of wholemeal bread contains 1.8 g of fibre (based on the Englyst method) and 2.5 g of fibre (based on the AOAC method). See Betteridge (2009) for further discussion about fibre definitions.

Dietary fibre components commonly found in bread wheat are arabinoxylans, β-glucan, cellulose and lignin (Shewry 2009). Arabinoxylans are most abundant [around 70% of the endosperm cell wall dry matter (dm)] with lower concentrations of β-glucan, cellulose and lignin. Overall, wheat provides relatively large quantities of insoluble fibre (for further discussion about the health properties of specific fibres, see the section on Possible health effects of the nutrients bread provides).

The EU-funded HEALTHGRAIN study examined the dietary fibre content of a large variety of wheat lines consumed globally (Gebruers et al. 2008). Winter wheat is commonly grown in the UK and used for bread making. A large variation in the contents of dietary fibre and its constituents involving different types of wheat and different varieties of each wheat type were observed. Common bread wheats (e.g. Tricicum aestivum) contained, on average, the highest level of fibre (11.5–18.3% of dm), as compared with uncommon bread wheat varieties used in the UK (e.g. einkorn and emmer wheats) (Gebruers et al. 2008).

Table 4 Nutrient content of various types of bread (amount per 100 g)

<table>
<thead>
<tr>
<th></th>
<th>White bread</th>
<th>Brown bread</th>
<th>Wholemeal bread</th>
<th>Granary bread</th>
<th>Wheat germ bread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kJ)</td>
<td>931</td>
<td>882</td>
<td>922</td>
<td>1005</td>
<td>935</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>219</td>
<td>207</td>
<td>217</td>
<td>237</td>
<td>220</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>7.9</td>
<td>7.9</td>
<td>9.4</td>
<td>9.6</td>
<td>11.1</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>1.6</td>
<td>2.0</td>
<td>2.5</td>
<td>2.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>46.1</td>
<td>42.1</td>
<td>42.0</td>
<td>47.4</td>
<td>39.5</td>
</tr>
<tr>
<td>Sugars (g)</td>
<td>3.4</td>
<td>3.4</td>
<td>2.8</td>
<td>2.9</td>
<td>3.8</td>
</tr>
<tr>
<td>Fibre* (g)</td>
<td>1.9</td>
<td>3.5†</td>
<td>5.0†</td>
<td>3.3†</td>
<td>4.0†</td>
</tr>
<tr>
<td>Starch (g)</td>
<td>42.7</td>
<td>38.7</td>
<td>39.3</td>
<td>44.5</td>
<td>35.8</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>177†</td>
<td>186†</td>
<td>106</td>
<td>209†</td>
<td>212†</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>137</td>
<td>216</td>
<td>253</td>
<td>191</td>
<td>269</td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>95</td>
<td>157†</td>
<td>202†</td>
<td>138†</td>
<td>219†</td>
</tr>
<tr>
<td>Sodium† (mg)</td>
<td>461</td>
<td>443</td>
<td>487</td>
<td>545</td>
<td>578</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>1.60</td>
<td>2.20†</td>
<td>2.40†</td>
<td>1.90</td>
<td>2.90†</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>0.8</td>
<td>1.3</td>
<td>1.6‡</td>
<td>1.1</td>
<td>2.3†</td>
</tr>
<tr>
<td>Iodine (μg)</td>
<td>4</td>
<td>6</td>
<td>trace</td>
<td>8</td>
<td>(22)</td>
</tr>
<tr>
<td>Selenium (μg)</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>12†</td>
</tr>
<tr>
<td>Copper (mg)</td>
<td>0.14</td>
<td>0.17†</td>
<td>0.23‡</td>
<td>0.18†</td>
<td>0.26†</td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>0.49†</td>
<td>1.14†</td>
<td>1.75†</td>
<td>0.82†</td>
<td>2.05†</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>23</td>
<td>45</td>
<td>66‡</td>
<td>39</td>
<td>64‡</td>
</tr>
<tr>
<td>Thiamine (mg)</td>
<td>0.24†</td>
<td>0.22†</td>
<td>0.25‡</td>
<td>0.24†</td>
<td>0.34†</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>1.6</td>
<td>2.8†</td>
<td>3.8‡</td>
<td>2.7†</td>
<td>3.6‡</td>
</tr>
<tr>
<td>Vitamin B6 (mg)</td>
<td>0.08</td>
<td>0.17</td>
<td>0.11</td>
<td>0.19</td>
<td>0.09</td>
</tr>
<tr>
<td>Folate (μg)</td>
<td>25</td>
<td>45‡</td>
<td>40‡</td>
<td>88†</td>
<td>38‡</td>
</tr>
<tr>
<td>Vitamin E equivalents (μg)</td>
<td>0.01</td>
<td>0.28</td>
<td>0.23</td>
<td>0.48</td>
<td></td>
</tr>
</tbody>
</table>

Source: FSA (2002).

The value in parenthesis is an estimated value.

*Non-starch polysaccharides (Englyst).

†1 g of sodium is equivalent to 2.55 g of salt.

‡Source of vitamin and/or mineral that provides 15% of the recommended daily allowance for a specific vitamin or mineral per 100 g; for fibre, ‘source’ must provide 3 g of fibre/100 g.

§High in vitamin and/or mineral that provides 30% of the recommended daily allowance for a specific vitamin or mineral per 100 g; for fibre, ‘high’ must provide 6 g of fibre/100 g.

g, gram; kcal, kilocalorie; kj, kilojoule; mg, microgram; mg, milligram.
The arabinoyxlan (water-extractable fraction) content of the flours of the different types of wheat varied between 1.70% and 2.00% of dm, with bran samples being richer in arabinoyxlan (winter wheat varied from 13.2% to 22.1% of dm) than white flour samples. Wholemeal flours made from winter wheat had the highest concentrations of β-glucan (0.75% of dm) (Gebruers et al. 2008). The wheat types analysed by Gebruers et al. (2008) contained lower levels of β-glucan than non-wheat varieties of grain such as oats, barley and rye that were analysed in the HEALTHGRAIN study (for discussion about the health benefits of β-glucan, see the section on Possible health effects of the nutrients bread provides). Lignin levels in wholemeal wheat flour were, on average, between 2.10% and 2.60% of dm (Gebruers et al. 2008).

**Micronutrients**

Bread provides various micronutrients, including calcium, iron, zinc, copper, magnesium, manganese, selenium and some B-vitamins, including folate (Table 4). As discussed previously, by law, white and brown flour is fortified with some micronutrients (i.e. calcium, iron, thiamine and niacin) (see the section on Restoration of nutrients lost during milling) and can therefore make a contribution to daily intakes of these nutrients. Any food that provides 15% or 30% of the recommended daily allowance (RDA; values listed in the Annex to the Regulation on nutrition and health claims) for a specific vitamin or mineral, per 100 g, is considered a ‘source of’ or ‘high in’, respectively, in the named vitamin or mineral (European Commission 2007). As Table 4 outlines, bread can be considered a ‘source of’ and/or ‘high in’ many micronutrients. It is worth noting that EU labelling RDAs are often different from the DRVs that exist in the UK (and other individual countries).

**Thiamine, niacin and folate**

The predominant vitamins in bread are the B-vitamins, specifically thiamine, niacin and folate (Table 4). Bread contains some vitamin B₆ and vitamin E, in smaller amounts. Data from the NDNS carried out in 2000/2001 in UK adults showed that cereal and cereal products were the main source of dietary thiamine, providing one-third of the mean daily intake (Henderson et al. 2003b) (equivalent data from 2008 to 2010 are not yet available). Two medium slices of bread (72 g) provides around 0.19 g of thiamine. According to the criteria in the EU Nutrition and Health Claims Regulation, white, brown, wholemeal and granary bread are a ‘source of’ thiamine and wheat germ bread is ‘high’ in thiamine. In the UK, the DRV for thiamine is 1.0 mg/day and 0.8 mg/day for men and women, respectively (DH 1991). Two medium slices of bread provides, on average, almost 20% of the DRV for men and 24% of the DRV for women (DH 1991). This shows that bread can make a valuable contribution to meeting daily thiamine requirements.

Bread also contains niacin (Table 4) and although the average niacin content of bread is lower than in meat (which is a valuable source), bread can still make an important contribution to niacin intake. The 2000/2001 NDNS data showed that 27% of the adult population’s niacin intake came from consumption of cereal and cereal products (Henderson et al. 2003b). Brown, wholemeal, granary and wheat germ bread can claim to be a ‘source of’ niacin. Two medium slices of bread provides, on average, 16% of the DRV for women, which is 13 mg/day, and 12% of the DRV for men, which is 17 mg/day (DH 1991).

The 2000/2001 NDNS data showed that cereal and cereal products provided 33% of mean daily intake of folate. This estimate includes fortified breakfast cereals, which are responsible for 11% of mean daily intake of folate, typically in the form of folic acid (Henderson et al. 2003b). On average, bread contains 47 µg of folate/100 g (Table 4). Granary bread can claim to be ‘high in’ folate, with brown, wholemeal and wheat germ being considered a ‘source of’ this vitamin. In the UK, the DRV for folate is 200 µg/day for adults (DH 1991); women of childbearing age are also advised to take an additional 400 µg/day in the form of a supplement (see the section on Possible health effects of the nutrients bread provides). Two medium slices of bread provides, on average, 47 µg/day, which is 17% of the DRV for adults (200 µg/day). Thus, bread can make an important contribution to meeting daily folate requirements.

**Minerals**

Bread contains a variety of minerals, at varying concentrations, depending on the type of bread (Table 4). According to the 2000/2001 NDNS, bread provided more than 10% of the adult dietary intake of iron, zinc, copper, magnesium; about one-fifth of calcium; and more than one-quarter of manganese (Henderson et al. 2003b). While the corresponding data have not been published in the newest NDNS data, given the fall in bread consumption over the past decade, bread is likely to have reduced its contribution to these nutrients.

**Calcium**

White, brown, granary and wheat germ bread are a ‘source of’ calcium. Wholemeal bread also provides
some calcium (although it is not fortified with calcium, by law, as outlined in the Bread Flour Regulations). According to the NDNS carried out in 2000/2001 in UK adults, white bread contributes 13% to the mean intake of calcium overall (Henderson et al. 2003b). Bread can make a considerable contribution to calcium intake. Two medium slices of bread provides, on average, 18% of the DRV for adults, which is 700 mg/day (DH 1991).

Phytic acid can reduce calcium absorption from foods by forming an insoluble salt in the gut, calcium phytate. Phytates are present in wholegrain cereals, including wholemeal bread, suggesting that calcium from white bread may be more easily absorbed than the calcium from wholegrain versions. However, comparisons of their bioavailability are limited. Leavened breads (the predominant type) have a higher bioavailability of calcium than unleavened breads because phytates are broken down during fermentation and baking (Ensminger et al. 1995). Phytases, present in yeast, can reduce the inhibitory effect of phytic acid on calcium absorption by reducing the phytate content of leavened bread. Two human studies carried out in the USA, which tested the calcium bioavailability of fortified breads, demonstrated that calcium absorption from calcium-fortified white and whole wheat bread compared favourably with absorption from milk (Weaver et al. 1991; Martin et al. 2002).

Iron

Bread provides iron (Table 4), which is found in the bran layer of the wholegrain kernel. Iron lost during processing is added back to white and brown flours, as described previously. Cereal and cereal products are the major source of iron in the diet [contributing over two-fifths (44%) of total iron intake] (Henderson et al. 2003b). Although the average iron content of bread is lower than the amount of non-haem iron found in other cereal-based products, such as breakfast cereals, bread can still make an important contribution towards iron intake. Two medium slices of bread provides, on average, 11% of the DRV for women, which is 14.8 mg/day, and almost one-fifth of the DRV for men, which is 8.7 mg/day (DH 1991).

Hydrogen-reduced iron powder is often used to fortify flour and human intervention studies investigating the bioavailability of iron in this form have provided inconsistent and conflicting results (Roe & Fairweather-Tait 1999; Walter et al. 2004). Bioavailability of iron powder relative to iron sulphate has been suggested to be in the range of 13–148% of that of iron sulphate (Hurrell 1977). The efficacy of iron fortificants, used in flour, to improve iron status is currently being debated and the SACN Report on Iron and Health concludes that although iron-fortified foods make a substantial contribution to intake, the evidence from efficacy trials suggests that foods such as flour fortified with elemental iron are unlikely to make a valuable contribution to increasing iron stores (owing to low solubility and low intestinal uptake) (SACN 2010b). The absorption of iron from a food depends not only on the type of iron present but also on the composition of other foods that make up the diet. For example, absorption of non-haem iron from foods can be improved by the presence of foods (e.g. meat and fish) or drinks containing vitamin C. In addition, iron status will impact on the efficiency of intestinal iron absorption; more iron will be absorbed from the diet in a state of iron deficiency.

Zinc

Bread also provides zinc (Table 4), which is located in the bran layer of the wholegrain kernel. A quarter of the zinc in our diets comes from cereals and cereal products, with white bread alone contributing 6% (Henderson et al. 2003b). Bread can make an important contribution to zinc intake with two medium slices of bread containing 1.02 mg (Table 4). Two medium slices of bread provides, on average, 14% of the DRV for women, which is 7 mg/day and, on average, 11% of the DRV for men, which is 9.5 mg/day (DH 1991).

Magnesium

Bread provides magnesium. Wholemeal and wheat germ bread are a ‘source of’ magnesium (Table 4). Cereal and cereal products provide over one-fifth of total magnesium intake (Henderson et al. 2003b). Two medium slices of bread provides, on average, 13% of the DRV for women, which is 270 mg/day and, on average, 11% of the DRV for men, which is 300 mg/day (DH 1991).

Selenium

Bread provides some selenium, the content being dependent on the selenium content of the soil in which wheat is grown. Flour from North America has a higher selenium content because it has been grown on selenium-rich soils, while European flour contains less selenium. In the last few decades, European wheat has replaced the selenium-rich wheat from North America in the UK (BNF 2001). However, some bread manufacturers still import flour from North America. Wheat germ bread,
in particular (see Table 4), provides valuable amounts of selenium.

Sodium

Bread contains sodium (Table 4), a component of common salt (sodium chloride). Salt in the diet comes from many sources and it is estimated that around 80% comes from processed foods, including bakery products (FSA 2009). Salt is added during the bread-making process to control yeast in the fermentation process. It also stabilises gluten, making it more stable and less extensible. Both processes influence the final texture of the bread. Salt also influences the palatability and shelf life of bread.

The average salt intake for adults in 2008 was estimated to be 8.6 g/day, yet current government recommendations for salt intake states that adults should consume no more than 6 g of salt/day (SACN 2003). Salt levels in bread have fallen substantially in the last number of years because of reformulation efforts. The Federation of Bakers has worked to reduce the salt content of pre-packaged sliced bread, for many years, by about one-third since the 1980s. The UK Food Standards Agency (FSA) Salt Reduction Programme aimed to reduce salt intakes in the UK in a stepwise manner (Wyness et al. 2012). In 2006, the FSA set salt reductions targets for all categories of food, including bakery products. These were designed to be met by 2010, to allow a gradual stepwise reduction in bread. Upon review of the salt targets (in 2009), the FSA published a new set of ambitious salt targets, across all food categories, to be achieved by 2012 (see Wyness et al. 2012). Further reductions in the salt content of bread are expected to be made by UK bakers to achieve these 2012 targets (0.4 g of sodium or 1 g of salt/100 g bread). In March 2011, the Responsibility Deal was launched by the DH. The Responsibility Deal is a new mechanism to take forward some aspects of work to improve health outcomes as outlined in the governments overall strategy for public health, the White Paper Healthy Lives, Healthy People. Five food networks have developed a series of pledges for action, including a salt pledge (see www.responsibilitydeal.dh.gov.uk/2012/01/17/public-health-responsibility-deal-collective-pledges/). The DH were expected to report on the progress of the salt pledge (alongside other pledges) last summer. However, there have been some technical issues with removing the salt content of bread owing to its functional role in the bread-making process (Wyness et al. 2012) and it may therefore take more time to achieve this.

According to data from the latest NDNS, bread contributes almost one-fifth (18%) to mean sodium intake (Bates et al. 2011b). A DH project is currently in the process of reviewing the bread and bakery products section of the Integrated Dataset [(New Composition of Foods (UK FoodComp) Project, (for more information about this project see Benelam and Yüregir 2009)]. It is intended that sodium values will be updated in the food tables, using data from manufacturers and retailers, to reflect changes in formulation since the last analyses were undertaken more than 10 years ago. Therefore, it is likely that the current NDNS data may be an overestimate of the contribution of bread, including other bakery products, to sodium intake.

Changes in the average intake of salt at a population level are measured using urinary sodium. This is the preferred method to monitor changes as a result of the discrepancies of assessing discretionary salt addition at the table and in cooking. A 1.4 g reduction in average salt intake in the UK has been observed since 2000/2001 (Salder et al. 2011) and this is assumed to be as a result of reformulation efforts made across all sectors (including the food industry and food service sectors) combined with changes in consumers’ dietary practices. However, many of us continue to exceed the maximum daily recommendation of 6 g/day for adults.

Bread contains smaller amounts of other minerals, including phosphorus and potassium, but, as is evident in Table 4, their content is lower compared with other minerals. The contribution of bread to total intakes among adults of these minerals is, on average, below 10% (Henderson et al. 2003b).

Phytochemicals

The highest amounts of phytochemicals are found in the outer layers of grains and include phenolic compounds, phytosterols and tocols (tocopherols and tocotrienols) (Mattila et al. 2005). These plant substances have been purported to have antioxidant properties in vivo. A study examining the total antioxidant capacity (TAC) of various foodstuffs, including cereals (such as wheat) and 18 cereal products, found that wholemeal buckwheat and wheat bran had the greatest TAC value, while white flour showed the lowest TAC value (Pellegrini et al. 2006), indicating that flour containing the outer layers of the wheat grain and germ has a greater potential antioxidant activity than white flour. However, the value of TAC assays to measure TAC of foods [e.g. total radical trapping parameter (TRAP) assay] has been questioned (Huang et al. 2005). The EU-funded HEALTHGRAIN project has
examined variations in the composition of bioactive compounds in cereal varieties, including 150 wheat lines with a wide geographical diversity in origin (Poutanen et al. 2008). Variations in the phenolic acid (Li et al. 2008), phytosterol (Nurmi et al. 2008), tocopherol and tocotrienol (Lampi et al. 2008) content of bread wheat (mostly winter wheat as this is dominant in many parts of Europe) and other types of wheat were assessed in this project (www.healthgrain.eu/pub/publications.php).

Li et al. (2008) examined the phenolic acid content of 130 winter bread wheat, 20 spring wheat, 5 spelt, 10 durum wheat lines and 5 lines each of einkorn and emmer genotypes, grown at the same time of year on a single site (Li et al. 2008). Winter wheats had the highest content of total phenolic acids (1171 μg/g). The most abundant phenolic acids in the winter and spring wheats were ferulic, vanillic, syringic and sinapic acids. Another US study also found that ferulic acid was abundant in wheat (Whent et al. 2012). The phytosterol content of the same wheat varieties was also assessed (Nurmi et al. 2008). The total sterol content of wheat assessed in this study varied from 670 to 959 μg/g of dm in winter wheat and from 797 to 949 μg/g of dm in spring wheat. The cultivated English variety Claire was the most phytosterol-rich winter wheat variety (959 μg/g). The most abundant phytosterol in all wheat genotypes was sitosterol. A wide variation in the total stanol content of wheat genotypes was observed involving the wheat lines (7–31% of total sterols). Campesterol, campestanol and sitostanol were found in all wheat lines in considerable amounts (Nurmi et al. 2008). The total tocopherol and tocotrienol content of the 175 genotypes of the different types of wheat used in the above studies were assessed in a study carried out in Finland (Lampi et al. 2008). The total content of tocopherols and tocotrienols present in the wheat genotypes varied widely (2.9-fold), on average, 49.4 μg/g of dm. β-Tocotrienol and α-tocopherols were the major vitamers present (Lampi et al. 2008).

A study carried out in Italy examined the phenolic content of 16 old and 6 modern Italian wheat varieties and identified 34 phenolic compounds belonging to the phenolic acid, flavonoid, coumarin, stilbene, proanthocyanidin and lignin chemical classes (Dinelli et al. 2011). In addition, 6 ancient wheat genotypes (Bianco Nostrale, Frassineto, Gentil Rosso, Gentil Rosso Mutico, Marzuolo d’Aqui and Verna) had a much higher phenolic diversity and content compared with the modern cultivars (Dinelli et al. 2011) (see the section on Potential health effects of the nutrients bread provides for a discussion of the potential health functions of these phytochemicals).

Contribution of bread to nutrient intake in the UK

Energy and macronutrients

According to the most recent NDNS data, 11% of total energy in UK adults (aged 19–64 years) and children aged 4–18 years comes from bread (Bates et al. 2011b). In adults and children aged 4–18 years, bread contributes 20% and 16%, respectively, to carbohydrate intake, and 9% and 11% to total protein intake. Due to its popularity, white bread makes the greatest contribution (Bates et al. 2011b).

Micronutrients

According to the latest NDNS data (Bates et al. 2011b), there is an inadequate intake of a number of nutrients relevant to bread in the UK population among both adults and children (see Table 5a). Older NDNS data have also identified suboptimal intakes of several micronutrients in older adults (Finch et al. 1998) (Table 5b).

While all of these nutrients can be found in other foods and provided by a varied, balanced diet that contains other foods from the starchy carbohydrate group, bread consumption can help to extend food choice and improve dietary variety. For example, sandwiches, which remain a popular lunch choice, not only provide the nutrients found in bread but also those provided by the filling selection (e.g. red meat, chicken, fish, cheese and salad).

More than 15% of girls aged 11–18 years and 6% of women, aged 19–64 years, have an average calcium intake below the LRNI, suggesting that calcium intake of many individuals in these groups are inadequate. In the male population, 8% of 11–18 years old and 3% of men had a calcium intake below the LRNI (Bates et al. 2011b). In older adults, a greater proportion of men and women living in their own homes had calcium intakes below the LRNI (5% and 9%, respectively) compared with those who were living in institutions (Table 5b) (Finch et al. 1998). As bread provides calcium, inclusion of more bread in the diet may increase intakes of calcium in these groups. Data from the NDNS carried out in 2000/2001 in UK adults showed that bread continued to provide around 19% of total calcium intake (Henderson et al. 2003b).

Iron intakes below the LRNI are particularly common in the female population, typically those of childbearing age and elderly females (Table 5a,b) (Finch et al. 1998; Bates et al. 2011b). The NDNS carried out in 2000/2001 in UK adults showed that bread provided around 15% of total iron take (Henderson et al. 2003b).
Although bread is not as rich in iron as some other foods and its efficacy of absorption from flour is unclear, it may still make an important contribution to total iron intake because it is typically consumed on a daily basis. The NDNS 2000/2001 showed that bread contributed to around 13% of magnesium intake in UK adults, on average (Henderson et al. 2003b). Magnesium intakes appear to be low in the UK population, particularly in children aged 11–18 years old and in both free-living and institutionalised older adults (especially males) (Finch et al. 1998), although it should be noted that it is possible that DRVs have been set too high owing to the lack of data on which to base them. Eating bread could encourage an increased intake of magnesium. Bread provides around 5% of total potassium intake (Henderson et al. 2003b).

The latest NDNS showed that selenium intakes were below the LRNI for a substantial proportion of adults and older boys and girls (11–18 years old) (Table 5a). Approximately half of the girls aged 11–18 years and women aged 19–64 years and 41% of adults aged 65 years and over had intakes below the LRNI (Bates et al. 2011b). While meat products are known to make the greatest contribution (6%) to total selenium intake per day, bread also makes a valuable contribution (around 5%) (SACN 2010a).

Folate intakes below the LRNI have been observed in young and older women (Table 5a,b). The latest NDNS data show that about 6% of girls aged 11–18 have a folate intake below the LRNI, whereas 3% of women are below the threshold (Bates et al. 2011b). Although folate status for the most recent NDNS has yet to be published, older data shows that marginal folate status is relatively common in the UK population. Up to 13% of young people and adults below 65 years had marginal folate status in the 2000/01 survey, and it was most common in 11–24 year olds. Severe deficiency was rare in this population group. In contrast, between 8% and 18% of older adults (65+ years) had severe folate deficiency, which is associated with megaloblastic anaemia, and between 15% and 29% had marginal folate status (Finch et al. 1998; SACN 2008). Bread contributes around 11% of total folate intake in UK adults.

Low zinc intakes have also been identified in some groups, namely in children aged 11–18 years old in the latest NDNS and in older men living in institutions (Table 5a,b). Bread contributes around 11% of total UK zinc intake (Henderson et al. 2003b).

Even though thiamine, niacin, manganese and copper intakes do not appear to be of concern in the UK, it is worth mentioning that around 14% of thiamine intake, 11% of niacin intake, 26% of manganese intake and 14% of copper intake in UK adults come from bread (Henderson et al. 2003b).

**Dietary fibre**

Many people in the UK would benefit from increasing their fibre intake, as average intake of NSP is currently 13.9 g/day among adults (Bates et al. 2011b), which remains below the DRV [of 18 g/day among adults (DH 1991)]. Bread provides varying amounts of fibre depending on the type of bread (see Table 4). Bread contributes around one-fifth of total fibre intake in UK adults (Henderson et al. 2003a).

---

**Table 5a** Percentage (%) of UK children, young people and adults with intakes below the LRNI* for micronutrients relevant to bread (Bates et al. 2011a)

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Boys 4–10</th>
<th>Men 11–18</th>
<th>Girls 11–18</th>
<th>Women 19–64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folate</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Calcium</td>
<td>0</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Iron</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Zinc</td>
<td>4</td>
<td>12</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0</td>
<td>27</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Selenium</td>
<td>0</td>
<td>22</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>Potassium</td>
<td>0</td>
<td>16</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

*The LRNI (Lower Reference Nutrient Intake), by definition, is only adequate for 2.5% of the population. Intakes below this level are almost certainly inadequate for most individuals.

**Table 5b** Percentage (%) of UK free-living elderly and elderly living in institutions (65+ years) with intakes below the LRNI* for micronutrients relevant to bread (Finch et al. 1998)

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Free-living</th>
<th>Living in institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men 65+</td>
<td>Women 65+</td>
<td>Men 65+</td>
</tr>
<tr>
<td>Folate</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Calcium</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Iron</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Magnesium</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Potassium</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td>Zinc</td>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</table>

*The LRNI (Lower Reference Nutrient Intake), by definition, is only adequate for 2.5% of the population. Intakes below this level are almost certainly inadequate for most individuals.
Possible health effects of the nutrients bread provides

As shown above, bread makes a substantial contribution to intakes of many nutrients and there is evidence that intakes of some of these nutrients may be inadequate in some groups in the UK. This section considers the health impact of low intakes of these nutrients, reviews evidence regarding the health benefits of specific components of bread [e.g. fibre and resistant starch (RS)] and describes the effect of bread consumption on satiety and appetite control.

Energy, starch and dietary fibre

Amylopectin is the major constituent of starch in wheat endosperm; amylose accounts for the remaining 20–30% of starch. Starch (present in the granules in endosperm cells) is one of the main forms of carbohydrate in the diet. Digestible starches (including wheat starch) are broken down by digestive enzymes in the small intestine to glucose molecules. The glucose is then absorbed into the blood and used by the body as an energy source. However, a small fraction of the starch may resist digestion [resistant starch (RS)] and pass through the small intestine to the colon where it is fermented by the intestinal bacteria to short-chain fatty acids (notably butyrate). Butyrate is an energy source for colonocytes (the cells lining the colon). The proportion of RS present depends on a number of factors, including the effects of food processing. Amylose (a straight chain polymer of glucose) is more resistant to digestion than amylopectin (a branched chain polymer of glucose) (Topping et al. 1997). Recently, genetically modified technology has been used to increase the amylose content of certain cultivars of durum wheat because of amylose’s correlation with the RS present in food (Sestili et al. 2010). In the UK, RS is currently not included in the definition of dietary fibre that underpins the DRV (DH 1991), but RS is encompassed in the definition of fibre that has now been adopted by the EC. In 2010, EFSA published a scientific opinion on DRVs for dietary fibre, in which fibre is defined as nondigestible carbohydrates plus lignin, including NSP, resistant oligosaccharides, RS and lignin (EFSA 2010), which has substantially been adopted by the EC. This definition is in accord with the methods of AOAC.

Fibre is important for gut health and improves bowel function. High fibre intakes, particularly from cereals, have been shown to lower the risk of heart disease (Brown et al. 1999) by positively influencing blood lipids (e.g. blood cholesterol levels). High fibre intakes have also been associated with a lower risk of bowel cancer (Aune et al. 2011), reduced risk of type 2 diabetes, increased satiety and hence, some degree of weight management (Lunn & Buttriss 2007).

Arabinoxylan (a component of NSP) consists of copolymers of two pentose sugars, arabinose and xylose, and is located in the starchy endosperm of the wholegrain kernel. Enzymatic hydrolysis of arabinoxylan – during the processing of cereal-based food products such as bread, yields arabinoxylan-oligosaccharides and xylooligosaccharides. There is some emerging evidence from human intervention trials, although most evidence is from animal studies, to support possible health-related effects resulting from dietary intake of arabinoxylans, arabinoxylan-oligosaccharides and orxylooligosaccharides (Broekaert et al. 2011). This includes the stimulation of beneficial intestinal bacteria (pre-biotic effect).

β-Glucans are glucose polymers with a branched structure. They are found in the endosperm but are most abundant in the bran layer of the wheat grain. Overall, they are present in smaller amounts in wheat compared with other cereals such as oats. β-Glucan fractions of barley and oats have been shown to reduce blood cholesterol levels (Tiwari & Cummins 2011) and to reduce the postprandial glycaemic responses after a meal (Braaten et al. 1994; Yokoyama et al. 1997). However, the extent to which these benefits or other health benefits, are shared by wheat β-glucan is unclear.

Lignin, a non-carbohydrate substance associated with plant cell walls, is located in the bran layer of the wholegrain wheat kernel. The physiological effects of lignin from wheat in humans are not well understood. Evidence from animal models proposes that lignans act as antioxidants (Lineback & Rasper 1988). However, no firm conclusions can be drawn from evidence in animal models; therefore, studies are required to examine the antioxidant effect of wholegrain cereal, particularly from wheat lignins in vivo. Cellulose is a polysaccharide that comprises 10 000 closely packed glucose units, arranged linearly, making cellulose very insoluble and resistant to digestion. Cellulose is located in the bran layer of the wholegrain wheat kernel. The health effects of cellulose in humans are unclear other than promoting bowel function.

Glycaemic response

Glycaemic index (GI) is a characteristic of the rate at which sugar is absorbed from the bloodstream after eating a specific food. It is determined by comparing the blood glucose response to ingestion of 50 g of available carbohydrate from a test food with that of a reference food (typically either glucose or white bread that is
made from wheat flour). Bread, like potatoes and white rice, is generally classified as a high GI food. However, the GI will vary, depending on a number of factors such as the type of grain (i.e. the use of barley and oats to make bread). Factors that influence gastric emptying and digestion rate include the physical structure of the bread, that is, the more compact the structure, the lower the glycaemic response (the particle size remains intact for longer, slowing down the digestive process); the fibre content; the type of starch in the bread (as RS slows gastric emptying); and the baking process (e.g. intensity of kneading) (Fardet et al. 2006). Adding fat to bread mixes reduces the GI but, of course, increases the fat and calorie content (Braaten et al. 1994). If bread is eaten with a meal, or in combination with other foods (such as a sandwich), the carbohydrate tends to be broken down more slowly and glucose enters the bloodstream at a slower rate (dependent on the macronutrient composition of the whole meal). The GI value given in the Foster-Powell table for 95 types of bread varies widely from 27 (e.g. barley bread with 75% wholegrain – bread containing intact cereal grains is digested more slowly) to 95 (e.g. French baguette – starch is readily digested) (Dinelli et al. 2011). A low-to-moderate GI value would be <70 and a high GI value would be in the range of 70–100. Increasing the content of fibre in bread has been shown to reduce the GI of bread in a recent dietary intervention trial (Broekaert et al. 2011). Given that white bread has a high GI value, recent advances in reformulating white bread by using composite flours (maize flour or flours from cereal-free grains such as amaranth) to produce novel bread products have improved glycaemic responses (Burton et al. 2011). Whether and how GI impacts on appetite control and therefore potentially helps with weight management is currently being debated by experts however. For a detailed review on the factors controlling the glycaemic responses to bread, see Fardet et al. (2006).

Satiety

Processing of cereal grains has been found to be an important determinant of postprandial satiety, as processing can affect the fibre content, with wholegrain meals being the most satiating (Slavin & Green 2007). The bulking effect of fibre can increase chewing time and gastric distension, promoting satiation (Benelam 2009). A number of studies have compared the differences in feelings of hunger and satiety after ingestion of various types of breads containing specific fibres (e.g. β-glucan) (Najjar et al. 2009; Vitaglione et al. 2009; Keogh et al. 2011; Lunde et al. 2011; Touyharou et al. 2012).

For example, Vitaglione et al. (2009) randomised volunteers to consume isocaloric breakfasts of either 3% β-glucan-enriched bread (BetaGB) or a control bread. Volunteers who were randomised to receive the BetaGB had a greater reduction in hunger rating, a greater increase in fullness and higher satiety ratings than the control group (Vitaglione et al. 2009).

Lunde et al. (2011) used a crossover design to compare three types of bread: regular coarse bread or fibre-enriched bread (pea fibre) with two levels of rape-seed oil. The fibre-enriched breads appreciably reduced postprandial glycaemic response. This study demonstrated that pea fibre-enriched breads can have favourable effects on postprandial satiety (Lunde et al. 2011).

Bread is rarely consumed by itself and the addition of other foods that provide macronutrients will alter the satiating effect of a given meal. Current evidence suggests that protein is the most satiating macronutrient, followed by fat and carbohydrate. The effects of carbohydrate-rich foods on satiety depend not only on the form of carbohydrate present in the food but also on the fibre content. The satiating effect of bread varies widely, depending on the type of bread, the cereal type used to make the bread, the fibre content and the type of fibre in the bread (Fardet et al. 2006).

Micronutrients

Folate

Folate functions together with vitamin B₁₂ (and other nutrients such as iron) to form healthy red blood cells. It is also required for normal cell division, for the normal structure of the nervous system and specifically, in the development of the neural tube (which develops into the spinal cord and skull) in the embryo. Therefore, adequate folate intake is particularly important for women of childbearing age. It is also recommended that women of childbearing age who are planning a pregnancy should take a daily supplement of folic acid (400 μg/day) to decrease the risk of neural tube defects (such as anencephaly and spina bifida) and to continue to do so for the first 3 months of pregnancy. However, as a large proportion of pregnancies are un-planned, ensuring an adequate folate intake and status is important for all women of childbearing age.

The amount of natural folate needed from the diet is also higher throughout pregnancy (women need an extra 100 μg/day, in addition to the DRV of 200 μg/ day), and in this regard, bread can play a role alongside other folate containing foods (e.g. fruits, green leafy vegetables and brown rice). In various parts of the
world, folic acid is added by law to flour and/or bread. At the global level, nearly 60 countries have already introduced mandatory folic acid fortification to prevent NTDs (FFI 2010), but to date, no countries within the EU have taken this step. There has been considerable debate about the benefits vs. the risks. Despite the clear benefit being prevention of NTDs, high intakes of folic acid could mask the effects of vitamin B12 deficiency in the elderly or strict vegetarians, leading to an increased incidence of neurological damage. There is also concern about an increased incidence of colorectal cancer with high intakes of folic acid in people with pre-existing cancerous lesions (Verhagen et al. 2011). The UK is yet to commit to this fortification, despite SACN advocating that mandatory fortification should be introduced and it is unlikely that there will be a move towards mandatory fortification in the near future.

Together with vitamin B6 and B12, folate is also involved in the maintenance of normal blood homocysteine levels. Elevated homocysteine levels have been associated with an increased risk of cardiovascular disease (CVD), dementia and Alzheimer’s disease. There has therefore been considerable interest in the preventative and therapeutic role of these vitamins in these conditions. While some intervention trials have found improvements in blood homocysteine levels with supplemental doses, those to date have failed to show benefit on CVD risk (B-vitamin Treatment Trialists Collaboration 2006) and studies investigating the effect of folic acid and vitamin B12 supplementation on the prevention or treatment of cognitive decline have yielded inconsistent findings (Vogel et al. 2009; Dangour et al. 2010).

**Calcium**

Calcium is essential for a number of vital functions. The body needs adequate dietary calcium (alongside vitamin D and other nutrients) to develop and maintain healthy bones and teeth. Calcium also plays a role in many systems, including intracellular signalling to enable the integration and regulation of metabolic processes, the transmission of information via the nervous system, the control of muscle contraction (including the heart) and blood clotting. Calcium levels in the blood are carefully regulated and blood plasma levels are maintained within narrow limits. When dietary calcium intake is poor over a prolonged period, the bone acts as a reservoir. For example, insufficient calcium in bones can result from an inadequate supply of vitamin D, which is essential for the absorption of calcium. In children, vitamin D deficiency results in rickets and, in adults, osteomalacia, in which bones become weak owing to a lack of calcium. In particular, young children and adolescents need to ensure that they consume adequate dietary calcium to support the developing skeleton. Calcium requirements are high for teenagers because their bones are growing in size and density. The amount of bone tissue in the skeleton (known as bone mass) peaks around the late 20s when bones have reached their maximum strength and density. Therefore, it is important to consume adequate dietary calcium in the early years to support bone health.

More recently, epidemiological and intervention studies have shown that calcium (milk and supplemental calcium) may decrease colon cancer risk and reduce the risk of reoccurrence of adenomatous polyps (Holt 2008). Emerging evidence has also suggested that calcium may have a role to play in weight regulation (via the promotion of faecal fat loss and oxidation, among other mechanisms) (Tremblay & Gilbert 2011). However, not all investigators have come to the same conclusion (Soares et al. 2011). Furthermore, the amount of calcium used in interventions may be difficult to achieve by diet alone.

**Iron**

Iron is essential for the formation of haemoglobin in red blood cells; haemoglobin binds oxygen and transports it around the body. Iron is also an essential component in many enzyme reactions; it has an important role in the immune system and is required for normal energy metabolism and wound healing. An inadequate supply of dietary iron depletes iron stores in the body and this can eventually lead to iron-deficiency anaemia. In particular, women of childbearing age and teenage girls need to ensure they consume adequate dietary iron because their requirements are higher than those of men of the same age. The latest NDNS data show that there is evidence of iron-deficiency anaemia and low iron stores in subgroups of the UK population is of critical public health importance given its effects on physical work capacity, pregnancy outcome, cognitive and psychomotor development in children, immune function and infection (SACN 2010b).

**Zinc**

The major function of zinc in human metabolism is as a cofactor for numerous enzymes. Zinc has a key role as a...
catalyst in a wide range of reactions. It is directly or indirectly involved in the major metabolic pathways concerned with protein, lipid, carbohydrate and energy metabolism. It is also essential for cell division and therefore for growth and tissue repair and for normal reproductive development. In addition, zinc is required for the functioning of the immune system and in the structure and function of the skin, and hence plays a vital role in wound healing. Mild zinc deficiency can aggravate infections by impairing immune system defence (Plum et al. 2010).

**Magnesium**

Magnesium is an essential mineral present in all human tissues, especially in bone. It has both physiological and biochemical functions and has important interrelationships with calcium, potassium and sodium. It is needed for the activation of many enzymes (e.g. enzymes concerned with the replication of DNA and the synthesis of RNA) and for parathyroid hormone secretion, which is involved in bone metabolism. It is also needed for muscle and nerve function. It has recently been suggested that suboptimal magnesium status over time may contribute to a number of disease states, including type 2 diabetes, metabolic syndrome, hypertension, osteoporosis and colon cancer (Rosanoff et al. 2012). However, more randomised controlled trials supplementing with magnesium are required to understand how low magnesium status can influence the incidence of disease.

**Selenium**

Selenium is an essential trace element. The main function of selenium is as a component of some of the important antioxidant enzymes (e.g. glutathione peroxidase) and therefore to protect the body against oxidative damage. It is also necessary for the use of iodine in thyroid hormone production, for immune system function and for reproductive function.

More recently, evidence from experimental and epidemiological studies propose a preventative association of selenium intake and status in a number of conditions, such as cancer (Clark et al. 1996), CVD (Blankenberg et al. 2003) and infertility (Keskes-Ammar et al. 2003). However, there remains a lack of evidence to support these claims (SACN 2012b).

**Sodium**

As mentioned previously, the UK population is consuming too much salt. High sodium intakes, along with obesity and high alcohol intake, are considered to be key risk factors for hypertension, which increases the risk of CVD and stroke (SACN 2003). While the FSA’s salt reduction programme has successfully reduced the average population salt intake in recent years, further reductions need to be made to achieve the population salt target (which is 6 g/day). Work is underway to further reduce the salt content of bread and other food commodities in the diet.

**Phytochemicals**

Much of the evidence on the health effects of phytochemicals to date is derived from studies using laboratory animals or *in vitro* studies. The suitability of using animal models, in terms of their relevance to human physiology, limits the interpretation of these results.

The most common phenolic acid found in wheat is ferulic acid, the antioxidant potential of which has recently been demonstrated in a rat model (Bolling et al. 2011). Tocols, present in wholegrain wheat, contribute to vitamin E activity; vitamin E is an antioxidant and is required to protect cells against oxidative damage caused by free radicals (e.g. oxidation of the lipids in cell membranes). Phytosterols are known to lower serum total and low density lipoprotein (LDL) cholesterol in humans (Jones 1999), but their health effects at the levels present in wheat have yet to be demonstrated, and thus fortification with stanols and/or sterols would probably be necessary to observe a cholesterol lowering effect.

For further information on the evidence supporting the health benefits of wholegrain consumption and wholegrain phytochemicals, see Okarter & Liu (2010). More research, particularly *in vivo* studies, is required to determine the potential health-promoting properties of phytochemicals present in different wheat varieties. Wholegrain phytochemicals and indeed other bioactive compounds may be responsible for their proposed health effects.

**Conclusion**

Although bread consumption has declined over the last 70 years, bread remains a staple food in many countries. Because of its high starch content, bread is positioned in the starchy food section of the UK’s *eatwell* plate and similar models elsewhere. Bread is low in fat and provides dietary fibre, and numerous vitamins and minerals, including calcium, iron, zinc, magnesium, thiamine, niacin and folate. Bread can therefore help to meet the daily requirements of these nutrients, particularly those...
for which low intakes have been identified in some subgroups. However, bread contributes to salt intake, which, if eaten in large amounts (independently of bodyweight), is a risk factor for high blood pressure. The food industry (including UK bakers) has reduced the sodium content of bread in recent years, including the levels in sliced pre-packed bread, through reformulation efforts. As a number of leading manufacturers have signed up to the salt pledge within the government’s Responsibility Deal, further improvements are expected. However, this will be dependent on technological advances, the introduction of new processing techniques and/or new salt ingredient alternatives. The capacity for further salt reduction in bread is uncertain, although it will likely happen in a stepwise manner to maintain organoleptic properties of bread that will be acceptable to consumers. Given the valuable contribution bread makes to fibre and vitamin and mineral intakes, bread remains a valuable food in our diets alongside other starchy carbohydrate foods, such as potatoes, pasta, rice and breakfast cereals.

Acknowledgement

The author is grateful to Catherine Collins, Principle Dietitian at St. George’s Hospital, London for her helpful comments on an early draft of this paper.

Conflict of interest

The British Nutrition Foundation is grateful to Warburtons for financially supporting time spent on the preparation of this review. However, the views expressed in this article are those of the author alone, and Warburtons has not been involved in writing or shaping any of the contents.

References


Medical Aspects of Food and Nutrition Policy. The Stationary Office: London.


Kantar WorldPanel (2011) In Home/Lunchbox consumption 12 months to end of November 2011.


