REVIEW

EuroFIR Synthesis report No 7: Food composition explained

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Summary

Food composition data are fundamental to the quantitative study of nutrition and are widely used in a variety of fields, including public health. However, knowledge of both the compilation and the limitations of food composition databases, which contain information on the concentrations of nutrients in food, is beneficial to ensure that users understand how to utilise the data appropriately. This guide provides background information on the importance of food composition data, and then explains the processes involved in producing and compiling these data. It then offers guidance on some of the key issues that users should be familiar with when using and

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manipulating food composition data. Suggestions for further reading are given for users who may need more detailed information on specific topics and the resources produced by the EuroFIR (European Food Information Resource) Network of Excellence are highlighted.

Keywords: food composition, guide, nutrition, nutrient databases, public health, users

1 Introduction

Information on the concentrations of nutrients and nutritionally important components in foods is used in many different fields of work, especially in public health and nutriton. This information is usually presented in the form of food composition tables or databases.

To ensure that food composition data are used appropriately and effectively, it is necessary for *users* to have some background knowledge on how food composition databases are produced and issues that should be considered in their application. This guide seeks to provide such background knowledge for *users* of food composition data and also to suggest where more detailed information can be found. It is specifically targeted at new entrants to the field, particularly nutrition/food science graduates, who need to have an understanding of food composition data and its limitations beyond the level that might have been covered during their undergraduate studies. However, it is hoped that it will be of interest to a wide range of food composition data users, including students.

The guide draws on work undertaken by, and resources produced by, the EuroFIR (European Food Information Resource) Network of Excellence (http://www.eurofir.net and http://www.eurofir.org/eurofir)[1]. EuroFIR, which is funded under the European Union (EU) 6th Framework Food Quality and Safety Programme, aims to develop and integrate a comprehensive, coherent and validated databank providing a single, authoritative source of food composition data.

Detailed guidance for the database *compilers* who construct food composition databases is available elsewhere, both in the form of publications (*e.g.* Rand *et al.* 1991; Greenfield & Southgate 2003) and via training courses. The latter includes a graduate short course on the production and use of food composition data in nutrition (http://www.vlaggraduateschool.nl/courses/food-comp.pdf), organised by Wageningen University (http://www.wageningenuniversiteit.nl/UK/) and advertised on the EuroFIR website.

[1]Hereafter referred to as EuroFIR.

2 Why food composition databases are important

2.1 History

Food composition tables in the format known today were first published towards the end of the 19th century, with the first European table published in Germany (Konig 1878). In 1896, tables were published in the USA (Atwater & Woods 1896), incorporating nearly 2600 analyses of a wide range of foods, including the main food groups but also some processed foods. Values were presented for 'fuel value', water, protein, fats, carbohydrates, ash and 'refuse' content of the foods. These tables can be viewed at: http://www.ars.usda.gov/Services/docs.htm?docid=9447.

The first UK tables, which became the well-known *McCance and Widdowson's The Composition of Foods* series, were published in 1940 (McCance & Widdowson 1940). Many other European countries were also early pioneers in the field of food composition, including Denmark, France, Italy, The Netherlands and Sweden. In addition, the Food and Agriculture Organization (FAO) published tables for international use (Chatfield 1949); these tables were primarily intended for the assessment of food availability at the global level.

Food composition tables were originally produced as printed versions, and for many years this remained the only format. However, computerised databases have become increasingly important because they can hold large amounts of data and allow easy access to and manipulation of data. In a more recent development, being facilitated and encouraged within Europe by EuroFIR, many national databases are now available online (see Section 3.7). A wide range of nutritional analysis software is also available (see Section 4.6 for issues to consider when using such software).

Further reading: Widdowson (1967); Church (2005, 2006)

2.2 Uses of food composition data

Food composition data are important in a range of fields, including clinical practice, research, government nutrition policy, public health and education, and the food manufacturing industry.

Examples of uses include:

- assessment of health and nutritional status, including risk assessment, at individual, regional, national and international levels;
- development and monitoring of government nutrition and health policy;
- formulation of appropriate institutional and therapeutic diets, including schools and hospitals;
- helping to identify the needs of nutrition education and health promotion and implementation of appropriate strategies;
- food and nutrition training in schools, tertiary education and in the workplace;
- research on relationships between diet and disease;
- nutrition labelling;
- nutrition and health claims;
- nutrient profiling;
- food product and recipe development;
- monitoring the nutritional value, safety, and authenticity of foods for food trade, and consumer protection and information;
- improvements to the food supply, such as plant breeding, and new methods of cultivation, harvesting and preservation.

Two specific examples of how food composition data are used are given in Boxes 1 and 2.

Box 1 Example – using food composition data to assess the energy intake of an obese patient

Why?

- To help estimate average daily intake and identify main dietary sources in order to provide personalised dietary advice as part of an overall weight management strategy.

How?

- Record the types of food eaten and the amounts consumed using appropriate dietary assessment methodology;
- Use information contained in a food composition database on the energy content of each food consumed to calculate total energy intake and to identify which foods are contributing most to energy intake.

Box 2 Example – using food composition data when developing a new food product

Why?

- To ensure that the food product meets any specified or desired criteria with respect to nutrient levels (*e.g.* fat, sugar, salt);
- To establish whether specific nutrition or health claims are appropriate and can be substantiated;
- For use in marketing and provision of information for consumers (*e.g.* nutrition labelling).

How?

- Use published food composition data as a reference point for nutrient levels in the new product;
- Determine nutrient content of the new product through chemical analysis or calculation from published nutrient data on its ingredients.

2.3 Evolving requirements for food composition data

In the first edition of *The Chemical Composition of Foods*, McCance and Widdowson (1940) stated that:

> 'A knowledge of the chemical composition of foods is the first essential in the dietary treatment of disease or in any quantitative study of human nutrition'.

This illustrates the main rationale for food composition studies at that time. Many years later, food composition studies remain central to *nutrition research* into the role of food components and their interactions in health and disease. However, there is an increasing level of sophistication and complexity. This has led to demands for complete, current and reliable food composition tables, together with information on a greater range of food components, including bioactive compounds.

In addition, international epidemiological studies and multi-centre research have highlighted the need for harmonisation and standardisation of food composition data produced at a national level (Deharveng *et al.* 1999). These national data have not previously been compatible owing to differences in, for example, food description and classification, nutrient definitions, methods of analysis, units, and modes of expression or matrix units (see Section 4.4).

National programmes for the *assessment of diet and nutritional status at a population level* have provided the motivation for continued support of food composition studies in many countries. Both epidemiological researchers and those assessing diets at a population level have particularly benefited from the development of computerised databases, which hold more data than printed tables and hugely facilitate the manipulation of data.

Food composition data are also used in the development of *therapeutic diets* (*e.g.* to treat obesity, diabetes, nutritional deficiencies, metabolic disorders, food allergy and intolerance) and *institutional diets* (*e.g.* schools, hospitals, prisons, day-care centres). These uses have also been facilitated by advances in information technology. For example, the recent focus on the nutritional content of school meals in the UK has led to the increased use of meal planning software, some of which has been designed specifically for this purpose. In Slovakia, a software application has been used to present food composition data in a user-friendly way for children. Data and recommendations are hidden behind pictures and food intake assessment is based on proportions, in comparison with an optimal food pyramid distribution.

The form in which most consumers are likely to see food composition information is on the nutrition labels of processed foods. Nutrition labelling is commonplace, driven by the demand for point-of-purchase information to ensure that consumers can make an informed choice. It is mandatory in some cases, such as if a claim is made. Where appropriate, the use of 'authoritative' data taken from compilations such as national food composition databases is permitted as an alternative to direct chemical analyses of products.

More recently, there has been a trend towards the use of front-of-pack or 'signpost' labelling such as the 'traffic light' concept in the UK or the Guideline Daily Amount concept across Europe. In addition, there has been a move towards nutrient profiling, a tool for categorising foods on the basis of their nutrient content. For example, it is planned that nutrient profiles will determine whether foods are eligible or not to bear nutrition and health claims under EU regulations, on the basis of their nutrient composition. Nutrient profiles are therefore currently being developed by the European Commission with advice from the European Food Safety Authority (EFSA).

In Sweden, the Keyhole Symbol (http://www.slv.se/en-gb/group1/Food--Health/Keyhole-symbol/) is a voluntary label scheme that identifies foods lower in fat, sugars and salt and higher in fibre compared with foods not displaying the symbol. A similar scheme exists for restaurants. These schemes have hugely expanded the user base for food composition data and have led to higher demands, in terms of both availability and food coverage.

In addition to forming the basis of nutritional labelling, food composition data have a number of other uses within the food manufacturing industry, including optimisation of product composition and supporting health claims substantiation (Roodenburg & Leenen 2007). A new EU regulation on nutrition and health claims made on foods (1924/2006/EC), which describes how nutrition and health claims should be used and how to apply for the authorisation of a claim, has recently been implemented (Aisbitt 2007). Good quality food composition data, both on nutrients and on other components that have a nutritional or physiological effect, are essential in supporting this regulation.

Further reading:

- *Uses of food composition data:* Egan *et al.* (2006, 2007); Rand *et al.* (1987); Harrison (2004); Williamson (2005); Pennington *et al.* (2007);
- *Use in the food industry:* Krines and Finglas (2006); Roodenburg and Leenen (2007);
- *Guideline Daily Amounts (GDAs):* http://gda.ciaa.eu; http://www.igd.com/igd-guidelinedailyamounts

3 How food composition databases are produced

3.1 Introduction

The earliest food composition tables were based solely on chemical analyses of food samples, which were mostly undertaken specifically for the tables. However, as the food supply has become more dynamic and diverse, and with the increasing number of nutritional and related components required, it has become impractical for compilers to rely only on chemical analysis that they have commissioned when compiling food composition databases. For example, in the UK, the third edition of *The Composition of Foods* (McCance & Widdowson 1960) introduced data on vitamin content of foods. Because of the amount of information already available and in order to avoid the need to analyse every food for every vitamin, values from the scientific literature were included for the first time, although the tables are still primarily based on analytical data.

Nowadays, food composition databases tend to be compiled using a variety of methods, including:

- chemical analysis;
- calculating and imputing values from data within the database;
- 'borrowing' or adopting values from other sources, including manufacturers and food composition databases from other countries.

3.2 Chemical analysis

When using chemical analysis, there are two primary considerations in the provision of reliable and representative food composition data:

• sampling, including the selection of appropriate samples, supported by unambiguous food description, and suitable sample handling;
• analysis using appropriate methods and, wherever feasible, accredited laboratories with quality assurance programmes in place.

3.2.1 Sampling

Sampling is a key element in the production of good quality food composition data. Food samples need to be carefully chosen to ensure that they are representative of the foods being consumed. This includes taking account of factors that could affect the nutrient content of a food as purchased (*e.g.* country or region of origin, season, brand, fortification) or as consumed (*e.g.* storage, preparation and cooking methods). Two specific examples of factors to consider when sampling are provided in Boxes 3 and 4.

Box 3 Example – factors to consider when sampling for carrots

• Variety or cultivar;
• Country/region of origin (differences in soil and climate);
• Season (new *vs.* old carrots);
• Processing (*e.g.* fresh, frozen, canned);
• Preparation (*e.g.* are the carrots peeled?);
• Cooking (*e.g.* raw, boiled, steamed, fried/roasted, addition of salt to cooking water).

Box 4 Example – factors to consider when sampling for mayonnaise

• Brand (which brands account for the largest market share?);
• Fat content (*e.g.* regular, light, extra light);
• Fat type (where stated);
• Presence of added ingredients (*e.g.* garlic).

In most cases, samples are collected at the retail level. Sampling should take place from a variety of retail outlets (*e.g.* supermarkets; specialist shops such as butchers, greengrocers; market stalls, etc.) relevant to the foods being studied, with regional sampling where appropriate. In some cases, samples may be collected from foodservice outlets or at a wholesale level.

It is common practice to combine appropriate foods into composite samples for analysis. This is a more cost-effective approach to obtaining nutritional data for representative samples. However, it does not provide any information on variation between samples. When choosing composite samples and subsamples, sources of variation are taken into account. The approach used will reflect, for example, the intended use of the data, the nutritional significance of sources of variation, and how consumers might report consumption. For example, respondents in a dietary survey might not report the country of origin of bacon that they had consumed, so it might be acceptable to combine samples from different countries in a composite sample.

In the hypothetical example in Box 5, chilled and frozen lasagnes are combined, because the freezing process is unlikely to result in differences of nutritional significance. Because this is a composite dish, the variation in formulation and hence nutrient content between brands will be greater but it would not be practical to analyse each brand separately. Therefore, different brands are also combined, in proportions that reflect, as far as feasible, market share. Reduced fat lasagne is analysed separately because it is expected that the fat content will be substantially lower than that of standard lasagne. In addition, consumers will often be aware that they have consumed a reduced-fat product.

Box 5 Example – composite samples and sub-samples for retail beef lasagne

• Composite sample 1 – Standard beef lasagne, retail: 10 sub-samples:
  ○ brand A chilled × 2
  ○ brand B chilled × 2
  ○ brand C chilled × 1
  ○ brand D chilled × 1
  ○ brand E frozen × 2
  ○ brand F frozen × 1
  ○ brand G frozen × 1
• Composite sample 2 – Reduced-fat beef lasagne, retail: 6 sub-samples:
  ○ brand H chilled × 2
  ○ brand J chilled × 1
  ○ brand K frozen × 3

Following purchase, food samples are transported, under appropriate conditions, to a laboratory. Because foods are unstable and susceptible to deterioration that can affect their composition, it is important that food samples are collected, transported and, where necessary, stored in such a way that loss of water and nutrients is minimised prior to analysis. In addition, appropriate labelling of samples in association with documentation (*e.g.* full description, date and place of sampling, transport and storage conditions, ingredients, edible proportion, methods of preparation and cooking, weight change on cooking, etc.) is undertaken so that users of the resultant nutrient data can accurately identify the foods that were analysed and judge whether the data are appropriate for their requirements.

In many cases, further preparation of samples is undertaken at the laboratory so that they are in the form in which they are usually consumed. For example, the parts of fruits and vegetables not usually consumed (*e.g.* fruit stones, inedible peel) might be trimmed, and bones and skin removed from fish. The weight of this 'inedible portion' will be recorded. Where appropriate, foods will be cooked, either according to manufacturers' instructions, for processed foods, or using standard cooking methods. The prepared food samples are homogenised, mixed and reduced, where necessary, to form the analytical sample, which is then stored under suitable conditions (*e.g.* frozen).

3.2.2 Analysis

These carefully collected, prepared and stored representative samples are analysed using appropriate methods. There is often more than one method available for determination of a nutrient [*e.g.* microbiological assay and high performance liquid chromatography (HPLC) for B vitamins] and it cannot be assumed that they will give comparable results. The microbiological approach measures vitamin activity of one or more vitamers but the HPLC approach separates and quantifies individual compounds, which can be summed to give the total vitamin content of a food. Wherever possible, the methods used will have been shown to be reliable and reproducible in several laboratories (*e.g.* in collaborative studies) and will have been recommended by organisations such as the Association of Official Analytical Chemists (AOAC), the European Committee for Standardization, the International Organization for Standardization (ISO) or the International Dairy Federation. They have to be applicable to the food being analysed and to the expected concentration of nutrient (*i.e.* some methods may perform less well at low nutrient concentrations).

A review of the analytical methods commonly used for the determination of nutrients, including their applications and limitations, has been published elsewhere (Greenfield & Southgate 2003). In addition, EuroFIR is drafting guideline information on analytical methods, which will outline key method steps and discuss comparability of methods. These guidelines will be used by national food composition database compilers to help evaluate data quality, as many of these compilers are not analytical chemists.

Wherever feasible, accredited laboratories (see Box 6) that have quality assurance programmes (*i.e.* preventive strategies to ensure that analytical data meet quality

Box 6 Laboratory quality terms explained

GLP (Good Laboratory Practice) can be defined as the 'application of standardised organisational processes and conditions under which laboratory studies are planned, performed, recorded and reported for the non-clinical testing of chemicals for the protection of man, animals and the environment' (EC Directive 2004/9/EC);

ISO 9001 is an internationally recognised standard for quality management, which is designed to apply to most products and services. Organisations certified as complying with ISO 9001 will have established quality objectives and produced and implemented a documented quality policy, which is subject to external audit;

ISO 17025 is similar to ISO 9001 but applies specifically to calibration and testing laboratories. It includes both management requirements (*e.g.* implementing an effective quality management system) and technical requirements (*e.g.* proficiency of personnel, procedures and equipment);

Accreditation is one way in which the technical competence of a laboratory to undertake analysis can be assessed. A European network of accreditation bodies (http://www.european-accreditation.org/content/home/home.htm) has been established. From this website, contact information for national bodies can be found;

Participation in *proficiency testing* allows the assessment of laboratory analytical performance through interlaboratory comparisons, usually by determination of specified analytes in specially prepared test materials.

requirements) in place are used for analysis. For example, laboratories may comply with the requirements of international standards such as ISO 9001 or ISO/IEC 17025 or with Good Laboratory Practice (see Box 6). They will utilise standard reference materials (SRMs) or certified reference materials (CRMs), which contain a known amount of a specified nutrient, to check the performance of analytical methods being used. Many laboratories participate in proficiency testing schemes such as the Food Analysis Performance Assessment Scheme (FAPAS) (http://www.fapas.com/), which is run by the Food and Enviroment Research Agency in the UK. The European Proficiency Testing Information System (EPTIS) database (http://www.eptis.bam.de/en/index.htm) lists proficiency schemes operating in a range of countries.

EuroFIR has developed a digital learning resource (e-learning module) on 'nutrient analysis for non-chemists', encompassing fats and fatty acids, proteins and amino acids, carbohydrates and fibre, and minerals. The module uses animations and visuals, together with interactive exercises, to cover chemical and technical principles, and the strengths and limitations of macronutrient analyses, together with the interpretation of laboratory results and evaluation of quality.

Further reading:

- *Producing food composition data:* Rand et al. (1991); Greenfield and Southgate (2003); Greenfield et al. (2008);
- *Prioritisation of foods for analysis:* Haytowitz *et al.* (2002);
- *Sampling and sample handling:* Greenfield and Southgate (2003);
- *Analytical methods:* Kirk and Sawyer (1991); AOAC (2006); EuroFIR e-learning module (http://www.eurofir.net);
- *Proficiency testing:* Earnshaw *et al.* (2009);
- *Reference materials:* http://irmm.irc.ec.europa.eu; http://www.nist.gov/

3.3 Calculating and imputing values

While chemical analysis is considered to be the preferred method for producing food composition data, in practice available resources are insufficient to permit determination of every nutrient in every food type. Therefore, food composition database compilers need to consider how analytical data can be further utilised to increase the number of values available within a dataset. Approaches commonly employed include:

- Estimation from similar foods. For example:
  - using values for a raw food to estimate values for the cooked version of the food;
  - imputing values between alternative forms of the same food, *e.g.* various cuts of beef, vegetables cooked using similar methods, fresh or frozen vegetables, different varieties of fruits and vegetables. This approach can be used only when the value is not likely to be substantially affected by the form of the food (including the cooking method), or where an adjustment can be made (*e.g.* for the lean to fat ratios of different cuts of meat);
- Calculation of values for composite dishes from the ingredients (*i.e.* recipe calculation), taking account of changes on cooking where appropriate (*e.g.* water loss or gain, fat loss or gain, vitamin losses);
- Assumed (or logical) zeros, which are often applied in situations where it is generally accepted that negligible amounts of a nutrient would be present in a food type (*e.g.* dietary fibre in meat) or where assumptions can be made based on levels of other nutrients (*e.g.* if total fat content is zero, concentrations of individual fatty acids can also assumed to be zero).

Although the concentrations of many nutrients in food are determined by analysis, values for some nutrients are derived by calculation. Nutrients may be 'derived' by calculation rather than analysed because, for example, they are the sum of analysed components (*e.g.* carbohydrate as the sum of individual sugars and starch) or to take account of differing biological activities of nutrient components. Nutrients derived by calculation include:

- *Energy:* available (metabolisable) energy is usually estimated by applying energy conversion factors (Atwater factors) to the amounts of protein, fat, carbohydrate, alcohol and sometimes fibre in a food;
- *Protein* is derived by applying a nitrogen conversion factor, which depends on the type of protein present, to the nitrogen content (determined by analysis) in a food;
- *'Available' carbohydrate*: this can either be derived from the sum of carbohydrate components (*e.g.* starch, individual sugars), or 'by difference' [=100 – sum (water + protein + fat + fibre + ash)];
- *Total vitamin A activity*, expressed as retinol equivalents, is derived from the relative activities of components with provitamin A activity (*e.g.* all-*trans* retinol, 13-*cis* retinol, β-carotene, α-carotene, cryptoxanthins);
- *Total vitamin E activity*, expressed as α-tocopherol equivalents, is derived from the activities of tocopherols and tocotrienols present in the food;
- *Vitamin D activity* may take account of the metabolite 25-hydroxy cholecalciferol;
- *Niacin equivalent* includes both niacin and a contribution from tryptophan (tryptophan/60), which can be converted by the body into nicotinic acid;
- *Folate equivalents:* combines naturally present folate and synthetic folic acid from enriched food in one value.

There is some debate and some variations in the calculation methods used and conversion factors applied for these nutrients. Further details are provided in Section 4.4.

Although it is recognised that their inclusion is inevitable owing to resource limitations, values obtained using these approaches are usually considered by food composition experts to be of lower quality compared with analysed values. Documentation (see Section 3.6) is especially important for calculated and imputed values.

Further information on calculating the composition of cooked dishes is provided in Section 4.5.

Further reading:

- *Procedures for estimating nutrient values:* Schakel *et al.* (1997)

3.4 Borrowing values from other sources

When chemical analysis is not feasible, and particularly when data are missing for specific nutrients, it is common practice to 'borrow' or adopt data that were originally generated or compiled by other parties. Possible sources include manufacturers' data and food composition databases from other countries.

Manufacturers' data, which may only be available for the nutrients included on food labels, is often used for processed foods. For example, it might be used for foods for which formulations are known to change (*e.g.* fortified breakfast cereals, fat spreads) and hence for which data quickly become obsolete or for foods where one brand dominates the market (*e.g.* confectionery). In these cases, it might be considered that allocation of resources to chemical analysis is not justified. Owing to limited resources for analysis, together with the diverse and dynamic nature of the food supply, particularly for processed foods, the use of food industry data is likely to increase and EuroFIR has considered ways in which exchange of data between the food industry and national food composition database compilers might be facilitated (Ovaskainen *et al.* 2005 2006).

For countries that have very limited resources or where food composition databases have been established relatively recently, it is common to borrow data from larger databases such as the United States Department of Agriculture (USDA) database or the UK *McCance and Widdowson's The Composition of Foods* series. Data may be borrowed for whole foods or just for specific nutrients, particularly vitamins, for which analyses are costly or where suitable laboratory facilities and method expertise are not available locally. Regional food composition networks (*e.g.* AFROFOODS for Africa; LATINFOODS for central and South American countries) have been established in many parts of the world through the INFOODS network (http://www.fao.org/infoods/index_en.stm) and these can facilitate data sharing. In Europe, EuroFIR is working to improve compatibility of data and will also provide easy access to a wider range of data produced by European countries, through an online resource (see Section 3.7).

When borrowing or adopting data from other sources, food composition database compilers will consider whether the values are appropriate for their own database. For example, because fortification practices can differ between countries, values for fortified breakfast cereals in one country's database might not be appropriate for another country. Similarly, fortification of salt with iodine and flour with folic acid varies from country to country. Food descriptions can be misleading (*e.g.* 'squash' can refer to a soft drink or to a vegetable). Even where foods are apparently similar, nutrients may have been determined using different methods or be expressed in a different way. Documentation of values (see Section 3.6) assists database compilers in judging whether data are appropriate for their requirements. Database users as well as compilers need to be aware of these data compatibility issues, which are discussed further at Section 4.4.

3.5 Data evaluation and quality

Before values can be incorporated into food composition databases, compilers will evaluate the data. This is an important step both for new analytical data and for values borrowed from other sources. Where feasible, values are compared with those for similar foods and other checks undertaken (*e.g.* the sum of water, protein, fat, carbohydrate and dietary fibre should approximate 100%). A range of data quality measures, relating to the food identity, sampling and analytical aspects, will be considered. However, in some cases, data that may be considered 'low' quality in terms of the sample could still be useful because it may be the only available data in relation to a specific food.

When evaluating data, compilers will consider a range of questions, such as:

- Is the identity (description) of the food clear and unambiguous?
- Is the food described applicable to the database (*e.g.* if data are borrowed from another country's food composition database, is the food a good match)?
- Has the sampling approach (including sampling design, purchase, handling and preparation) resulted in

a sample that is representative of the food described, as purchased or as consumed?
• Are the analytical data of acceptable quality (*e.g.* choice of analytical method, quality assurance procedures in place)?

For example, a multi-nutrient data quality evaluation system has been developed in the USA (Holden *et al.* 2002). The five evaluation categories used are: sampling plan, number of samples, sample handling, analytical method and analytical quality control. The ratings for each category are combined to give a 'Quality Index' and a confidence code, which are disseminated alongside the nutrient data, giving users an indication of the level of confidence in each value.

EuroFIR is currently developing a data quality evaluation system, which is based on the USDA system and other existing systems but can be applied to data collected by different organisations within Europe. Not only will EuroFIR's system allow for evaluation of analytical data, as the other systems do, but it also aims to evaluate the quality of data from other sources. These sources are referred to as 'non-analytical data' and include data generated by recipe calculation, estimated from similar foods, or taken from food labels. This aspect is particularly relevant given that, owing to resource limitations, many databases contain considerable amounts of data that were not generated by laboratory analysis.

The ultimate goal of every database is to contain only high-quality data that reflect the true value of a nutrient present in a country-specific food in the best possible manner. However, owing to the resources that would be required to achieve this goal, this remains an aspiration. Even so, a first and important step is the quality evaluation process itself, because having information about the quality of data (whether it be high or low quality) is already better than not knowing the quality. The next step is the gradual improvement of data quality. Once the EuroFIR quality evaluation system is completed and implemented, it will allow users to easily judge the quality of all data so that they can quickly assess whether the data fits their intended purpose.

EuroFIR is not only developing an evaluation system to visualise the quality of the food composition data, but also a more general quality framework for the entire compilation process of food composition data. This quality management system is structured around three modules: quality management, project management and technical and scientific competence. Key elements that have been identified and developed include:

• a harmonised compilation process (including a consistent system of documentation and the data evaluation process) and the identification of its hazards and critical points, with the development of corresponding Standard Operating Procedures (SOPs);
• future 'certification' of compilers, through a programme of initial and ongoing professional development, and audits to evaluate/monitor compiler performance; and
• improvements in addressing users' and stakeholders' needs.

The preparation of the SOPs is a first for the food composition community (Westenbrink *et al.* 2009). The generic compilation process and the generic SOPs can assist the food database compilers as a basis to develop their database-specific quality documents.

Further reading: Castanheira *et al.* (2007a,b; 2009a,b); Holden *et al.* (2002); Westenbrink *et al.* (2009)

3.6 Documentation

An important part of the food composition data compilation process is the documentation of information about the food, the nutrient values associated with that food, and how those values were derived. This information will enable users to assess the quality of the data and whether the food and values are appropriate for the user's intended purpose. In addition, documentation is valuable for the compilers themselves, both to update the food composition database and to justify decisions made during compilation.

With technological advances and, in particular, the computerisation of the compilation process, it is now much easier to make documentation available to users. For example, the French national database (AFSSA/CIQUAL 2008) provides information, for each food where available, on minimum and maximum values found in the different data sources used, the number of samples used to determine the selected value, a reference code corresponding to data sources for a given value, and a confidence code (A, B, C or D) characterising the quality of the selected value. However, for many national databases, documentation of older data will have been in the form of hard copies, which may have been archived or even destroyed. It will, therefore, not always be possible to access historical documentation, and providing complete documentation is likely to remain an aspiration for some national databases for the foreseeable future.

However, there has been a growing interest in food composition data interchange and harmonisation, both within Europe and further afield. Based on earlier work (*e.g.* Schlotke *et al.* 2000), EuroFIR has developed a framework for the documentation of food composition data, which will form the basis of a new European standard (http://www.eurofir.org/eurofir/). In addition, national compilers within the EuroFIR consortium have undertaken documentation of their datasets, or subsets of their data, according to the value documentation framework developed.

Some documentation (*e.g.* food name, component name, unit) is essential for meaningful values. Documentation should include as much as possible of the following, as appropriate and where available:

- *Food*: name, description, physical form, treatments applied, cooking and/or preservation methods, packaging, area of origin, brand, edible portion, etc.;
- *Data source/acquisition type*: *e.g.* analytical, recipe, estimated/imputed, 'borrowed' from another data source;
- *Sample*: number of samples, dates and area of sampling, composite sample breakdown, etc;
- *For analytical data*: date of analysis/report; methods used, including references, quality assurance details, statistical data (if available);
- *For estimated/imputed/recipe values*: basis of value, including recipe information;
- *For 'borrowed' data*: references;
- *Component description*: component name;
- *Units*.

3.7 Formats available

While printed tables are still produced in most countries, computerised databases have become increasingly important because they can hold large amounts of data and allow easy access to and manipulation of data. Electronic formats range from ASCII (plain text), spreadsheet formats on disk, CD-ROMs and databases within online access.

EuroFIR has encouraged and supported national food database compilers in making data available online and over 20 European databases are now available online. EuroFIR is also developing a facility that will allow users to search for data across a range of food composition databases and thus improve accessibility to international data.

As well as official versions of food composition tables in printed and electronic format, there are many other products based on, or dependent on, food composition data. Products are aimed at a wide spectrum of users, including consumers, health professionals and caterers. These include:

- abridged (shortened) versions of tables, traditionally in a printed format, but more recently also for online access (*e.g.* calorie and carbohydrate counters);
- user-friendly formats (*e.g.* expressed per portion; in formats suitable for nutritional labelling);
- nutritional analysis software or online nutritional analysis – a wide range of products, including products aimed at health professionals (including nutritionists and dietitians), education, food industry (labelling and product development) and caterers (menu planning) (see Section 4.6); and
- novel products (*e.g.* food weighing scales that incorporate information on the nutrient content of foods).

Further reading:

- *European food composition databases, including links to national databases and online data, where available*: http://www.eurofir.org/eurofir/EuropeanDatabases.asp
- *Online databases worldwide (including links)*: http://www.eurofir.org/eurofir/FoodCompInfo.asp
- *Lists of food composition tables and databases available, including web links:*
    - http://www.langual.org/langual_linkcategory.asp?CategoryID=4&Category=Food+Composition (web information);
    - http://www.fao.org/infoods/directory_en.stm (includes both printed copies and online databases).
- *EuroFIR databases search facility*: Møller et al. (2007); further details available from: am@danfood.info or paul.finglass@bbsrc.ac.uk

3.8 Specialised databases

There is a growing body of evidence to suggest that some biologically active plant constituents, other than nutrients, may have potential benefits on health, including promoting optimal health and reducing the risk of some chronic diseases such as cancer and coronary heart disease. These constituents, known as bioactive compounds or phytochemicals, include flavonoids, phenolic acids, carotenoids and phytosterols (Gry *et al.* 2007).

In order to assess intakes of individual bioactive compounds, particularly in relation to epidemiological research on plant foods and health, it is vital that composition data on the types and amounts present in foods are available. This information may also be used to assess health claims on foods and nutritional supplements and to evaluate novel foods. However, data on bioactive compounds have not tended to form part of programmes to determine the nutrient content of food or to be included in food composition databases. Therefore, a number of specialised databases have been developed, to include information on either specific bioactive compounds or a range of compounds. For example, in the USA, databases on flavonoids, proanthocyanidins and isoflavones are available.

In particular, the EuroFIR-BASIS database, which is under development, includes critically assessed composition data on a wide range of bioactive compounds present in edible plants and plant-based foods. It also provides access to critically assessed data on the biological effects of these compounds. This database has also been extended by merging with the NORTOX-BASIS database on bioactive compounds with toxic effects as part of a project being supported by EFSA. The enlarged database will be utilised by EFSA for supporting their work on nutrition and health claims and risk assessment.

Specialised databases may also be produced to help assess the intake of dietary supplements, which can contribute substantially to intakes of micronutrients. Owing to the dynamic nature of the dietary supplement industry, it is often necessary to compile these databases specifically for a dietary survey or research project and then update them on a regular basis.

Further reading:

- *Plant bioactive compounds and EuroFIR-BASIS database:* Black *et al.* (2008); Denny and Buttriss (2007); Gry *et al.* (2007);
- *US specialised databases (individual bioactive compounds, dietary supplements):* http://www.ars.usda.gov/Services/docs.htm?docid=5121
- *Further details about accessing EuroFIR's bioactive databases available from:* paul.finglass@bbsrc.ac.uk

4 Considerations in the use of food composition databases

4.1 Limitations of food composition data

> 'There are two schools of thought about food tables. One tends to regard the figures in them as having the accuracy of atomic weight determinations; the other dismisses them as valueless on the ground that a foodstuff may be so modified by the soil, the season, or its rate of growth that no figure can be a reliable guide to its composition. The truth, of course, lies somewhere between these two points of view'.
>
> Widdowson and McCance (1943)

This statement, made over 65 years ago, remains equally valid today. Food composition databases are, as discussed in Section 2, vital tools in many fields, but they do have limitations. These have been summarised elsewhere (Ershow 2003; Greenfield & Southgate 2003) but include:

- variability in the composition of foods;
- partial or limited coverage of foods or nutrients;
- errors arising in database use;
- inappropriate database or food composition values (see Section 4.2);
- incompatibility of data sources (see Section 4.4);
- differences in software packages (see Section 4.6).

4.1.1 Variability in the composition of foods

Analysis of foods for nutrient content is, as far as possible, undertaken on representative samples (see Section 3.2). However, foods, both at the commodity level and processed foods, do vary in their composition. Where feasible, food composition databases should, ideally, provide some indication of variability. However, in practice, limited resources may prevent this, particularly because analyses are often undertaken on pooled samples of foods. It is important to recognise that values in food composition tables are typical values and that any given food will differ from those values, even if the data are current and of high quality.

Some examples of factors affecting the composition of foods are given in Box 7.

4.1.2 Other limitations specific to the content and coverage of databases

Owing to limited resources, the diversity of diets, and the continuously changing nature of the food supply (types and composition of foods consumed), it is not feasible for food composition databases to be comprehensive in terms of food or nutrient coverage, or to be completely up to date. Further information on the implications of incomplete coverage ('missing values') and how to deal with it is provided in Section 4.3.

Some values in food composition databases may not be ideal owing to the age of data or because values that have been 'borrowed' from other sources (*e.g.* food composition tables from other countries) have limitations or are not compatible (see Sections 3.4, 4.2 and 4.4).

Thus, values provided in food composition databases cannot be considered to be completely accurate and users need to recognise their limitations. It is also important that users ensure that data limitations are taken into account when interpreting and reporting results of studies using food composition data.

4.1.3 Errors arising in database use

Even using the most comprehensive and well-documented food composition databases does not guarantee robust and reliable results, as there are many errors that can arise in using food composition data. These include errors in matching foods, use of incompatible data, inappropriate strategies for dealing with

Box 7 Examples of factors affecting the composition of foods

- Plant-based foods:
  - country or region of origin (*e.g.* soil composition, climate);
  - cultivar or variety;
  - fertiliser use;
  - season;
  - transport conditions;
- Animal-based foods:
  - season;
  - feeding regimen;
  - age of animal;
  - cut of meat;
  - trimming practices (*e.g.* lean : fat ratio and inedible portion);
- Processed foods:
  - as above for composition of individual ingredients, plus:
  - formulation/recipes;
  - variation during production (*e.g.* quantities of ingredients, cooking times);
  - fortification levels;
  - brand;
- All foods:
  - storage time and conditions;
  - preparation methods (*e.g.* peeling of vegetables, trimming of meat, addition of salt, type of fat used for frying, cooking time and temperature);
  - cooking methods (*e.g.* boiling, steaming, stir-frying, microwave cooking, roasting, grilling, frying).

missing values, and problems relating to the use of nutritional analysis software. Using food composition data to estimate nutrient intakes or the nutrient content of a recipe or menu can yield further errors owing both to the limitations of dietary assessment techniques and to errors associated with dietary assessment (*e.g.* conversion of reported portion descriptions to weight).

4.2 Are the data appropriate for the intended purpose?

Users of food composition data should evaluate the information available, to ensure that it meets their requirements in terms of applicability and quality, especially when using data from a range of sources. Requirements of users will vary according to the intended use of the data. For example, a researcher assessing the intake of a specific micronutrient as part of a nutritional epidemiology study might have different requirements compared with a dietitian trying to obtain an overview of a patient's diet. Some of the questions that users might consider are suggested in Box 8. (Further information on compatibility of data is provided in Section 4.4.)

4.2.1 Food description and classification

Even when using the most comprehensive and up-to-date food composition data, errors will be introduced if the food chosen from a food composition database does not match the food required by the user. Some food names may be ambiguous; for example, 'sherbert' can be a flavoured sweet sparkling powder (confectionery), a drink of sweet diluted fruit juice, or a frozen dessert (sorbet). There may be regional or international variations in the name of an apparently similar food (*e.g.* fish finger in the UK *vs.* fish stick in the US). In addition, food names are not always easily understood by those using another language, which can cause difficulty when using data from 'foreign' food composition databases. For example, aubergine is also known as 'eggplant' but does not contain eggs!

Food composition database compilers use a range of methods to identify foods. As well as providing the 'food name', some databases also include a longer and more explanatory 'food description'. In addition, foods may be classified according to food group, whereby foods with similar characteristics are aggregated or grouped (*e.g.* dairy products, milk, cereal products, bread).

Box 8 Are the data appropriate for the intended purpose?

- Does the food description/classification match that of your required food (*e.g.* beware regional and international variations in food names)?
- Does the preparation method (*e.g.* processing method, raw *vs.* cooked, cooking method, recipe) match that of your required food?
- How old are the values?
- Are the nutrient levels likely to have changed (*e.g.* owing to changes in formulation or fortification in processed foods)?
- If taken from a variety of data sources, are the values compatible?

LanguaL (Langua aLimentaria or language of food) is an automated method for describing, capturing and retrieving data about food. This multi-lingual thesaurus system (http://www.langual.org/) uses facetted classification that is independent of language. Each food is described by a set of standard, controlled terms chosen from facets that describe different characteristics of foods (*e.g.* food origin, physical attributes (state), processing, packaging, geographic origin). For example, a starchy root or potato would be assigned code A0829 while a food that has been baked or roasted would be assigned a code G0005. In Europe, nearly all national food composition databases have been indexed using LanguaL as part of EuroFIR, giving about 28 000 indexed foods (http://www.eurofir.org/eurofir/). This will allow database compilers to exchange data more easily and other users to compare the nutrient content of equivalent foods across a range of European food composition databases.

4.2.2 Preparation/processing methods, including fortification

The variability in the nutrient content of foods, owing to both natural variation and to extrinsic factors, is discussed in Section 4.1. Owing to a lack of data, users may not be able to adjust for such variability. However, there may be cases where the data in food composition databases may not be the most suitable for the intended purpose and alternative data sources should be considered.

For example, fortified breakfast cereals are an important source of iron (and some other micronutrients) in the European diet. However, fortification levels may vary between countries. Even within a country, levels vary by brand and it is not feasible to provide values for all brands in the national food tables. A UK study compared iron intakes estimated using values from the UK tables with those estimated using brand-specific manufacturers' data for breakfast cereals (O'Hara *et al.* 2004). Use of data from the UK tables produced estimates of iron intake that were between one-third greater and one-fifth less than those estimated using brand-specific data. This has implications both for dietary studies and for dietitians formulating advice.

4.2.3 Age of data

As already discussed, the production and compilation of food composition data is time-consuming and costly. Therefore, it is not always possible to ensure that the data in food composition databases, and particularly in printed tables, are representative of foods consumed at a given time. This is especially true as the food supply becomes more diverse and complex. For example, there can be high turnover rates of manufactured foods (Gillanders *et al.* 2002). In addition, some foods are enhanced or modified to provide potential additional health benefits. These include functional foods and enriched or fortified foods such as orange juice with added calcium and fat spreads with added plant sterol esters (Spence 2006).

Although the nutrient content of individual foods may change gradually over time, the changes may only be quantified when new analyses are undertaken. Thus, a major update of a food composition database can create a break in trends for dietary nutrient intake. For example, during the early 1990s, a programme was undertaken to analyse carcase meats and poultry in the UK, replacing data from previous studies undertaken in the 1970s. The application of the new data to the then National Food Survey of household food consumption in 1994 resulted in an apparent decrease in fat intake from 84 g/person/day in 1993 to 80 g/person/day in 1994 (DEFRA 2001). The decrease in fat intake reflected a real change in the composition of meat, but suggested that the change had taken place over a short period of time, rather than over a number of years.

Similarly, the incorporation of new data on individual carotenoids, some of which have a lower biological activity compared with β-carotene, led to an apparent decrease in the intake of β-carotene equivalents from 2445 μg/person/day in 1989 to 1877 μg/person/day in 1990 (or 1220 μg/person/day to 1100 μg/person/day of retinol equivalents). In this case, updates to the food composition database resulted in improved data but did not reflect real changes in intake.

Similarly, a study in The Netherlands found that about half of a decrease in population fat intake, as assessed in two national food consumption surveys undertaken about 4 years apart, could be attributed to changes in nutrient databanks (Hulshof *et al.* 1996). Changes in food composition included: the introduction of fat spreads with lower fat content, reductions in the fat content of some dairy desserts and cheeses, and new values for the fat content of meat that reflected changes over a relatively long period of time. To allow valid comparisons of nutrient intake over time in these national food consumption surveys, some adjustments were made to avoid artificial changes, such as differences resulting from improvements to data quality (Beemster *et al.* 2000). A US study also reported that reanalysing data from its national food consumption study using updated food composition data resulted in minor but statistically significant differences in mean intakes of several nutrients, and in the contribution made by some food groups to intake (Ahuja *et al.* 2006).

Where documentation of food composition databases is available, users can check the age of the data, and make informed judgements as to whether values are suitable for the intended purpose. Even where no documentation is available, knowledge of where changes in composition might be expected can be used to make such judgements.

For example, as potential links between diet and chronic disease become established, there is now an increasing trend towards changes in the nutrient profiles of mainstream prepared and processed food products. Such changes can benefit consumers without them needing to adjust their dietary habits. For instance, many food manufacturers have changed their formulations or fat sources in order to reduce the *trans* fatty acid content of products such as fat spreads, biscuits and cakes, as well as fast food within the catering sector. If the intake of this component is being assessed, it might be necessary to use alternative data sources, such as manufacturers' data. Similarly, food manufacturers in many European countries are working to reduce the amount of salt in their products.

Further reading:

- *Food description and classification:* Ireland and Møller (2000); Ireland *et al.* (2006); LanguaL international framework for food description: http://www.langual.org/;
- *Studies considering the implications of changes in food composition on dietary assessment:* Hulshof *et al.* (1996); Beemster *et al.* (2000); Gillanders *et al.* (2002); O'Hara *et al.* (2004); Spence (2006).

4.3 Incomplete coverage (missing values)

Owing to limited resources, the diversity of diets and the continuously changing nature of the food supply, it is not feasible for food composition databases to be comprehensive in terms of food or nutrient coverage. Therefore, users will find that foods of interest are missing or that the nutrient profile for some foods is incomplete, especially with respect to micronutrients.

One of the outcomes of EuroFIR has been the provision of new food composition data on traditional foods and ethnic foods, both areas where a need for data had been identified. Although the nature of these pilot studies was such that only a small amount of new data has been provided, standardised procedures for the production of data have been developed. It is hoped that these methods, including recipe calculation procedures, will be used to extend the available data on traditional and ethnic foods in the future.

Where complete foods of interest are missing, users will need to seek alternative data sources, which might include:

- manufacturers' data (*e.g.* from labels or direct from food manufacturers or retailers);
- composition tables from other countries;
- recipe calculations (*e.g.* using household recipes or commercial product formulations for processed foods);
- data from another similar food or a different form of the food within the same database (*e.g.* boiled broccoli might be used in place of missing data for steamed broccoli); or
- values for other components in the same food (*e.g.* chloride from sodium, fatty acids from fat content where there is one main fat source, of known fatty acid composition).

When substituting another food, users should consider whether the food chosen is a sufficiently close match for the intended purpose (see Section 4.2) and, if using data from another source, whether the data are compatible (see Section 4.4).

Limited resources prevent the analysis of every nutrient in every food. Thus, nutrient analyses are often prioritised to include those for which a food is an important source, nutrients that cannot easily be estimated, and those of particular interest in health terms. In addition, the focus in terms of nutritional interest and, to a lesser extent, developments in analytical methodology has evolved with time. For example, vitamins have been present in the Dutch food tables since the 1940s, but values for folate and vitamin B12 were introduced for the first time in 2001. Because it takes many years to build data for a component newly added to a food composition database, incomplete coverage, or the presence of missing values, is a particular challenge for such components.

Individual missing values, or 'gaps' within a food may be presented as a 'blank' field or may be indicated using a specific symbol *e.g.* 'N' in the UK tables (FSA 2002). If these missing values are treated as zeros in calculations of nutrient content of recipes or dietary intakes, the resultant outputs will be an underestimate. For example, an analysis of missing UK data in dietary records of young children suggested that missing values resulted in underestimates of more than 10% in the intakes of some nutrients (*e.g.* vitamins D and E), although the impact on intakes of many nutrients was much smaller (Cowin & Emmett 1999).

Users should therefore consider, on a case by case basis, how to deal with missing values:

- ideally, the 'gaps' should be filled using alternative data sources (see above);
- it is important to be aware that the majority of commercial nutrient analysis software products do not take account of missing values in their calculations, although some do 'flag' missing values (see Section 4.6);
- where a decision is made not to add estimates for missing values, their presence and implications for the results presented should be emphasised.

Further reading:

- *Implications of missing values:* Cowin and Emmett (1999);
- *Procedures for estimating nutrient values:* Schakel *et al.* (1997);
- *Traditional foods:* Trichopoulou *et al.* (2006 2007); Weichselbaum *et al.* (2009);
- *Ethnic foods:* Church *et al.* (2006); Gilbert and Khokhar (2008); Chen *et al.* (2009); Khokhar *et al.* (2009).

4.4 Compatibility of data from different sources

Users of food composition data may often need to use more than one source of data. For example, a specific food might not be available in the national tables, nutrient values may be missing (see Section 4.3), or there may be reasons why the data are inappropriate for the intended use (see Section 4.2). In such cases, users will need to either estimate or calculate values based on recipes (see Sections 3.3 and 4.5) or use other sources, including manufacturers' data and food composition databases from other countries. In recent years, international epidemiological studies and multi-centre research have highlighted the need for harmonisation and standardisation of food composition data produced at a national level (Deharveng *et al.* 1999; Ireland *et al.* 2002). EuroFIR has built on previous work in this area to draft recommendations that will form the basis of a European standard for food composition (Møller *et al.* 2007).

When 'borrowing' (adopting) food composition data, users should, as always, consider whether the data are applicable for the intended purpose (see Section 4.2). In addition, users should ensure that data from each different source are as compatible as possible. For example:

- food descriptions can be misleading (*e.g.* 'squash' can refer to a soft drink or to a vegetable);
- the nutrient content of animal products such as meat and dairy products can vary according to breed, feeding regimen and season;
- similarly, the nutrient content of plant foods such as cereals, fruit and vegetables can vary according to variety, season, growing conditions (*e.g.* soil type), country of origin and storage;
- as fortification practices can differ between countries, values for fortified breakfast cereals in one country's database might not be appropriate for another country;
- even where foods are apparently similar, nutrients may have been determined using different methods or be expressed in a different way;
- the basis of nutrient values can also differ between food composition data sources. For example:
  - nutrient units (*e.g.* sodium is generally expressed in mg in food composition databases but is expressed in g on food labels);
  - the derived unit [*e.g.* per 100 g edible portion, per 100 g as purchased (*i.e.* with inedible parts), per portion, dry weight basis, per unit volume].

Documentation of values (see Section 3.6), where available, assists database users in judging whether data are appropriate for their requirements. For example, in the new EuroFIR standard for value documentation, different nutrient descriptors are applied according to the analytical procedure used, the conversion factors applied or the mode of expression/matrix unit. EuroFIR documentation can also assist in correctly identifying foods, as it uses the LanguaL food description system (see Section 4.2). Where documentation is not available, it is important that users refer to the notes provided in the food composition table being used (*e.g.* the introduction to Food Standards Agency 2002).

Examples of components and nutrients for which differences between sources commonly occur are discussed in the subsequent sections.

4.4.1 *Energy*

Available (metabolisable) energy is usually estimated by applying energy conversion factors (Atwater factors) to the amounts of protein, fat, carbohydrate and alcohol in a food. General Atwater factors, which were derived at the end of the 19th century and relate to any food, are widely used (Atwater & Bryant 1900, reproduced in Greenfield & Southgate 2003). More recently, values for sugar alcohols, organic acids, oligosaccharides and dietary fibre have been suggested, but these are not widely used in food composition databases. Food-specific Atwater factors (Merrill & Watt 1973, reproduced in FAO 2003) are based on heats of combustion applicable to components or specific food groups and may result in different energy values. There may be differences in the conversion factors used on nutritional labelling compared with some food composition databases. For example, the UK tables (FSA 2002) use a factor of 3.75 kcal/g (16 kJ/g) for carbohydrate (expressed as monosaccharide equivalent), whereas a factor of 4 kcal/g (17 kJ/g) is used for labelling. Before EU labelling concepts were incorporated into the Slovak food composition database, a complex energy calculation procedure had been applied, including four different factors, based on food commodity, for carbohydrate. Thus, users of food composition data should consider which conversion factors might have been applied to 'borrowed' data (*e.g.* values taken from food labels will comply with EU labelling conventions, while documentation accompanying tables from other countries should indicate the conversion factors applied).

4.4.2 *Protein*

The protein concentration in a food is derived by applying a nitrogen conversion factor to the nitrogen content of the food, determined by analysis. The nitrogen factor can either be the generic factor of 6.25, which is specified for use in EC nutrition labelling, or food-specific factors [*e.g.* 5.70 for non-wholemeal wheat flour, 6.38 for milk and milk products (FAO/WHO 1973; main factors listed in Greenfield and Southgate 2003)]. In addition, non-protein nitrogen, such as urea, purines and pyrimidines, which are present in significant quantities in some foods, may be excluded from the calculation if it has been analysed separately. Thus, when comparing food composition data from different sources, users should consider the nitrogen conversion factor applied and whether non-protein nitrogen has been excluded in the derivation of protein content.

4.4.3 *Carbohydrate*

There are several methods of estimating and expressing carbohydrate:

- *'Available'* vs. *'total'*: 'available' includes starch, individual sugars and some oligosaccharides, but excludes dietary fibre, whereas 'total' includes dietary fibre. However, often the term used is simply 'carbohydrate' and it is necessary to check the notes accompanying the food composition data to confirm the definition;
- *'By sum'* vs. *'by difference'*: carbohydrate values can either be derived:
  - from the sum of carbohydrate components (*e.g.* available carbohydrate includes starch, individual sugars and some oligosaccharides), or
  - 'by difference' [*e.g.* available carbohydrate = 100 – sum (water + protein + fat + fibre + ash + alcohol)]. The 'by difference' method can only give an approximation of carbohydrate and the value will incorporate any errors arising from the determination of each of the components used to derive it;
- *'Monosaccharide equivalents'* vs. *'weight basis'*: the UK food composition tables differ from those in most other countries in that they express total carbohydrate and its components as monosaccharide equivalents, following hydrolysis (FSA 2002, which includes conversion factors). For foods containing disaccharides (*e.g.* sucrose, lactose, maltose), oligosaccharides and polysaccharides (*e.g.* starch), and particularly for starchy foods, carbohydrate values expressed as monosaccharides will be higher than those expressed on a weight (anhydrous) basis.

Box 9 illustrates some of the values that are possible using the different methods.

4.4.4 *Dietary fibre*

Dietary fibre is a good example of a component for which the analytical method used can affect the value given. Values obtained by the widely used AOAC gravimetric method (method 985.29; AOAC 2000), which measures lignin, resistant starch and all other indigestible carbohydrates, may be higher than those obtained on the same foods using the 'Englyst' method (Englyst *et al.* 1994), which measures non-starch polysaccharides. Examples of values obtained on the same samples using the two different methods are given in the UK

Box 9 Example of different methods for calculating carbohydrate

*Eating apple, average, raw, flesh and skin**

Water	= 84.5 g/100 g
Protein	= 0.4 g/100 g
Fat	= 0.1 g/100 g
Starch	= Trace (taken as zero)
Glucose	= 1.7 g/100 g
Fructose	= 6.2 g/100 g
Sucrose (expressed as monosaccharide equivalents)	= 3.9 g/100 g
Non-starch polysaccharide (NSP; dietary fibre)	= 1.8 g/100 g
Ash	= 0.1 g/100 g

Available carbohydrate (using sum method and expressed as monosaccharide equivalents):

= starch + glucose + fructose + sucrose
= **11.8** g/100 g

*Total carbohydrate (*i.e. *including unavailable carbohydrate) (using sum method and expressed as monosaccharide equivalents):*

= starch + glucose + fructose + sucrose + NSP
= **13.6** g/100 g

Available carbohydrate (using by difference method and expressed as monosaccharide equivalents):

= 100 – water – protein – fat – NSP – ash
= **13.1** g/100 g

Available carbohydrate (using sum method and expressed on a weight basis):

= (starch/1.10) + glucose + fructose + (sucrose/1.05)
= **11.6** g/100 g

*Source: FSA (2002)

food tables (FSA 2002; Section 3.2). A recent EC Directive (2008/1000/EC) has defined 'fibre' as carbohydrate polymers with three or more monometric units, which are neither digested nor absorbed in the small intestine, including naturally-occurring and synthetic carbohydrate polymers and those obtained from food raw material by physical, enzymatic or chemical means.

4.4.5 Vitamin A

Total vitamin A activity, often expressed as retinol equivalents (for mixed diets), is usually derived from the relative activities of components with provitamin A activity (*e.g.* all-*trans* retinol, 13-*cis* retinol, β-carotene, α-carotene, cryptoxanthins).

At the simplest level, retinol equivalent may be expressed in databases as follows:

$$\text{Retinol equivalent} = \text{retinol} + \frac{\beta\text{-carotene}}{6}.$$

Owing to ongoing discussions regarding the calculation of retinol equivalent, some databases, such as the French database (AFSSA/CIQUAL 2008) provide retinol and carotene values, but not retinol equivalent. Some databases (*e.g.* UK, Danish, Dutch; see FSA 2002; NEVO 2006; Saxholt *et al.* 2008) take account of the lower activity of 13-*cis* retinol compared with all-*trans* retinol and/or the lower activity of α-carotene and cryptoxanthins compared with β-carotene. The use of specific factors for the individual components is dependent on the presence of values for these components, but data may be incomplete. Thus, it may have been necessary when compiling a database to assume that all retinol is all-*trans* retinol and all carotenoids are β-carotene. This will result in an overestimate of vitamin A activity, which, while mostly not nutritionally significant, may affect values for foods that are good sources of vitamin A.

In addition, to take account of the lower activity of α-carotene, β-carotene and cryptoxanthins in green leafy vegetables and fruit, the vitamin A is sometimes expressed as Retinol Activity Equivalent (μg RAE). In this case, the provitamin A activity (*e.g.* all-*trans* retinol, 13-*cis* retinol, β-carotene, α-carotene, cryptoxanthins) is preferably divided by at least 12.

4.4.6 *Vitamin E*

Similarly, total vitamin E activity, expressed as α-tocopherol equivalents, may be derived from the activities of tocopherols and tocotrienols present in the food [see FSA (2002) for conversion factors, reproduced from McLaughlin and Weihrauch (1979)]. As for vitamin A, incomplete data on vitamin E fractions can lead to an overestimate of the total activity in some foods (*e.g.* seeds and their oils) that contain forms of tocopherol other than α-tocopherol. In addition, there is some debate regarding the activity of the different tocopherols and tocotrienols.

4.4.7 *Vitamin D*

Vitamin D activity may take account of the metabolite 25-hydroxy cholecalciferol (25-OH-D_3), which is present in meat and fish, as well as cholecalciferol (vitamin D_3) and ergocalciferol (vitamin D_2). However, there are variations in the activity factor applied to 25-OH-D_3 [*e.g.* a factor of 5 is used in the UK and Danish tables (FSA 2002; Saxholt *et al.* 2008)].

4.4.8 *Niacin equivalent*

This usually includes both niacin (nicotinic acid plus nicotinamide) and a contribution from tryptophan (tryptophan/60), which can be converted by the body into nicotinic acid. Users should check whether values in the database being used refer to niacin only or niacin equivalent. In addition, some countries make adjustments for the reduced bioavailability of niacin from cereals.

4.4.9 *B vitamin analysis*

For many years, microbiological assay was used to determine levels of B vitamins, but the use of HPLC has now become more widespread. For some vitamins, and particularly where HPLC methods are less well established, values obtained using the two methods may differ (*e.g.* folates).

Further reading: Deharveng et al. (1999); Schlotke et al. (2000); Leclercq et al. (2001); Ireland et al. (2002); Puwastien (2002); Merchant and Dehghan (2006); Egan et al. (2007); Slimani et al. (2007a, b)

4.5 Calculating the nutrient content of composite dishes

Composite dishes form an important part of European diets but, owing to the number and variety of composite foods available, comprehensive analysis is not feasible. Many databases do include analytical data on the most commonly consumed composite dishes available at retail level. However, nutrient values for many composite dishes, and particularly for 'home-made' versions, in food composition databases are often derived using recipe calculation procedures.

For uncooked composite dishes (*e.g.* fresh fruit salad; sandwiches), the calculation is simply based on the relative weight of each ingredient and the nutrient content of each ingredient. (Particular attention is needed to the presence of 'missing values' and to the edible portion of foods.)

However, for cooked foods it is necessary to take account of:

- weight changes of ingredients during cooking (the 'yield' factor), owing to, for example:
  - water loss (*e.g.* baked or grilled foods);
  - water gain (*e.g.* boiled pasta and rice);
  - fat loss (*e.g.* cooked meats); or
  - fat gain (*e.g.* deep fried foods);
- changes in the nutrient content of ingredients on cooking, particularly vitamin losses – 'nutrient retention' factors.

Yield factors should ideally be ascertained by preparing and cooking the recipe. However, published values (*e.g.* FSA 2002) for similar dishes are sometimes used. Nutrient retention factors are also published and those used in Europe have been collated (Bell *et al.* 2006).

The recipe calculation procedures used vary between countries (Reinivuo & Laitinen 2007; Reinivuo *et al.* 2008). For example, yield and retention factors can be applied at:

- recipe level (*i.e.* the whole dish); or
- ingredient level (*i.e.* to the weight or nutrient content of each ingredient); or
- a combination of both (*e.g.* yield factor at recipe level, retention factors at ingredient level).

In the absence of evidence to assess the relative accuracy of the different procedures, EuroFIR has recommended that its members should adopt the most commonly used approach, in which yield factors are applied at the recipe level and retention factors at the ingredient level (Reinivuo & Laitinen 2007; Reinivuo *et al.* 2008). This procedure is summarised in Box 10.

Box 10 The proposed EuroFIR compilation process for recipe calculation

1. Collect recipes

Use the most popular standard cookbooks or the most popular recipe archives on the Internet. If you use recipes from the website, do not forget to print out the recipe. If no written recipes are available (*e.g.* ethnic or traditional foods), conduct field work to develop.

2. Determine weights of uncooked ingredients

Convert household measures to gram weights. If the weight of an ingredient includes inedible waste (*e.g.* banana with peel), correct the weight of the ingredient to the edible weight.

3. Sum the weights of uncooked ingredients

4. Correct the weights for effect of cooking by applying a yield factor to the total uncooked weight

Total cooked weight (g) = total uncooked weight (g) × yield factor

5. Calculate the nutrient values

Nutrient content per 100 g of cooked weight = nutrient content of uncooked ingredient × uncooked weight of ingredient (g)/total cooked weight (g)

6. Correct the nutrient values for the effects of cooking

Apply the appropriate retention factors at ingredient level. Adjust also the nutrient values for water, alcohol and fat, if they are lost or gained during cooking.

Nutrient content per 100 g of cooked weight = nutrient content of uncooked ingredient × uncooked weight of ingredient (g) × retention factor/total cooked weight (g)

Total water content of cooked dish = total water content of cooked dish – weight loss (g)

7. Documentation

Document the used sources for recipes (*e.g.* cookbooks) and for yield and retention factors.

When using the recipe calculation functions available in nutritional analysis software packages, users are advised to check whether and how yield and retention factors are taken into account (see Section 4.6).

Further reading:

- *Recipe calculation:* Bognár and Piekarski (2000), Greenfield and Southgate (2003) Appendix 6*; FSA (2002) Appendix 4.3*, Reinivuo and Laitinen (2007); Reinivuo *et al.* (2008);
(*include worked examples of recipe calculations)
- *Yield and nutrient loss and gain factors:* Bell *et al.* (2006).

4.6 Using nutritional analysis software

Food composition data are often accessed and used through one of the many nutritional analysis software packages that are commercially available, including online nutritional analysis. Although nutritional analysis software packages have many benefits in terms of speed and convenience, users need to be aware of the limitations in the food composition data on which they are based (see Section 4.1) and of differences in functionality between some packages.

When choosing nutritional analysis software, it is important to consider which packages are most suitable for the intended use. The functionality, as well as the target audience, of products is often reflected in the price. Many packages are suitable for analysis of diets, recipes and menus, but some are more specialised, such as those aimed at institutional catering or the foodservice industry, while others are intended for educational use and may have a limited range of foods and nutrients, as well as limited functionality.

Users are advised to check if the software incorporates the latest editions of the food composition tables of interest, as well as the full range of nutrients required. Some packages include published data from other countries or data on branded foods, in addition to national datasets. The compatibility issues outlined in Section 4.4 may apply to these data sources.

Additional functions are incorporated into most of the software commonly used by nutritional professionals, including data on portion sizes, the ability to edit data, comparisons with recommended nutrient intakes or standards, dietary assessment tools, cost analysis functions, or outputs that meet the requirements of nutritional labelling in terms of format, units and conversion factors.

'Missing values' (see Section 4.3) are present in the vast majority of software packages but, ideally, should be flagged. This flagging of missing values in software packages enables users to make a judgement on how to take account of them (*e.g.* values might be estimated from similar foods in the database or from other data sources).

Many users will wish to calculate the nutritional value of composite cooked dishes from the nutrient content of the individual ingredients (see Section 4.5). Most software packages therefore include recipe analysis functions. However, it is important to take account of cooking losses and strategies for taking account of these will be an important consideration in selecting a software program. The change in weight of a food on cooking can have a substantial effect on the calculated nutrient content of a cooked dish. Many packages have an approach to take account of this, often via an option to input a percentage weight loss value or yield factor. Weight loss values can be obtained by weighing a composite dish before and after cooking, or it may be possible to use published values for cooked foods or composite dishes. For the assessment of micronutrient content or intake, an option to take account of vitamin losses (retention factors) during cooking or processing will also be relevant, although this option is not always present in software packages.

Further reading: Church and Krines (2008)

5 Conclusions and future role of EuroFIR

Food composition data are vital tools in many different fields of work, but they have important limitations, which users need to consider when applying the data.

According to Ershow (2003), ideally, food composition databases should include the foods most commonly eaten by the national or study population together with a selection of other foods (*e.g.* those that are important sources of one or more nutrients in population subgroups). Samples should have been chosen to be statistically representative of the national or study population. Sampling should also take account of sources of variation (*e.g.* natural, processing). Nutrient coverage should include components that are of high priority for public health or for scientific interest. Analytical methods used should be 'state of the art', supported by documented quality assurance procedures. Values should be presented as mean and range.

In practice, resource limitations will prevent many food composition databases from achieving all of these characteristics. However, both compilers and users of food composition data will wish to ensure that the data are of acceptable quality in terms of the sample, the analytical procedures and quality assurance, and the compilation from a range of data sources.

EuroFIR is working to improve accessibility to food composition data within Europe, through the provision of a single, authoritative source of food composition data. This work has encompassed many activities, described throughout this guide, including areas that will be of substantial benefit to users, such as harmonisation and standardisation of food composition data and the development of a quality framework for the compilation of food composition data.

The activities and role of EuroFIR should continue under the umbrella of the newly established EuroFIR AISBL that has been set up as a non-profit organisation based in Belgium (http://www.eurofir.net/public.asp?id=10385).

Further reading:

- *General information on EuroFIR:* http://www.eurofir.net; Williamson and Buttriss (2007); Denny and Buttriss (2009)

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Conflict of interest

The author has no conflict of interest to declare.

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