

2.4

Food composition tables and databases

Edwige Landais and Michelle Holdsworth

Key points

- Food tables are a vital resource, but to avoid errors from their use, it is essential to understand their strengths and limitations.
- The composition of a particular food can vary as a result of differences in plant and animal genetics, strain and breed variety, farming practices, soil quality, climate, storage conditions and the way in which food has been processed, manufactured or cooked.
- Food tables do not take into account the extent to which a nutrient is absorbed (bioavailability).

Food composition data provide information on the nutritional composition of the edible part of foods, and are available in print (food composition tables) and computerised formats (food composition databases). They are generally used to calculate the food intake of individuals and groups from information gathered during dietary assessment (see Chapter 2.3, Dietary assessment). They are used in different settings, including clinical practice, research, health promotion and the agri-food industry, as shown in Table 2.4.1.

Data in food composition databases come from different sources:

- Original analytical values obtained from chemical analysis of food samples.
- Analytical values from scientific literature or food labels for branded foods.
- Imputed values derived from analytical values of a similar food.
- Calculated values derived from recipes using weight yield and nutrient retention factors.
- Values taken from other tables or databases.
- Presumed values that are assumed to be null.

National food tables

UK food tables

Tables of food composition have been published in the UK since the 1920s, stimulated by concerns over food shortages in the First World War (Church, 2006). They were continued by the pioneering work of McCance and Widdowson, initially conducted under the

auspices of the Medical Research Council and subsequently the Ministry of Agriculture, Fisheries and Food (MAFF). In 1987, MAFF, in conjunction with the Royal Society of Chemistry, began the production of a computerised UK National Nutrient Databank (UKNND), from which the fifth edition of *McCance and Widdowson's The Composition of Foods* (Holland *et al.*, 1991a) and a number of detailed supplements were produced. In 2000, responsibility for the maintenance of the UKNND was transferred to the Food Standards Agency (FSA), and in 2016 to the Institute of Food Research (IFR), when it was renamed Food Databanks. The Food Databanks National Capability (FDNC) publishes the tables in book form as *McCance and Widdowson's The Composition of Foods* and electronically as the Composition of Foods Integrated Dataset (CoFID), available at <https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid>.

The printed form of the summary edition of *McCance and Widdowson's The Composition of Foods* (Finglas *et al.*, 2015) is widely used; however, it should be appreciated that, while convenient, the single volume edition does not contain the complete set of data available, but only a subset of foods and nutrients. The most comprehensive information is contained within the separately published supplements, as shown in Table 2.4.2, and a complete collection of these should be regarded as the definitive UK food tables. Most of these are now in electronic form and have been integrated into the UKNND (www.food.gov.uk), and are regularly updated as part of a rolling programme of food analysis and analytical reports.

Table 2.4.1 Role of food composition tables

Use	Clinical practice	Health promotion	Research	Agri-food industry
Assessing nutritional status at individual, community and national levels	✓	✓	✓	
Preparing educational materials	✓	✓		✓
Designing therapeutic diets, e.g. hospitals	✓		✓	
Devising food and nutrition labelling				✓
Assessing diet–disease links	✓		✓	
Developing food products and recipes				✓
Monitoring food and nutrient availability		✓	✓	✓
Developing food and nutrient guidelines	✓	✓	✓	
Monitoring food legislation and safety – consumer protection		✓		✓
Completing missing values in a data set	✓	✓	✓	✓

Table 2.4.2 UK food tables and supplements**Single volume summary**

McCance and Widdowson's The Composition of Foods, 7th edition Finglas *et al.* (2015)

Supplements

Amino acid composition and fatty acid composition	Paul <i>et al.</i> (1980)
Immigrant foods	Tan <i>et al.</i> (1985)
Cereals and cereal products	Holland <i>et al.</i> (1988)
Milk products and eggs	Holland <i>et al.</i> (1989)
Vegetables, herbs and spices	Holland <i>et al.</i> (1991b)
Fruit and nuts	Holland <i>et al.</i> (1992a)
Vegetable dishes	Holland <i>et al.</i> (1992b)
Fish and fish products	Holland <i>et al.</i> (1993)
Miscellaneous foods	Chan <i>et al.</i> (1994)
Meat, poultry and game	Chan <i>et al.</i> (1995)
Meat products and dishes	Chan <i>et al.</i> (1996)
Fatty acids	Ministry of Agriculture, Fisheries and Food (1998)

Others

Foods commonly consumed by South Asians Judd *et al.* (2000)

Note: Details of the analysis of specific food products and nutrients, e.g. salt in bread, are available at www.food.gov.uk.

A range of nutrient analysis software programmes using the UKNND is available for dietitians and nutritionists (see Chapter 2.3, Dietary assessment). Some less sophisticated nutrient analysis programmes need to be used with caution, particularly those designed for the general public or schools, which comprise summarised data derived from main food tables. Data for groups of foods may either be averaged or confined to a few selected options, e.g. data for meat may be confined to a few possible choices from the hundreds cited in the main food tables. Dietary estimates based on such generalised figures can be misleading.

Food tables used outside the UK

In order to be useful and accurate, food tables need to reflect the foods consumed in the food culture in which they are used. Dietary investigations carried out in other parts of the world should use the appropriate local data. Many other countries produce national food composition tables, including several European Union countries, and the first was published in Germany in the 1800s (Church, 2006). The European Food Information Resource project (EuroFIR) initiative was established in 2005 to deliver a comprehensive and validated European databank for nutrients and bioactive compounds for 27 European countries (www.eurofir.org). EuroFIR led to the establishment of a longer-term platform to continue some of these activities through a non-profit international association – EuroFIR AISBL – to support the development and application of food composition data, through international harmonisation. Within the EuroFIR framework, the bioactive constituents of plant-based foods, as well as their biological effects, are combined in a database (Electronic BioActive Substances in Food Information System, or eBASIS, available at <http://ebasis.eurofir.org/Default.asp>).

The USA also began producing food composition tables in the 1800s and has continued to produce accessible electronic food tables (www.ars.usda.gov). In the late 1970s, the Center for Food Safety and Applied Nutrition (CFSAN) of the US Food and Drug Administration (FDA) developed a standardised system for describing food. This system, called LanguaL (Langua aLimenta-ria) (www.langua.org), facilitates links to many different food databases and enables data exchange of over 35,000 food products. In the USA, the Department of Agriculture maintains the nutrient database (www.ars.usda.gov).

In 1984, the United Nations University's Food and Nutrition Programme set up the International Network of Food Data Systems (INFOODS), coordinated by the Food and Agriculture Organization (FAO), to improve the quality of food data and also to enable worldwide access. The website of INFOODS (www.fao.org/infoods/

infoods/en/) provides information about all existing food composition tables, some of which are directly accessible through the website.

Derivation of food table data

Before using food table data, it is essential to read the introduction explaining how the values in the tables were derived. This is particularly important if food composition data from more than one source are used alongside standard food table data, e.g. food labelling information, or food tables from other countries, because the definition and expression of the nutrients may not be the same. The factors discussed in the following subsections should be considered when using food composition tables or databases.

Analytical methodology

Different analytical techniques can be used to obtain estimates of the same nutrient. Historically, food analysis consisted of determining the percentage of water, fat, nitrogen and ash (minerals) in a food. Multiplying the percentage of nitrogen by 6.25 derived protein content, as protein is 16% nitrogen on average. While the latter is still widely used, it is now recognised that the amount of nitrogen depends on the protein source (FAO, 2003). Carbohydrate content was estimated by difference, i.e. the percentage of other nutrients was calculated, and carbohydrate was assumed to be the remaining percentage needed to give 100%. This derived figure for carbohydrate included the contribution from dietary fibre or other dietary components.

More recently, chemical analyses methods have become more sophisticated, so different types of sugars (glucose, fructose, galactose, sucrose, maltose, lactose and oligosaccharides) and complex carbohydrates (dextrins, starch and glycogen), amino acids and fatty acids, as well as individual minerals and vitamins, can now be determined. Information on manufactured foods not included in the food tables can increasingly be obtained from food labels or food manufacturers, but much commercial food analysis is still carried out using simpler analytical techniques.

The use of a range of methodologies will result in different estimates of nutrient content. Carbohydrates may be determined as monosaccharide equivalents, actual weights or by difference, as described earlier. Monosaccharide equivalents, the usual form of expression in UK food tables, result in slightly higher estimates of carbohydrate content than when expressed as actual weight, as on most food labels (due to the fact that disaccharides and polysaccharides gain water when hydrolysed). Direct determination of carbohydrates is used in the Food Databanks.

Dietary fibre can be analysed using different methods that give differing estimates. The *McCance and Widdowson* tables and the Food Databank give estimates for non-starch polysaccharides (NSP) based on the Englyst method (Englyst *et al.*, 1994). However, the food industry measures fibre by the AOAC

enzymatic gravimetric method, which is now recommended for food labelling purposes. The AOAC method usually gives much higher estimates of fibre content, particularly for cereals, because it includes lignin (or substances measuring as lignin) and resistant starch. The seventh edition of *McCance and Widdowson's The Composition of Foods* (Finglas *et al.*, 2015) includes fibre content of foods measured by both the Englyst and AOAC methods.

Many vitamins are composites of substances with variable degrees of activity and the concentrations will depend on the type of analysis performed. For example, vitamin A may be expressed as retinol and beta-carotene separately, or as retinol equivalents. Different units may also be used (micrograms or International Units, IU). The two components of vitamin A are given separately as retinol (RET) and carotene (CAREQU). Retinol is expressed as the weight of all trans retinol equivalents, i.e. the sum of all trans retinol plus contributions from the other forms after correction to account for their relative activities.

Energy conversion factors used to calculate data

The energy content of food may be measured by bomb calorimetry, but not all food energy can be metabolised; therefore, the conversion factors accounting for this are used to calculate energy yield. Atwater and colleagues derived these factors from meticulous human studies over a century ago (Atwater & Benedict, 1902). It is important to remember that slightly different Atwater factor systems may be used, and the energy content of foods may vary between *McCance and Widdowson* tables or the Food Databanks and those required for food labelling declarations (Table 2.4.3).

Sampling procedure

Food composition data are derived from a sample of foods and, therefore, their accuracy depends on how representative the sample is. The UK food tables are designed to be as representative as possible. Significant numbers of food samples are purchased from different retail outlets and pooled before analysis. Market share information is used to assess which brands of a particular type of food are included, and recipes are chosen to be as similar as possible to those used in the normal domestic setting. Other sources of food composition data may not be based on such high standards. Details of the samples used in analysis are given for each food item in the tables and database.

Regular data updating

Food composition tables need to be regularly updated for the following reasons:

- New manufactured foods are constantly developed – new manufacturing practices may change the composition of manufactured foods as a result of product reformulation, altered manufacturing processes,

Table 2.4.3 Energy conversion factors (source: Webster-Gandy *et al.* 2012, Table 1.2, p. 11. Reproduced with permission from Oxford University Press)

Nutrient	kcal/g	kJ/g	Comments
Protein	4	17	For food labelling purposes, multiplying the nitrogen content in all foods by 6.25 derives protein content. UK food tables use specific conversion factors for different types of foods.
Fat	9	37	The original Atwater factor was 8.9 kcal, but the lower kJ figure is preferable.
Carbohydrate	3.75	16	If carbohydrate is expressed directly or by difference, 4 kcal/g is used, which is the figure used on food labels. Values for available carbohydrate are expressed as monosaccharides.
Fibre	2	8	
Polyols (sugar alcohols)	2.4	10	Food labelling uses mean value.
Alcohol (ethanol)	7	29	
Glycerol	4.31	18	Complete metabolism assumed.

fortification and use of nutrients such as beta-carotene or vitamin C as colourings or antioxidants.

- Changes in farming practices can alter the composition of plant and animal products. For example, the fat content and fatty acid profile of meat has changed considerably in the last 30 years due to selective breeding programmes to produce leaner animals, changes in feeding techniques and from modern butchery techniques removing more carcass fat. Development of new crop varieties or changes in fertiliser use can also affect nutritional composition.
- Domestic preparation and cooking practices may change, e.g. vegetables may be steamed rather than boiled, and bread may be made from a domestic bread-making machine.
- New varieties or new sources of supply for raw materials – previously unfamiliar foods are now available in shops, e.g. associated with migrating populations.
- More accurate methods of analysis are developed, e.g. fibre.

The use of old analytical data will considerably increase the likelihood of errors, which will introduce significant errors in even the most detailed dietary assessment. However, in some circumstances, e.g. the analysis of dietary information obtained many years ago, it may be necessary to use composition data that were contemporary at the time in order to obtain realistic estimates of nutrient intake. It is particularly important that those engaged in dietary survey work be aware of the implications of using data from older editions and supplements of *McCance and Widdowson's The Composition of Foods* (Black & Paul, 1999). There are also a number of differences in code numbers between editions of food tables, which can have implications in computerised analysis; a list of current and previous codes is included in the food index to the seventh summary edition of *McCance and Widdowson's The Composition of Foods* (Finglas *et al.*, 2015). It is also important to know which data have been incorporated into nutrient analysis programmes.

Limitations of food composition data

Food tables are an extremely valuable resource, but it is important to understand their limitations and associated problems. Food tables and databases will always have limitations for several reasons, including variability between foods consumed and food table values and bioavailability.

Variability between foods consumed and food table values

Despite careful sampling, the resultant values may be representative of a particular food, but there will still be some variation from foods actually consumed. A number of factors – such as plant or animal species, seasonal changes in feeding practices or growing conditions, or the effects of storage on water content – affect the composition of foods such as meat, milk, eggs or plant crops. Further variability is likely to occur as a result of differences in food manufacture, catering or domestic cooking practices. For example, a lasagne may be a manufactured ready meal, an item prepared by a restaurant or made at home. All will differ in composition, and probably none will exactly match the values given in food tables. In Western diets, comparisons of the nutrient content of diets calculated from food tables and analysed by direct analysis have been shown to range between 2 and 20% (Bingham, 1987). This variability is most likely to occur with micronutrient content due to the following reasons:

- The soil in which a plant was grown, e.g. soil variation can markedly affect selenium content.
- Agricultural practices, e.g. antagonism between soil fertilisation using nitrogen and vitamin C.
- Stage of maturity, e.g. in plant foods, vitamin C content decreases during ripening, whereas carotenoid content increases.
- Duration and conditions of storage before consumption, e.g. water-soluble vitamin content will diminish with time.

- The way the food is cooked, e.g. the potassium content of boiled vegetables will depend on the amount of water used and length of cooking time.
- Use of food fortification in some but not all brands of a particular food, e.g. folate or iron added to breakfast cereals.
- Use of food additives that are also nutrients, e.g. beta-carotene (colour) or vitamin C (antioxidant) may be unexpectedly present in foods such as meat products.

Vitamin C and folic acid naturally vary widely in foods, and both are sensitive to heat and light. In food table analyses, vegetables would usually have been cooked in distilled water and without added salt. This means that the measured content of sodium, chloride and calcium (present in tap water) will be lower than is likely in the domestic setting.

For most dietetic purposes, the importance of any differences between theoretical and actual nutrient composition may be relatively insignificant in the average mixed diet. However, for metabolic studies based on the consumption of very few foods, or where extreme precision is required, duplicates of the actual foods concerned must be prepared for direct laboratory analysis.

Bioavailability

Bioavailability is defined as the proportion of a nutrient that can be absorbed and hence available to the human body. Bioavailability can vary according to several factors:

- Source, e.g. calcium in milk is absorbed more readily than calcium in bread.
- Chemical form, e.g. absorption of haem iron is greater than that of non-haem iron.
- Ease with which the nutrient can be released from the food, e.g. some carbohydrate in fibrous foods cannot be digested and is lost in faeces.
- Presence of factors that inhibit absorption, e.g. phytates in cereal foods can reduce calcium absorption.
- Presence of factors that enhance absorption, e.g. vitamin C enhances absorption of non-haem iron.
- Physiological factors – absorption may be increased in states of nutritional depletion or at times of increased need, e.g. pregnancy.

Bioavailability is most likely to impact on minerals and trace elements such as calcium, magnesium, iron, zinc, copper, manganese and selenium, and vitamins such as folate and B₆. Since these interactions are so variable, UK food tables take no account of bioavailability, and the nutrient content given in the food table is the amount present in the food. The only exception is the allowance made for the reduced activities of the different forms of some vitamins, e.g. 13-cis retinol and retinaldehyde (vitamin A), carotenes other than beta-carotene, and tocopherols and tocotrienols other than alpha-tocopherol (vitamin E). It is important to check if the food composition data nutrient values have been modified to account for bioavailability.

Errors associated with the use of food composition data

Coding errors

In addition to the inherent errors in food table data, additional errors may be introduced into nutrient analysis programmes in the following ways:

- Missing nutrient values in food composition tables may be treated as zero values during calculation, resulting in an underestimation of nutrient intake.
- There may not be a suitable code for the food consumed, or an inappropriate code may be chosen.
- There may be incorrect entry of food code numbers into the computing system.
- Errors can occur in the measurement, recording and estimation of food weights.
- Misclassification can result from a food having different names in different countries or regions within. This is particularly important when working with other nationalities, e.g. in the USA, chips refer to potato crisps rather than fried potatoes as used in the UK.

Interpretation errors based on contribution to the diet

Food tables are useful to help identify good and poor food sources of nutrients, but are not always used appropriately. The values given in tables will identify foods that are particularly concentrated sources of a nutrient, but this does not necessarily mean that a food is an important source of that nutrient in the typical diet. The contribution that a particular food makes to nutrient intake depends on the:

- Concentration of nutrient in the food (content per 100 g) and its bioavailability.
- Amount of the food consumed, i.e. portion size.
- Frequency with which the food is consumed.

For example, parsley is a highly concentrated source of vitamin C, but is unlikely to be a significant dietary source, because it is usually eaten infrequently and in small quantities. In contrast, potatoes are a much less concentrated source of vitamin C, but, because they are a regular feature of many UK diets, they may make a major dietary contribution to vitamin C intake. When giving dietary advice, it is important to remember that, however valuable a food may be as a source of a particularly nutrient, it will make only a small contribution to dietary intake if it is rarely eaten.

Further reading

- Greenfield H, Southgate DAT. (2003) *Food Composition Data: Production, Management and Use*, 2nd edn. Rome: FAO.
- Klensin JC, Feskanich D, Lin Truswell AS, et al. (1989) *Identification of Food Components for INFOODS Data Interchange*. Hong Kong: The United Nations University.
- Rand WM, Pennington JAT, Murphy SP, et al. (1991) *Compiling Data for Food Composition Data Bases*. Hong Kong: The United Nations University.

Internet resources

EuroFIR Project Website with Information on European Food Composition Databases, <http://www.eurofir.org>
 FAO – INFOODS Information for Nutrient Database Compilers and Suppliers <http://www.fao.org/infoods/infoods/en>
 Food Databanks National Capability, <https://fdnc.quadram.ac.uk>
 USDA Nutrient Data Laboratory, http://www.ars.usda.gov/main/site_main.htm?modecode=80-40-05-25

References

- Atwater WO, Benedict FG. (1902) *Experiments on the Metabolism of Matter and Energy in the Human Body, 1898–1900. US Office of Experiment Stations Bulletin No. 109.* Washington, DC: Government Printing Office.
- Bingham S. (1987) The dietary assessment of individuals: methods, accuracy, new techniques and recommendations. *Nutr. Abstr. Rev.* 57: 705–742.
- Black AE, Paul AA. (1999) McCance & Widdowson's Tables of Food Composition: Origins and Clarification of the Fifth Edition. *J. Hum. Nutr. Diet.* 12: 1–5.
- Chan W, Brown J, Buss DH. (1994) *Miscellaneous Foods: Fourth Supplement to The Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Chan WW, Brown J, Lee SM, et al. (1995) *Meat, Poultry and Game: Fifth Supplement to McCance and Widdowson's The Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Chan W, Brown J, Church SM, et al. (1996) *Meat Products and Dishes: Sixth Supplement to McCance and Widdowson's The Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Church SM. (2006) The history of food composition databases. *Nutr. Bull.* 31: 15–20.
- Englyst HN, Quigley ME, Hudson GJ. (1994) Determination of dietary fibre as non-starch polysaccharides with gas–liquid chromatographic, high-performance liquid chromatographic or spectrophotometric measurement of constituent sugars. *Analyst.* 119: 1497–1509.
- Finglas PM, Roe MA, Pinchen HM, et al. (2015) *McCance and Widdowson's The Composition of Foods*, 7th summary edn. Cambridge: Royal Society of Chemistry.
- Food and Agriculture Organization of the United Nations (FAO). (2003) *Food Energy – Methods of Analysis and Conversion Factors (Technical report)*. Rome: FAO/UN.
- Holland B, Brown J, Buss DH. (1993) *Fish and Fish Products: Third Supplement to the Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Holland B, Unwin ID, Buss DH. (1988) *Cereals and Cereal Products: Third Supplement to McCance and Widdowson's The Composition of Foods*, 4th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Holland B, Unwin ID, Buss DH. (1989) *Milk Products and Eggs: Fourth Supplement to McCance and Widdowson's The Composition of Foods*, 4th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Holland B, Welch AA, Unwin ID, et al. (1991a) *McCance and Widdowson's The Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Holland B, Unwin ID, Buss DH. (1991b) *Vegetables, Herbs, and Spices: Fifth Supplement to McCance and Widdowson's The Composition of Foods*, 4th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Holland B, Unwin ID, Buss DH. (1992a) *Fruit and Nuts: First Supplement to McCance and Widdowson's The Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Holland B, Welch A, Buss DH. (1992b) *Vegetable Dishes: Second Supplement to McCance and Widdowson's The Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Judd PA, Kassam-Khamis T, Thomas JE. (2000) *The Composition and Nutrient Content of Foods Commonly Consumed by South Asians in the UK*. London: The Aga Khan Health Board for the United Kingdom.
- Ministry of Agriculture, Fisheries and Food (MAFF). (1998) *Fatty Acids: Seventh Supplement to The Composition of Foods*, 5th edn. Cambridge: Royal Society of Chemistry/MAFF.
- Paul AA, Southgate DAT, Russell J. (1980) *Amino Acid Composition (mg per 100g food) and Fatty Acid Composition (g per 100g food): First Supplement to McCance and Widdowson's The Composition of Foods*, 4th edn. London/Cambridge: HMSO/Royal Society of Chemistry.
- Tan SP, Wenlock RWW, Buss DH. (1985) *Immigrant Foods: Second Supplement to McCance and Widdowson's The Composition of Foods*, 4th edn. London/Cambridge: HMSO/Royal Society of Chemistry.
- Webster-Gandy J, Madden A, Holdsworth M. (2012) *Oxford Handbook of Nutrition and Dietetics*, 2nd edn. Oxford: Oxford University Press.