Collaboration

A comparative analysis of food composition tables and databases included in the EuroFIR network

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Abstract

Food composition data are an essential requirement in many aspects of nutrition and dietetics as they are used to assess the nutritional status of a population, to study diet-disease relationships, to prescribe therapeutic diets, in nutritional interventions, or in the food industry, in nutritional labelling and food reformulation.

EuroFIR is a European association of organisations that compile food composition data and its goals include the harmonisation of food composition databases.

The goal of this work is to compare open-access food composition databases listed in EuroFIR in order to assess their advantages and disadvantages, their utility and possibilities for improvement. It is an adapted version of a Master's thesis project conducted in the Spanish Agency for Food Safety and Nutrition (AESAN) and defended as part of the University Master's Degree in Food Safety at the Complutense University in Madrid.

Keeping in mind the information provided by different open-access food composition databases compiled by EuroFIR, Denmark's Frida Food Data appears to be one of the most complete databases, as it provides an extensive list of different nutrients for each food, with detailed information on carbohydrates, fats, proteins, minerals and vitamins, along with the most common contaminants.

The Spanish food composition database (BEDCA) is the only database in Spanish in EuroFIR and it is currently being updated. Its lines of improvement may include, among others, an increased number of nutrients and foods, the ability to search by recipe, the possibility of comparing nutrients or foods, incorporating a food diary, and a daily intake calculator.

Key words

Tables, databases, composition, food, nutrients, EuroFIR.

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1. Introduction

Food composition tables and databases provide data on the nutritional composition of foods. Initially these data were collected in tables, but nowadays it is more common for them to be contained in databases in formats that may be accessed online. For the purposes of this paper, they are all referred to as food composition databases.

The food composition data reflected in the databases are obtained from the quantitative chemical analysis of representative samples of the foods and beverages consumed in a country, or from data from scientific publications. They typically contain data on macronutrients such as carbohydrates, lipids and proteins, as well as micronutrients, vitamins and minerals (Md Noh et al., 2020).

These data must be of sufficient analytical quality, having been obtained by means of reliable and appropriate methods for the food matrix and the nutrient to be analysed. The laboratories involved must meet quality assurance and control criteria (Md Noh et al., 2020). In the European Union, these criteria refer to compliance with the Standard ISO/IEC 17025, which establishes the general requirements regarding the technical competence of testing and calibration laboratories (ISO, 2017).

In this regard, EuroFIR, a European association of organisations for the compilation of food composition data, whose goals include the harmonisation of food composition databases, states that the data included these databases may come from different sources (EuroFIR, 2021):

- Chemical analysis of food samples that are representative of the foods consumed in a country.
- Calculating values using yield and nutrient retention factors: adjustments for weight change due to cooking and changes in nutrient content when cooked (e.g., vitamin losses) are included.
- Taking values from a database in another country or manufacturer data, whose quality must be assessed before being included in the database.

1.1 Uses of food composition databases

Food composition data is an essential requirement in many aspects of nutrition and dietetics as it is used to assess the nutritional status of a population, to study diet-disease relationships, to prescribe therapeutic diets, in nutritional interventions and, in the food industry, in nutritional labelling and food reformulation (Md Noh et al., 2020).

In terms of nutrition labelling, this is a compulsory requirement of Regulation (EU) No. 1169/2011 (EU, 2011) which establishes three possible sources of information that may be used for labelling:

a. the food analysis conducted by the manufacturer;
b. the calculation made on the basis of known or effective mean values of the ingredients used, or
c. calculations performed on the basis of generally established and accepted data.

It is therefore understood that this type of data may be derived from food composition databases.

This data is relevant for a wide range of stakeholders and users, including researchers, food and health policy makers, health professionals, industry (food, agriculture, software developers), consumers, and it is also used for educational purposes. The main source of data for both non-commercial (research, academic, public operators or educators) and commercial use are national food composition datasets, which are usually produced and published by national government bodies, but also by research institutes and other non-governmental agencies (Kapsokefalou et al., 2019).

In addition to nutrients, researchers are increasingly interested in including and providing information on non-nutrient bioactive compounds, as many of them may have beneficial health effects or on the contrary, they may be toxic (natural) or constitute anti-nutrients (Kapsokefalou et al., 2019). EuroFIR eBASIS (Bioactive Substances in Food Information Systems) has therefore been created as a unique limited-access database, since access is not free of cost, on food composition and biological effects for plant-derived bioactive compounds with potential health benefits. It lists more than 300 European plant foods and provides information on 17 classes of compounds (e.g., phytosterols, polyphenols, glucosinolates and lignans) (EuroFIR - eBASIS, 2021).

Approximately 2 billion people around the world suffer from micronutrient deficiencies, with an estimated 17.3 % at risk of zinc deficiency, while almost 30 % suffer from anaemia, in many cases due to iron deficiency. Phytate is found in high concentrations in vegetables and its high mineral-binding capacity affects the bioavailability of zinc and iron, as it impedes their absorption. Phytate is therefore often classified as an anti-nutrient, as it can cause deficiencies in populations where wheat, rice and maize are staple foods. Similarly, oxalate, which is found in vegetables and other foods, impedes calcium absorption by affecting its bioavailability. There are few compositional databases that include phytate among their components; for this reason, in 2016, the Food and Agriculture Organization of the United Nations (FAO) and the International Network of Food Data Systems (INFOODS) decided to compile data on phytate and report its content alongside the selected minerals (iron, zinc and calcium) (Dahdouh et al., 2019).

On the other hand, there are examples of the need for food composition databases in order to maintain the well-being and health of consumers with pathologies or intolerances. Thus, the Department of Pharmaceutical and Health Sciences of the Faculty of Pharmacy of the University of San Pablo-CEU developed a project to create a database on the composition of gluten-free products based on the ingredients listed in the label and the nutritional information provided by the manufacturer, compiling gluten-free products available in the Spanish market. This is a matter of interest, as patients with coeliac disease require gluten-free products in their diets, and studies that assess the diets of these patients must use up-to-date data on the composition of the gluten-free product. Additionally, as they require a more restrictive diet, they may face complications when choosing certain foods, therefore it is necessary to constantly update these products (Fajardo et al., 2020).

1.2 Problems of food composition databases

Food composition data is produced in many countries, although food and nutrient coverage may be limited. International research networks have initiated the standardisation of methods for the collecting, processing and publication of food composition data, but not with the same speed as the progress in information technology. The European Food Safety Authority (EFSA) has pointed out the limitations of European food composition data, with the following challenges (Kapsokefalou et al., 2019):

- The availability of data may lead users to use them without being aware of their limitations, as not all national data includes the same nutrients, e.g., individual sugars or individual fatty acids may not be included. This is not a problem if the users only employ data from one country, but it may become one if data is combined from different countries and sources which have different data collection criteria.

- Another challenge is to provide and maintain data reflecting the variety of foods and their composition, as the nutritional composition of complex foods changes over time and databases must be constantly revised to provide data on new foods and on foods whose composition has changed.
- Financial problems lead most compilers to work with increasingly limited resources, which is one of the main reasons for data obsolescence in food composition databases, as they lack funded programmes to incorporate new data and conduct analyses.

1.3 Food composition databases in Spain

In Spain, several food composition databases have been published, either free of charge or sold commercially (Lupiañez-Barbero et al., 2018).

For example, Jiménez and Cervera published a food composition table in 1988 (Jiménez-Cruz and Cervera-Ral, 1988). In 1992, Olga Moreiras et al. developed food composition data tables that present the nutritional composition of foods and include tables, recommended intakes and home measurements, with a total of 259 foods and 41 nutrients (Moreiras et al., 1992), and updated editions have subsequently been published (Moreiras et al., 2018). Other food composition data tables were published in 1993 by the University of Granada (Mataix-Verdú et al., 1993), and were also subsequently updated (Mataix-Verdú et al., 2003). These composition tables are not freely available, as they are commercially sold books (Lupiañez-Barbero et al., 2018).

In 1995, the Ministry of Health and Consumer Affairs published a series of food composition tables containing the nutritional analysis of foods for the Spanish public, in collaboration with the Complutense University of Madrid, but they have not been updated since then (MSC, 1995).

In 2003, the CESNID (*Centre d'Ensenyament Superior de Nutrició i Dietética*) food composition data tables were published in book format, commercially available in Spanish and Catalan, and include the data methodology and sources, along with recipes, portions, liquid foods, scientific names, and food equivalents in English and French. It also came with a compact disc (CD) with which to make nutritional calculations (Farrán et al., 2003). In 2004, Ortega et al. published "La composición de los alimentos, herramienta básica para valoración nutricional", in a commercially available book format (Ortega et al., 2004).

Finally, the first version of BEDCA, the Spanish food composition database, was published in 2010. BEDCA was developed by a network of public research centres, administrations and private institutions created with the financial support of the Ministry of Science and Innovation. The BEDCA network involved universities and research centres, as well as institutions linked to the food industry. It was coordinated and funded by the Spanish Agency for Food Safety and Nutrition (AESAN) and with the technical support and backing of EuroFIR (BEDCA, 2021).

2. Purpose and objectives

The goal of this work is to compare open-access food composition databases listed in EuroFIR in order to assess their advantages and disadvantages, their utility and possibilities for improvement.

This collaboration is an adapted version of a Master's thesis project conducted in the Spanish Agency for Food Safety and Nutrition and defended as part of the University Master's Degree in Food Safety at the Complutense University in Madrid.

3. Materials and methodology

Various sources of information located through scientific search engines and websites have been used.

3.1 EuroFIR and the FoodEXplorer and LanguaL tools

EuroFIR AISBL is an international non-profit association created in 2009 to ensure the promotion of food information in Europe. Its origins lie in the European Food Information Resource project, a Network of Excellence composed of 48 partners from 27 countries funded by the European Union's 6th Framework Programme for Research. The objective of EuroFIR is to develop, publish and exploit food composition information and to promote international cooperation and harmonisation of standards to improve data quality, storage and access. It brings together food information available worldwide from 26 compiling organisations in Europe, the United States and Canada (FoodEXplorer), in addition to validated information on bioactive compounds (eBASIS) (EuroFIR AISBL, 2021).

FoodEXplorer is a search interface that allows users to look up information from food composition databases from 29 countries simultaneously, mostly European but also from Canada, Japan, New Zealand and the United States (Kapsokefalou et al., 2019). Users must log in to the platform, and they have access to a wide range of data, linking foods and nutrients through harmonised data using the LanguaL description system, standardised components, and value descriptions using EuroFIR thesauri (standard vocabularies) and nutritional value information. Searches may be conducted by name or food group, with the possibility of comparing components between foods, and the results may be downloaded (EuroFIR-FoodEXplorer, 2021).

LanguaL ("Food Language") is an automated method for describing food data, launched in the late 1970s by specialists in food technology, information science and nutrition from the Center for Food Safety and Applied Nutrition (CFSAN) of the US Food and Drug Administration (FDA). Since 1996, the European Technical Committee of LanguaL has managed the thesaurus, as a standardised language for describing foods and classifying food products, where each food is described according to the characteristics of nutritional quality and identified by a unique code with equivalent terms in different languages. More than 40 000 European, North American and foods from other countries have been indexed with the LanguaL system to facilitate searching in EuroFIR (LanguaL, 2020).

3.2 EuroFIR quality criteria

One of EuroFIR's strategic objectives is to establish a quality framework for food composition databases and associated testing laboratories, which covers quality management, project management and technical and scientific competence. The key elements that have been developed include (Astley et al., 2019):

- Harmonised data collection process and the identification of hazards and critical points associated with data collection, through the development of Standard Operating Procedures.
- Future certification of compilers, by means of an initial and continuous professional development programme, and audits to assess compiler performance.
- Improvements to address user and stakeholder needs.

3.3 Food composition databases included in EuroFIR

The analysis of the food composition databases has been conducted by obtaining information from the official websites of each database via the EuroFIR website. Below we list the European and third-country databases that belong to EuroFIR, together with their name, language and URL (Table 1).

Table 1. Databases that are part of EuroFIR: access link to your website, languages and type of access (free: free of charge or restricted: for a fee)

Country	Database	Name	Language	URL
Germany MRI	https://blsdb.de/	BLS	English/German	Restricted
Germany MedPharm	https://www.sfk.online/#/home	SFKDB	English/German/ French	Restricted
Austria	https://www.oenwt.at/	OENWT	German	Open
Belgium	https://www.nubel.com/	NIMS	Dutch/French	Restricted
Bulgaria	Available through FoodEXplorer	FCTBL_BG	Not free of cost	Restricted
Canada	https://food-nutrition.canada.ca/cnf-fce/index-eng.jsp	Canadian Nutrient File (CNF)	English/French	Open
Denmark	https://frida.fooddata.dk/	Frida	Danish/English	Open
Slovakia	http://www.pbd-online.sk/en	SDCBD	Slovak/English	Open
Slovenia	http://opkp.si/en_GB/cms/vstopna-stran	OPKP	Slovenian/English	Restricted
Spain	https://www.bedca.net/	BEDCA	Spanish/English	Open
United States	https://fdc.nal.usda.gov/	FoodData Central	English	Open
Estonia	https://tka.nutridata.ee/en/	Nutridata	Estonian/Russian/ English	Open
Finland	https://fineli.fi/fineli/en/index	Fineli	Finnish/Swedish/ English	Open
France	https://ciqual.anses.fr/	CIQUAL	French/English	Open
Greece	https://www.eurofir.org/food-information/food-composition-databases/eurofir-aisbl-e-book-collection/	Greek Food Composition Dataset	Not free of cost	Restricted

Table 1. Databases that are part of EuroFIR: access link to your website, languages and type of access (free: free of charge or restricted: for a fee)

Country	Database	**Name**	**Language**	**URL**
Ireland	https://www.eurofir.org/food-information/food-composition-databases/eurofir-aisbl-e-book-collection/	Irish Food Composition Dataset	Not free of cost	Restricted
Iceland	https://matis.is/naeringargildimatvaela-isgem/efnainnihaldmatvaela-leitarvel/	ISGEM	Icelandic/English	Open
Italy (IEO)	http://www.bda-ieo.it/	BDA	Italian/English	Open
Italy (CREA)	https://www.alimentinutrizione.it/	-	Italian	Open
Japan	https://www.mext.go.jp/en/policy/science_technology/policy/title01/detail01/1374030.htm	-	Japanese/English	Open
Latvia	https://partikasdb.lv/	-	Latvian	Restricted
Lithuania	https://www.eurofir.org/food-information/food-composition-databases/	-	Not free of cost	Restricted
Norway	https://www.matportalen.no/	-	Norwegian/English	Open
New Zealand	https://www.foodcomposition.co.nz/	-	English	Open
The Netherlands	https://www.rivm.nl/nederlands-voedingsstoffenbestand	NEVO	Dutch/English	Open
Poland	http://www.izz.waw.pl/en/?lang=en	-	Polish/English	Restricted
Portugal	http://portfir.insa.pt/	-	Portuguese/English	Open
United Kingdom	https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid	CoFID	English	Open
Czech Republic	https://www.nutridatabaze.cz/en/	IAEI	Czech/English	Open
Serbia	http://104.155.19.23/serbianfood/index.php	-	Serbian/English	Open
Sweden	https://www.livsmedelsverket.se/	-	Swedish/English	Open
Switzerland	https://naehrwertdaten.ch/en/	-	English/German/French/Italian	Open
Turkey	http://www.turkomp.gov.tr/main	-	Turkish/English	Open

Of the 33 databases available in EuroFIR, 13 were selected for further analysis. The selection criteria for these databases were:

- Only those within the European Union that were publicly accessible and free of cost were selected for consultation and the assessment of their characteristics.
- Databases whose websites were not available in a language most easily understood by a stand-

ard Spanish user were discarded. This means that Spanish, Italian, English and French were selected as working languages.

- Based on this criteria, the EuroFIR databases from Spain, France, Czech Republic, Denmark, Estonia, Finland, Italy, the Netherlands, Portugal, Slovakia and Sweden were selected. Additionally, given that the United Kingdom's exit from the European Union is relatively recent, the UK database was also assessed, and it is worth mentioning some of its characteristics.

4. Development

Next we explain the different ways of searching for foods or components, and other specific characteristics of the databases (which in the case of the UK is a food composition table), in order to make a comparative analysis.

4.1 Type of search

Firstly, when searching a food composition database, one may search by "food" or by "nutrient/component", e.g., "turkey meat, raw" or "total protein". The number of foods and nutrients/components included in different databases is shown below (Table 2).

Table 2. EuroFIR databases. Type of search and number of food and nutrient/components

Country	Database	No. of nutrients	No. of foods
Denmark	Frida	±105	1170
Slovakia	SDCBD	54	1437
Spain	BEDCA	40	968
Estonia	Nutridata	60	3620
Finland	Fineli	55	4156
France	CIQUAL	±65	3185
Italy (CREA)	BDA	±120	900
Italy (IEO)	-	±90	978
The Netherlands	NEVO	±133	2152
Portugal	-	42	1329
United Kingdom	CoFID	279*	2887*
Czech Republic	IAEI	99	934
Sweden	-	56	2245

*As it is not a database but a table, it lacks a specific search engine.

±: not all databases provide a fixed number of nutrients per food but present more or less nutrients depending on the food.

As may be seen, currently the databases from Slovakia, Spain, Portugal and Sweden provide a lower number of nutrients for each food, whereas food composition databases from Italy (CREA), the Netherlands, and by far the UK table, provide the highest number of nutrients/components.

In terms of the number of foods, the French, Estonian and Finnish databases provide an extensive list of foods. Conversely, the Spanish, Czech and Italian databases have a smaller list of foods.

4.2 Possibility of exporting data

A point of interest is the ability to extract the data and even graphs mapping the percentage of nutrients or energy provided by the food, after conducting the search and thus having the data available in a more visual format, as well as archiving them for processing. The databases from which information can be exported are given below, together with a graphical representation, if available (Table 3).

Table 3. Countries whose databases provide the option of downloading data and/or graphical representation

Countries	Possibility of exporting data	Format	Graphical representation
Finland, France, United Kingdom, Sweden	Yes	Excel	Finland
Italy (IEO), Czech Republic	Yes	PDF	Italy (CREA)
Portugal	Yes	Excel/PDF	Portugal
Denmark, Slovakia, Spain, Estonia, Italy (CREA), Netherlands	No	-	-

4.3 Bibliographic sources and methods of analysis for data collection

Another aspect worth highlighting is the availability of the sources from which the data for the food composition databases has been collected, together with the methods of analysis (Table 4). In order to inform users about the origins of the data, sources are usually indicated for each nutrient by means of a special code in a column of the table, and when this number is selected, the bibliographic information is displayed. Similarly, the method of analysis, the origin of the data, e.g., analytical, calculated or based on data published in other reference sources, are indicated with a code/word. Additionally, the table indicates the databases that display the LanguaL coding system, the multilingual thesaurus required by EuroFIR, where each food is described by standard terms thus facilitating the harmonisation of food classification, although it is not compulsory to display it on the website (Table 4).

Table 4. Databases containing bibliographic sources, methods of food analysis, and which display the LanguaL food coding system code

Country	Bibliographic sources	Methods of analysis	Displays LanguaL code
Denmark	Yes, for nutrients (but not all)	-	-
Slovakia	Yes, for each nutrient	-	-
Spain	Yes, for nutrients (but not all)	-	-
Estonia	Yes, for each nutrient	Yes, for each nutrient	-
Finland	Yes, for nutrients (but not all)	Yes, for each nutrient	-
France	Yes, for each nutrient	-	-
Italy (CREA)	Yes, for each nutrient	Yes, for each nutrient	Yes
Italy (IEO)	Yes, for each nutrient	Yes, for nutrients (but not all)	-
The Netherlands	-	Yes, for each nutrient	-
Portugal	-	-	Yes
United Kingdom	Yes, for each nutrient	Yes, for each nutrient	-
Czech Republic	Yes, for nutrients (but not all)	-	-
Sweden	-	-	Yes

4.4 Assessment of the results of the consultation of food composition databases

The criteria used to describe the characteristics of each database, from the number of foods to their nutrient content, as well as other additional information displayed, are described below, in order to make a comparative assessment.

4.4.1 List of foods after the search

There are notable differences with regard to the foods found after the search, as when searching for the same food type in different databases, some of them offer a very broad list of foods within the same category, from unprocessed to mostly processed, with different types of cooking, raw, etc., while others offer a smaller number. This finding may be seen in the following example, where a search for “apple” in different databases yields the following food listings (Figure 1).

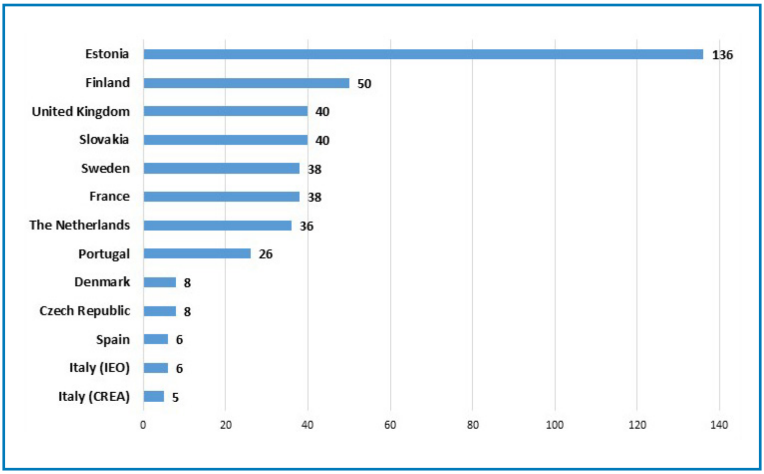

Figure 1. Number of food items retrieved by searching for the term apple in different databases.

Therefore, the number and variety of foods vary from database to database, with some databases including a wider range of processed foods, composite dishes and recipes, as well as foods prepared and cooked in different ways, as in the case of the Estonian database.

4.4.2 List of nutrients after the search

A similar situation occurs with the list of nutrients that appear after the search, where some databases have an extensive list of different nutrients, while others offer a basic composition of the macro and micronutrients, without distinguishing between the possible nutrient types within a single category, as may be seen below (Table 5).

Table 5. Components presented in food composition databases from different countries

Country	Food quantity	List of components	Carbohydrates	Fats	Proteins	Vitamins	Minerals	Salt (≠ Na)
Denmark	100 g	Extensive	Total CHO with fibre, available CHO, declared CHO, added sugars, total fibre, etc. (depending on the food, greater breadth)	Total fat, cholesterol, FA (+)/(-) according to food	Total proteins, total amino acids, total nitrogen	(+)/(-) depends on the food	(+)/(-) depends on the food {Mo, Hg, Pb, Ni, Cd, As}	-
Slovakia	100 g	Limited	Total HDC, starch, total fibre, polyols (depending on the food, greater breadth)	Total fat, cholesterol, 7 FA (for all foods)	Total proteins	14 vitamins (for all foods)	12 minerals (for all foods) {S}	Yes
Spain	100 g	Limited	Total HDC, total fibre (for all foods)	Total fat, cholesterol, 13 FA (for all foods)	Total proteins	10 vitamins (for all foods)	9 minerals (for all foods)	-
Estonia	100 g	Limited	Total CHO, total fibre, available CHO, starch, polyols, sugars, sucrose, lactose, maltose, glucose, fructose, galactose (for all foods)	Total fat, cholesterol, 9 FA (for all food)	Total proteins	18 vitamins (for all foods)	13 minerals (for all foods) (Ni)	Yes
Finland	100 g + other weights	Extensive	Total CHO, total sugars, polyols, fructose, galactose, glucose, lactose, maltose, sucrose, starch, total fibre (insoluble/soluble) (for all foods)	Total fat, cholesterol, 12 FA (for all foods)	Total proteins, tryptophan	13 vitamins (for all foods)	9 minerals (for all foods)	Yes
France	100 g	Extensive	Total CHO, total fibre, sugars, fructose, glucose, lactose, maltose, sucrose, starch, polyols, etc., (depending on the food, greater breadth)	Total fat, cholesterol, FA (+)/(-) depends on the food	Total protein, protein N x 6.25	(+)/(-) depends on the food	(+)/(-) depends on the food	Yes
Czech Republic	100 g	Extensive	Total CHO, available CHO, total fibre, sugars (fructose, glucose, lactose, maltose, sucrose), starch, polyols (for all foods)	Total fat, cholesterol, 34 FA {for all foods}	Total proteins, total amino acids, total nitrogen	15 vitamins (for all foods)	10 minerals (for all foods)	Yes

Table 5. Components presented in food composition databases from different countries

Country	Food quantity	List of components	Carbohydrates	Fats	Proteins	Vitamins	Minerals	Salt (≠ Na)
Italy (CREA)	100 g	Limited	Total CHO, sugars, total fibre, starch (for all foods)	Total fat, cholesterol, FA (+)/(-) according to food	Total protein, amino acids (limiting and chemical index)	(+)/(-) depends on the food	(+)/(-) depends on the food	-
Italy (IEO)	100 g	Extensive	Total CHO, starch, soluble CHO, total fibre, etc. (depending on the food, greater breadth)	Total fat (animal vs. vegetable), cholesterol, FA (+)/(-) according to food	Total protein, amino acids	15 vitamins (for all foods)	13 minerals (for all foodstuffs) {Mn, S}	-
The Netherlands	100 g	Extensive	Total CHO, total fibre, mono/di/polysaccharides, polyols (for all foods)	Total fat, cholesterol, FA (+)/(-) according to food	Total proteins (animal vs. plant)	(+)/(-) depends on the food	12 minerals (for all foodstuffs) {heme / non-heme Fe}	-
Portugal	100 g	Limited	Total CHO, total sugars, sucrose, lactose, available oligosaccharides, starch, total fibre (for all foods)	Total fat, cholesterol, 5 FA (for all foods)	Total proteins	13 vitamins (for all foods)	7 minerals (for all foods)	Yes
Sweden	100 g + other weights	Limited	Total CHO, mono/di saccharides, total sugars, sucrose, total fibre, total whole grains (for all foods)	Total fat, cholesterol, 17 FA (for all foods)	Total proteins	14 vitamins (for all foods)	9 minerals (for all foods)	Yes
United Kingdom	100 g	Extensive	Total CHO, starch, oligosaccharides, total sugars, glucose, galactose, fructose, sucrose, maltose, lactose, non-starch polysaccharides, resistant starch/lignin	Total fat, cholesterol, 108 FA (for all foods)	Total proteins, total nitrogen	17 vitamins (for all foods)	12 minerals (for all foods)	-

4.4.2.1 Carbohydrates

Firstly, all databases present total carbohydrates, sugars and fibre, although some databases distinguish between total sugars, available carbohydrates, soluble sugars, carbohydrates with fibre (these are the so-called "carbohydrates with a difference" mentioned in the Danish database), declared carbohydrates and added sugars. Other databases offer more detailed sugars such as fructose, glucose, galactose, lactose, maltose, sucrose, and total polyols or sorbitol (Denmark). Within fibre, they distinguish between starch, soluble and insoluble fibre (Finland), total whole grains (Sweden), hexoses/pentoses/uronic acid/cellulose (Denmark) and even lignin in the case of the UK, and again, Denmark.

4.4.2.2 Fats

In terms of lipids, they all show total fat, cholesterol and the various fatty acids. Some display the same fatty acids for all types of food, while others change the fatty acids shown according to the type of food. Additionally, all databases show the *trans* fatty acid content, except the databases for France, Italy, Spain and Sweden. It is worth noting the abundance of FA types offered by the UK composition tables. Another interesting fact is the distinction between animal fat and vegetable fat made by the Italian database (IEO).

4.4.2.3 Proteins

With regard to protein content, most of them provide only total protein, but others also provide amino acid values and even total nitrogen. A particular case in point is the Italian database (CREA), which provides amino acids together with the limiting amino acid and its chemical index. On the other hand, the Dutch database distinguishes between animal and vegetable proteins.

4.4.2.4 Vitamins

In general, they all offer a similar number of vitamins, and some of them distinguish between water-soluble and fat-soluble vitamins, with a fixed or variable number of vitamins depending on the food.

4.4.2.5 Minerals

Again, they all offer a similar number of minerals, with a fixed number or adapted to each food. Some databases have noteworthy features, such as the Danish database which offers, in addition to the most common minerals, the contaminants Mo, Hg, Pb, Ni, Cd and As, and the Estonian database which also offers the value of Ni in food. Similarly, the Italian (IEO) database presents the Mn and S content, and the Slovakian database shows the S content. Finally, the Dutch database is the only one that distinguishes between total Fe, heme Fe and non-heme Fe.

Some databases also distinguish between Na and salt (NaCl), giving two different values, while others consider total Na as equivalent to salt, or the other way around, which is not as accurate.

4.4.2.6 Other components

Some databases display not only the main nutrients, but also other components that help to know the composition of foods with greater precision (Table 6).

Table 6. Databases that display other components and possible allergens

Country	Other components/Allergens
Denmark	Energy, water, ethanol, ash, dry matter, organic acids (benzoic acid), biogenic amines
Slovakia	Energy, water, ethanol, ash, organic acids, dry matter
Spain	Energy, water, ethanol
Estonia	Energy, water, ethanol, ash
Finland	Energy, water, ethanol/alergens (special diets)
France	Energy, water, ethanol, ash
Italy	Energy, water, ethanol, others (phytic acid)
(CREA)	Energy, water, ethanol, ash, organic acids
Italy (IEO)	Energy, water, ethanol
The Netherlands	Energy, water, ethanol, ash, organic acids
Portugal	Energy, water, ethanol, ash, organic acids
United Kingdom	Energy, water, alcohol, phytosterols, organic acids (citric and malic), glycerol, cryptoxanthins, lutein, carotenes, lycopene, (among others)

The values for energy (in kcal and kJ), water and ethanol, are common to all the databases and, most of them include ash content, as an analytical term equivalent to inorganic residue that remains after calcining the organic matter (Márquez Siguas, 2014), and the dry matter content of the food.

Within more extensive databases such as those of the Czech Republic, Denmark, United Kingdom and others such as those of the Netherlands, Portugal, Slovakia and Italy (CREA), organic acids such as benzoic, phytic, citric, malic, and other acids are included. Another interesting datum is the biogenic amine content present in the Danish database, as numerous studies identify histamine as the cause of scombroid food poisoning, due to the consumption of fish or fishery products with a histamine level > 1000 ppm, where tuna may have higher concentrations (Doeun et al., 2017).

The United Kingdom's table of food composition data also stands out for its phytosterols or glycerol content and for including other components such as cryptoxanthins, lutein, carotenes, lycopene, etc. Finally, the Finnish database is the only one that provides data on allergens, indicating whether the food is suitable for certain types of diets, such as gluten-free, lactose-free, etc., which is of significant value for the population suffering from allergies and/or intolerances.

4.4.3 Additional information

Finally, food composition databases offer other data of interest such as the description of the food, with the full name, the family or species, and even the function of the nutrient (Table 7).

Table 7. Additional information in each food composition database

Country	Other data
Denmark	Description of the food, N/fatty acid conversion factors, nutrient value variations, median, number of samples
Slovakia	Description of the food, N/fatty acid conversion factors
Spain	Description of the food and function of the nutrient
Estonia	Food description, option to compare foods, search by recipe, data on fruit seasons, compulsory/voluntary/detailed nutritional information in the labelling
Finland	Description of the food, option to compare foods, recommendation for special diets, description of each nutrient/function, food diary (calculation of daily intake)
France	Confidence code of the values (from A= very reliable to D= less reliable)
Italy (CREA)	Description of the food
Italy (IEO)	Description of the food
The Netherlands	Description of the food
Portugal	Description of the food, food comparison option, food diary (calculation of daily intake)
United Kingdom	Description of the food, number of samples, N/glycerol conversion factors
Czech Republic	Description of the food
Sweden	Description of the food, option to compare foods, personal food list, compulsory/voluntary/detailed nutritional information in the labelling

In the case of France, a confidence code of values is provided to inform the user about the quality of their data, ranging from A confidence (= very reliable) to D confidence (= less reliable), where reliability is estimated mainly on the basis of the representativeness of the data in relation to the French market, its timeliness and the analytical method.

The Danish and Slovakian databases, together with the UK database, are the only ones showing conversion factors for nitrogen and fatty acids, while the latter also shows the conversion factor for glycerol. In turn, the Danish one shows variations in the value of the nutrient and even a median, as it is not always a fixed value and depends on various factors (climate, agricultural practices, temperature, etc.) and the number of samples analysed, similar to the UK database.

Another important and very useful feature is the ability to compare foods and nutrients, for example, in order to see which food has a higher content of free sugars and to be able to choose the healthiest option, or the food with a higher lactose content with regard to food intolerance.

In the case of Estonia, its database can be searched by recipe, which is very practical when looking for several foods that make up a dish. It also provides information about the seasonality of the fruit, fostering consumption thereof, which is positive for sustainability and the environment. In this regard, the EFSA has published a call for proposals to EFSA's partner organisations for the creation, development, publication and maintenance of an EU food composition database and a database on the environmental impact of food, as the scientific community is very aware of the environmental impact of diet. In this regard, the European Commission has published recommendations on how to assess the environmental footprint of food and the harmonisation of the methodology for the collection of food composition data is expected to significantly improve the quality of the data and the results of the studies in which they are used (EFSA, 2021).

The Estonian and Swedish databases show the list of nutrients in different ways, as they can offer the list of the mandatory nutrition labelling (energy, carbohydrates and sugars, lipids and saturated fatty acids, proteins and salt), the voluntary nutrition labelling list, with a wider range of nutrients, and all the detailed nutritional information of the food, according to the interest of each user.

Finally, the Finnish and Portuguese databases have a food diary or personal list, in which we can enter foods that we consume regularly, even daily, and make a calculation of the daily intake, which is of great interest for nutrition and dietetics.

4.5 Nutritional assessment and comparison between different types of foods

A comparative table of the main macronutrients in different foods is shown below to check the differences in the values reported in different databases (Table 8).

Table 8. Assessment of different foods and their macronutrients in different databases. E: Energy (kcal), G: Fats (g), HdC: Carbohydrates (g), P: Protein (g)

Country	Raw apple of all varieties (100 g)				Whole cow's milk (100 ml)				Sliced turkey (100 g)				Plain wholemeal bread (100 g)				Pizza (100 g)			
	E	G	HdC	P	E	G	HdC	P	E	G	HdC	P	E	G	HdC	P	E	G	HdC	P
Eslovaquia	49	0.4	13	0.37	63	3.5	4.8	3.2	101	1.8	3.1	18.1	226	2	46.9	8.9	271	9.6	37.7	9
España	50	Tr	12	0.3	65	3.8	4.7	3.06	148	9.4	0.4	15.3	251	**3**	44	10.9	211	9.8	22.2	8.2
Francia	54.5	<0.5	11.9	<0.5	65.1	3.63	4.85	3.25	151	**1.7**	1.29	20.9	244	1.8	44.3	8.38	233	8.39	27.3	10.7
República Checa	52	0.4	10.5	0.4	63	**3.4**	4.8	3.3	161	**9.8**	**4.0**	14.3	229	2.0	39.8	8.9	246	**4.4**	ND	12.5
Dinamarca	55	0.2	12.1	0.3	63	3.5	4.6	3.4	107	1.8	1.7	21	249	2.6	45.5	8.3	257	9.8	29.5	11.8
Estonia	48.3	0	10.9	0	69.8	4.2	4.7	3.3	104	4	3	14	251	2.1	45.1	10	250	**14.1**	**16.1**	14
Finlandia	**37**	<0.1	7.7	0.2	66	3.6	5.0	3.1	94	1.8	1.6	17.5	232	**1.3**	41.0	**6.7**	195	7.8	18.0	12.2
Italia (CREA)	44	Tr	10	0.2	63	3.6	4.7	3.3	117	2.6	**0**	23.3	224	**1.3**	44.1	8.5	255	7.6	35.5	12.1
Italia (IEO)	38	Tr	10	0.2	63	3.6	4.7	3.3	**182**	6.8	**0**	**30.2**	**255**	**1.3**	**53.8**	7.5	279	5.6	**52.9**	**5.6**
Países Bajos	56	0.2	12	0.3	61	**3.4**	4.5	3.3	113	2.4	3.2	19.8	234	2.3	**39.0**	**11.1**	228	9.0	26.5	9.2
Portugal	**64**	0.5	13.4	0.2	62	3.5	4.7	3	**85**	1.9	2.6	**13.8**	232	**3**	39.9	7.6	**281**	12.5	29.2	11.7
Suecia	48	0.05	10.6	0	60	**3.0**	4.7	3.5	98	2.1	1.1	18.3	248	2.2	46.10	7.41	**192**	8.73	18.7	8.6
Reino Unido	51	0.5	11.6	0.6	66	3.9	4.8	3.2	114	1.9	1.2	23.0	**217**	2.5	42.0	9.4	255	10.3	29.1	**13.2**

Tr: amount below analytical limits, detected but not quantified.

Grey shading: The values with the most notable differences are highlighted.

The variability of nutrient content may be due to the place and state of storage (humidity, light, oxygen, etc.) as these can change the composition, together with the technological and culinary processes (temperature, hydrogenation, light, pH, etc.) used in industry and households. Furthermore, not all nutrients are affected similarly, as macronutrient changes are smaller than micronutrients, while there may be errors and discrepancies in the nutrient content of the database due to the method of analysis, sampling and date of food collection (Martínez-Victoria et al., 2015).

Concerning apple as a fruit, there is a notable difference in values in the case of energy (in kcal) calculated by the Portuguese database with 64 kcal/100 g and the Finnish database with 37 kcal/100 g, while the rest of the values differ to a lesser extent. These changes among nutrients may be due to different growing conditions and varieties (Fuji, Granny Smith, Gala, etc.), agricultural practices, soil type or climate and irrigated or rainfed (Martínez-Victoria et al., 2015).

For more processed products, changes may be due to differences in farming practices (as in the case of milk), food packaging, different processing methods and consumer preparation (Martínez-Victoria et al., 2015). In recent years, the rate of changes in the composition and foods consumed has increased due to a greater emphasis on the role of diet in health (Kapsokefalou et al., 2019).

With regard to whole milk, there is similarity between the fat values shown above as there are rules for the common organisation of the market in milk and milk products by Regulation (EC) No. 1308/2013 (EU, 2013), which sets the values for whole milk, in particular if it is standardised with a minimum content of 3.50 % (m/m). It is the case that three databases, namely those of the Netherlands, the Czech Republic and Sweden do not reach the minimum percentages, and this reflects the great need for constant updating of the databases, as although commercially the products comply, they are not adequately presented in their database. In terms of the protein content, there are also similarities in the contents thanks to the provisions of Regulation (EC) No. 1308/2013, where the protein proportion per 100 parts of milk must be multiplied by 6.38 of the total nitrogen content.

With regard to pizza, there are differences because despite having tried to choose a type of pizza with similar characteristics, there are no foods that are exactly the same in all the databases. It is very complicated when it is a complex food, with so many ingredients, as some pizzas have more meat or other types of meat, more cheese and fattier or protein rich types, etc., but we have tried to choose the most common pizza, such as a "cooked ham" pizza with cheese and tomato.

4.6 Comparative assessment of a diet

Below is an example of a daily intake corresponding to a fictitious diet in a very general way, without taking into account weight, height, gender, genetics and other factors, and to check the kcal and other nutrients of the foods according to the different databases taken as an example, and thus compare the data obtained:

- Breakfast: glass (150 ml) of semi-skimmed cow's milk with coffee + two small slices of wholemeal toast (30 g x 2) + one tablespoon (10 g) of extra virgin olive oil and tomato (two tablespoons or 20 g).
- Morning snack: a handful of nuts: raw almonds (30 g) + a banana.
- Lunch: two medium chicken breast fillets (90-120 g) + grilled courgette (150 g) with spices + one tablespoon (10 g) extra virgin olive oil + one nectarine.

- Afternoon snack: one natural yoghurt (125 g) + one apple.
- Dinner: chickpea salad (40 g) + one medium tomato (100 g) + half a cucumber (100 g) + one hard-boiled egg + one tin of natural tuna (65 g) + one tablespoon (10 g) of extra virgin olive oil.

Table 9. Additional information in each food composition database

Database	Energy (kcal)	Fats (g)	Proteins (g)	Carbohydrates (g)
Spain (BEDCA)	1431.48	68.72	88.78	114.47
France (CIQUAL)	1388.77	65.29	91.76	108.53
Italy (IEO)	1303.60	62.68	85.7	99.17
United Kingdom	1435.84	65.4	102.97	108.84

As can be seen, there are no major differences between the energy (kcal) obtained from the intake analysed according to the Spanish database and the UK one, so there would be no difference in using one database or the other to make a diet, but the difference between the protein content is interesting, with 88.78 g (Spain) and 102.97 g (UK), as it could affect a patient following a low protein diet due to a kidney condition. Comparing the above-mentioned databases with that of France, there is a slight difference in terms of energy (kcal), as it has a lower energy content, and the difference in intake is even more accentuated according to the Italian (IEO) database, which has the lowest kcal content, as it also has a lower nutrient content for the same foods.

Conclusions

In conclusion, according to all the characteristics that have been detailed about the composition databases throughout the work, and taking into account the information provided by each of them (food, nutrients, other components, additional information, etc.), the Danish database may be the most complete, as it is the one that provides the most information:

- Extensive list of different nutrients for each food.
- Different and food-specific carbohydrates.
- Total fat, cholesterol content and large number of fatty acids for each food.
- Total protein, but also all amino acids and total nitrogen.
- Food-specific minerals and vitamins, along with the most common contaminants.
- Other components: organic acids and biogenic amines.
- Other data: nitrogen and fatty acid conversion factors, nutrient variations and median.

It can be seen that it is a very complete and well thought out database, although there are others that also offer other interesting data such as the possibility of comparing nutrients, allergens, phytosterols, etc., but a comparative analysis of the whole set of components and data shows that the Danish database is one of those that provides the most complete data.

The Spanish database (BEDCA) is in the process of being updated and may be subject to various improvements:

- Expansion the number of nutrients, as it only presents 40 types, and the number of foods, as it is below 1000, and even include a search by recipe.
- Allow data to be exported in Excel and/or PDF format, together with a graphic representation.
- Inclusion of bibliographic sources for each nutrient and not only for some of them, as at present. It could also provide the method of analysis and thus reveal the origin of the data.
- Present LanguaL code and the Foodex code.
- In terms of nutrients, it should specify the different types of carbohydrates in greater detail (simple sugars, monosaccharides, disaccharides and polysaccharides, polyols, soluble and insoluble fibre, starch, etc.) as it only presents total carbohydrates and fibre. With regard to fats, the number of fatty acids should be expanded, as there are only 14 fatty acids, and with regard to the protein content, it would be interesting to also show the amino acids and total nitrogen. With regard to the micronutrients (vitamins and minerals), the number can be increased, showing 10 and 9, respectively, and it would be possible to differentiate between salt and sodium, and thus have two more precise values.
- With regard to other components, mineral ashes, some organic acids, and even allergens could be indicated, being of great use for specific population groups suffering from intolerances and/or allergies.
- Finally, and as additional information, it would be interesting to have a confidence code of values to assess the reliability of the data together with a range of variation of the nutrient, which is indicated by minimum and maximum values found, as it is not always a fixed value and thus gives a more realistic view of the content. The possibility of comparing nutrients/foods would also be a good tool, together with a food diary and a calculator to calculate daily intake. The Estonian food composition database presents data on the seasonality of fruit, which is an interesting factor in terms of sustainability and environment. It would also be useful to distinguish between mandatory, voluntary and detailed nutrition labelling information including all nutrients, depending on the user's interest.

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